

DeSForM 2023 Boundless

Aesthetics, Human Experience and Intelligence for the New Normal

Dr. ir. Miguel Bruns, Prof. Lin-Lin Chen, Dr. Sara Colombo, Dr. Jun Hu, Prof. Steven Kyffin, Yihyun Lim, Dr. Ozcan Vieira, E. Jeroen Raijmakers, Prof. Lucia Rampino, Dr. Edgar Rodriguez Ramirez, Prof. Dr. Dagmar Johanna Steffen, Prof. Calvin Wong

Design and Semantics of Form and Movement

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AiD Lab

Laboratory for
Artificial Intelligence in Design
人工智能設計研究所



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DeSForM 2023 Programme

	Conference Programme (5 July)
0900 – 0930	Conference Registration
0930 – 0945	Opening <i>Prof. Calvin Wong , CEO & Centre Director of AiDLab., Cheng Yik Hung Professor in FASHion, PolyU</i>
0945 – 1015	Keynote Presentation: Everything Everywhere All at Once <i>Dr. Delman Lee, Vice Chair at TAL Apparel Limited</i>
1015 – 1045	Keynote Presentation: Navigating Uncharted Territory with Meaning-driven and Design-centred Innovation <i>Prof. Erin Cho, Dean and Professor, School of Fashion and Textiles, PolyU</i>
1045 – 1105	Panel Discussion: AI and Design: Creative Innovation and Challenges Moderator: <i>Prof. Jeanne Tan, COO and Assistant Centre Director, AiDLab, Professor, School of Fashion and Textiles</i> Panelists: <i>Dr. Delman Lee, Prof. Erin Cho, Prof. Calvin Wong</i>
1105 – 1120	Refreshment Break
	Paper Session: Form, Interactivity and the Human Experience Chair: Jun Ho
1120 – 1240	A-Vibe: Exploring the Impact of Animal-form Avatars on Students' Connectedness and Social Presence through Delivering Honest Signals in Live Online Classes <i>Tianqin Lu and Jun Hu</i> An exploration on UX Automotive in the 5G era new interaction processes through gesture control and haptic feedback <i>Venanzio Arquilla, Fausto Brevi, Federica Caruso, Flora Gaetani and Peng Lu</i> Comfort Between the Top and Bottom: A Cost-Effective Ergonomic Monitor Stand with Automatic Height Adjustment Based on Machine Learning <i>Yanze Wang and Jianfei Ma</i> Giving Form to the Invisible: Can we make in-home network data traffic tangible to users? <i>Sabine Junginger, Beat Tödl and Tom Ulmer</i>
1240 – 1400	Lunch Chair: Dr. ir. Miguel
1400 – 1500	K-means based group clustering approach for Group recommender System in a metaverse environment <i>M.W. Geda, Yuk Ming Tang, Sze Chit Leong, C.K.M. Lee and Chung Hin Lai</i> Interstitial Diagramming: Mapping Temporal Experience <i>Stephen Neely and Michael Arnold Mages</i> Big data analytics for marketing strategy <i>Jingying Liang, Yuhua Jiao, Sui Ying Chung and C.K.M. Lee</i>
	Paper Session: Innovation in Product and Service Design Chair: Amy Chen
1500 – 1540	Disappearing Stitch: Exploring e-textiles design for disassembly <i>Amy Chen</i> A Priori: Design Knowledge in AI <i>Ryan Bruggeman, Estefania Ciliotta Chehade, Yi Han and Paolo Ciuccarelli</i>
1540 – 1600	Refreshment Break
1600 – 1730	Workshops: Human-Centred AI Design Methods to Understand “Textiles Hand” Chipp Jansen, Lissy Hatfield, Zhengtao Ma, Boyuan Tuo, Elif Ozden Yenigun, Sharon Baurley, Kun-Pyo Lee and Stephen Wang

	Conference Programme (6 July)
0900 – 0930	Conference Registration
0930 – 1000	Keynote Presentation: Acceleration with AI for Fashion <i>Prof. Calvin Wong , CEO & Centre Director of AiDlab., Cheng Yik Hung Professor, PolyU</i>
	Paper Session: Innovation in Product and Service Design Chair: Cyriel Diels
1000 – 1020	Towards a Data-Informed-Design (D-I-D) Framework for Autonomous Vehicle Design <i>Cyriel Diels, Kostas Styliadis, Farhana Safa, Cynthia Charwick, Herin Haramoto, Yichen Shu, Jiayu Wu and Dale Harrow</i>
	Paper Session: Fashion: Process, Visualizations, Artifacts and Beyond
1020 – 1040	Deep Fabric Prints Generation for Fashion <i>Fangjian Liao, Xingxing Zou and Waikung Wong</i>
1040 – 1100	Refreshment Break
	Chair: Dr. Edgar Rodriguez
1100 – 1140	The Effect of Heel Base Design on Plantar Pressure and Wear Comfort of Healthy Females <i>Luk Sin-Hang, Kit Lun Yick and Li-Ying Zhang</i>
	M-VTON: Multi-layer Virtual Try-on System <i>Kaicheng Pang, Xingxing Zou, Fangjian Liao and Waikung Wong</i>
1140 – 1300	Exhibition & Tour Atrium Link, Hong Kong Science Park
1300 – 1430	Lunch
1430 – 1530	Short papers & Interactive Demo Mixed Reality (MR)-assisted Spatial Logistics Facility Layout Design <i>Wai Wai Chong, Ka Man Lee, Yung Po Tsang and Yim Shan Au</i>
	Effect of Body Shapes, Garment Size and Silhouette on the Visual Effect of Body Image <i>Xing Su, Jiayin Li, Pik Yin Mok and Jintu Fan</i>
	AI Ethical Issues (AIEI) Cards: Supporting Responsible AI-Enabled Solutions Design in Healthcare <i>Fan Li and Yuan Lu</i>
	New Design Concepts to Enhance Communication and Interaction among Unsociable Young People in Co-living Areas <i>Hi Ying Lon and Yi-Teng Shih</i>
	The Connection of Educational Toy and Technology <i>Lok To Christy Chen, Sin Ting Charis Chiu and Yi-Teng Shih</i>
	Slow Tourism Service System for the Post-Pandemic Decade <i>Ka Po Tsui and Yi-Teng Shih</i>
	Designing a product that imitates and substitutes a guide companion for the visually impaired <i>Wai Dik Au, Yi-Teng Shih</i>
	An Interactive Neural Network-Based System for Confined Stylization of Product Design <i>Tang Man Kit</i>
1530 – 1545	Refreshment Break
1545 – 1715	Workshops: Wearables for Personalised Posture <i>Tong Lo, Narges Pourshahrokhi, Tom Stables, Rama Gheerawo and Ali Asadipour</i>
1900 – 2200	Conference Dinner

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0900 – 0930	Conference Registration
	Paper Session: Fashion: Process, Visualizations, Artifacts and Beyond
	Chair: Yihyun Lim
0930 – 1030	Fashion Sketch to Real Image System: A Designer Aids based on Generative Adversarial Network <i>Shumin Zhu, Xingxing Zou and Wai Keung Wong</i>
	Unorthodox Interventions – Fashion Garment Creation through Modification of FFF 3D Printing Processes <i>Lionel Zhen Jie Wong and Hoi Shan Jamela Law</i>
	Creating an environment to fight the fashion system: Fashion Tech Farm <i>Marina Toeters, Loe Feijs, Troy Nachtigall and Beam Contrechoc</i>
	Paper Session: Wearables and Alternative Skins
	Chair: Prof. Dr. Dagmar Johanna Steffen
1030 – 1130	Doctor Kiwi - A persuasive game concept to treat skin sores among children in New Zealand <i>Edgar Rodríguez Ramírez, Mailin Lemke and Gillian McCarthy</i>
	"I had pee sneezes" Factors influencing the health-seeking process and use of wearable devices among women with pelvic floor disorder <i>Edgar Rodríguez Ramírez, Mailin Lemke and Gillian McCarthy</i>
	FeedBreath: Designing Complementary Treatment Wearable Biofeedback System for Teenagers with anxiety disorder <i>Paolo Perego, Livia Teresa S. Stevenin and Qi Wang</i>
1130 – 1140	Closing Ceremony
1140 – 1240	AiDLab Tour & Networking AiDLab, 16/F, 19W, Hong Kong

Keynotes

Dr. Delman Lee

Vice Chair at TAL Apparel Limited



Everything Everywhere All at Once

It seems like we are in a period of great scientific and engineering marvels, and at the same time unprecedented challenges to our earth and societies. I would like to explore the multi-disciplinary nature of innovations and technologies in the fashion industry. What are some of the challenges that the industry faces? What are the current hot trends and buzzwords? What were in vogue, but no longer? Topics that will be covered include, for example, sustainability, machine learning in design, traceability and on-demand manufacturing. What kind of mindset and culture are essential in this modern fast paced world?

Dr. Delman Lee is currently the Vice Chair of TAL Apparel Limited. He leads TAL Apparel on its long-term strategy and continuous innovations in various aspects of the business. Major focuses are digital transformation, disruptive technologies, business model innovations and sustainability. He is responsible for the innovative services of TAL such as Vendor Managed Inventory and leads the sustainability journey of TAL for the past 15+ years. Dr. Lee holds a doctorate from the University of Oxford and a bachelor's degree in Electrical and Electronic Engineering from the Imperial College, London. Dr. Lee possesses extensive experience in information technology and management in global operations. He also has a strong background in research. Dr. Lee is also a board member of Sustainable Apparel Coalition and the Chairman of HKMA Hong Kong Sustainability Committee.

TAL Apparel Limited is one of the world's largest and most admired apparel manufacturers, TAL Apparel produces shirts, blouses, knits, pants, outerwear and suits for many of the most famous garment brands. Headquartered in Hong Kong, TAL Apparel has factories and offices in 7 countries and a workforce that is more than 26,000 strong. Since 1983, TAL Apparel has sold over 1,000,000,000 garments. Today, 1 out of every 6 dress shirts sold in the U.S. is manufactured by TAL Apparel! As a tireless innovator, TAL Apparel invents numerous quality products including pucker-free and wrinkle-free shirts, together with advanced water repellent and water management technologies. Long term investment in R&D has enabled TAL Apparel to innovate almost every aspect of garment manufacturing.

Keynotes

Prof. Erin Cho

Dean and Professor of the School of Fashion and Textiles, The Hong Kong Polytechnic University



Navigating uncharted territory with Meaning-driven and Design-centred Innovation

With rapid and breakthrough technology advancement, we tend to frame innovation at the attribute and functional levels of what a specific technology delivers. However, we should not lose sight of the core question and mission of why we want to innovate what we want to innovate. That is, we develop technology and its applications for the betterment of humanity, the society we live in, and the planet we all share. To stay in this course, we must constantly and intentionally focus on the value and meaning of the experience that technology could deliver from the perspective of users and other critical stakeholders in its ecosystem. Design sensibility can help us be immersed in this mindset as design is by nature a human-focused endeavour. Meaning driving innovation, which digs up human perception and cognition involved in object-human and human-human interactions, allows us to have a deeper understanding as to why a certain form of efficiency and novelty innovation brought about are seen as more relevant and desired to adopt. My talk delves into these aspects to surface some cautions and directions to maximize the values to humankind brought by technology-driven innovation.

Erin Cho is the Inaugural Executive Dean and Professor of the School of Fashion and Textiles at The Hong Kong Polytechnic University. SFT had existed under its engineering school for over 65 years. As of Fall 2022, the university spun it out and established it as an independent school to exploit the growing demands and new opportunities in fashion.

Dean Cho received her BA and MA degrees from Seoul National University in Korea. She finished her Ph.D. degree at the University of Wisconsin-Madison in the United States. She has over 25 years of experience in academia across different institutions. In particular, Dean Cho possesses extensive management experience. Before joining PolyU, she was a tenured full professor of design strategies at the Parsons School of Design (Parsons) at The New School, New York, where she progressed steadily into a leadership position over the past years. She was appointed Faculty Director of Parsons Executive Education and Partnerships in 2013, moved up to Executive Director of Executive Education in 2017, and assumed her role as Dean of the School for Undergraduate Studies at The New School in 2020. She was the first Asian Dean in over 100 years of the university's history.

She is also a highly regarded scholar whose research is situated in the intersections between design, management, and technology in the areas of fashion, branding, e-commerce platform and digital innovation, design strategies, and entrepreneurship. She has built a prolific research profile alongside an extensive record of corporate consulting and engagement. Many noted academic and industry associations had invited Professor Cho to deliver keynote addresses including Adobe Max, the Digital Leaders' Forum, Tsinghua University Executive Education Alumni Conference, Fashion Executive Talks in Seoul, the Sensory and Neuromarketing Conference, the Design and Management Society, etc. Professor Cho's work has been widely adopted by companies in organizing innovation teams and projects, and she has given numerous executive seminars and training to numerous global corporations. She served as an advisor for notable incubators and venture funding boards, such as National Retail Federation, XRC lab, Impact Entrepreneurship, E-lab, Emotional Engineering Lab, etc.

Keynotes

Prof. Calvin Wong

CEO & Centre Director of AiDLab
Cheng Yik Hung Professor in Fashion,
The Hong Kong Polytechnic University



Acceleration with AI for Fashion

With the advancement of prevalent AI technologies, such as GAN, stable diffusion, Midjourney, etc. AI has an emerging presence in design arena in terms of creating generative visual styles. This talk will discuss how the role of AI will play in fashion industry and how it interacts with fashion at various levels. Various market-ready innovations recently developed by AiDLab, such as AI based Fine-grained Fashion Attribute and Colour Recognition System (Mixi) for enhancing shopping experience and assisting fashion brands to drive the clickthrough rate and revenue, AI based Interactive Design Assistant for Fashion System (AiDA) for fashion designers to lead AI for streamlining their creative process and facilitating their inspiration, etc. will be introduced.

Prof. Calvin Wong is currently the CEO & Centre Director of Laboratory for Artificial Intelligence in Design (AiDLab), a research platform established by the Hong Kong Polytechnic University (PolyU) and Royal College of Art (RCA) in the UK, and is funded by the HKSAR Government under the InnoHK Research Clusters. Calvin's leading role brings together cutting-edge research by practitioners and scholars of both institutions to establish a new AI creative innovation cluster in the region.

Calvin is a trailblazer in the application of AI innovations within the context of the fashion industry for design, manufacturing, and retail. Ranked among the world's top 2% of most-cited scientists in the field of "Artificial intelligence & Image Processing", he has been bridging academia and industry with his cutting-edge research since 2010. Calvin and his team are building new intelligent systems to disrupt the fashion industry.

In 2019, he worked with Alibaba Group to establish the first-of-its-kind "Fashion AI Dataset", which improves the accuracy of online searches for fashion images impacting the shopping experiences of millions of users on the platform.

In 2022, he has developed the world's first designer-led AI system, named "AI based Interactive Design Assistant for Fashion" system (AiDA). AiDA assists the designer to streamline their creative process and facilitates their inspiration by automatically generating original collections based on their unique inspirations and thus speeds up ideation. A "AI x Fashion" show at M+ Museum Hong Kong showcased 80 outfits to demonstrate the outcomes of international fashion brand and designers working with AiDA and attracted over 120 local and international media coverage, including VOGUE, BBC News, The Times, MIT Technology Review, etc. AiDA being featured in WGSN Big Ideas Report 2025 (Fashion) demonstrates its influential role in the future development of fashion industry.

With a passion to bring research into real world contexts, his success in AI applications is supported by his work derived from his publications of more than 160 high impact journals in SCI journals including influential publications such as IEEE Transactions on Neural Networks and Learning Systems (TNNLS), IEEE Transactions on Cybernetics, IEEE Transactions on Image Processing, etc.

Panel Discussion

AI and Design: Creative Innovation and Challenges

The utilisation of generative AI technologies for design has garnered global attention in the past year, with burgeoning concerns that the technology will lead to homogenised creations and depleting the design landscape of authentic processes, products, and experiences. How can AI be harnessed as a tool for the creative industries? What are the benefits and challenges of synergizing AI and design for creative innovations?

Moderator:

Prof. Jeanne Tan

COO and Centre Assistant Director, AiDLab

Professor, School of Fashion and Textiles, The Hong Kong Polytechnic University

Panellists:

Prof. Erin Cho

Dean and Professor of the School of Fashion and Textiles, The Hong Kong Polytechnic University

Dr. Delman Lee

Vice Chair at TAL Apparel Limited

Prof. Calvin Wong

CEO & Centre Director, AiDLab

Cheng Yik Hung Professor of Fashion, The Hong Kong Polytechnic University

Workshops

Human-Centred AI Design Methods to Understand “Textiles Hand”

Date: 5th Jul, 2023 (Wednesday)

Chipp Jansen, Lissy Hatfield, Zhengtao Ma, Boyuan Tuo, Elif Ozden Yenigun, Sharon Baurley, Kun-Pyo Lee and Stephen Wang

This collaborative workshop aims to co-generate tactile-based sensorial data for AI design tools. The project teams experienced in AI design methodologies and sensory materials assessment will deliver a material centric design workshop to understand embodied and tacit knowledge of the textile’s world. Participants will get a brief overview of the tradition and state-of-the-art in assessing textile hand (i.e. the feel of a textile), followed by hands-on experience of assessing a selection of textile materials. With the contribution of participants, this workshop will conclude with a co-creative activity in envisioning future technologies for design tools in textile material assessment.

Wearables for Personalised Posture

Date: 6th Jul, 2023 (Thursday)

Tong Lo, Narges Pourshahrokhi, Tom Stables, Rama Gheerawo and Ali Asadipour

Bodily posture is key to physical and mental health. As we adopted new modes of working, this presents challenges for workers to manage their spinal health.

Join us in this 90-minute workshop to learn more about using inclusive design and wearable sensory solutions for addressing posture-related issues. This workshop aims to bring together people from various backgrounds to facilitate multidisciplinary learning and collaboration. Through open discussions and interactive co-design activities, we will share inclusive design techniques that you can combine with your own areas of expertise and experiences to develop an inclusive and personalised posture management intervention.

The workshop will focus on using wearable technologies to deliver personalised care. We will explore together the design of a wearable device in the context of personalised posture. In addition, we will present a range of user experiences and scenarios as a prompt for discussing integration wearable systems to people’s daily lives.

Topic

01/ Form, Interactivity and the Human Experience

This conference theme focuses on exploring the relationship between tangible artifacts and their experiential function; each supporting the other to ensure seamless adoption by consumers. How can form, materials and construction that involve precise considerations, together with advanced technology, contribute to the human experience? How can we move between the boundaries of three-dimensional forms and two-dimensional materials to mass customize products that are adapted to users' needs? We welcome submissions that explore user-centred design methodologies incorporating interactive technologies, ergonomic investigations and inclusive practice that aim to enhance quality of life through design, development and customization of products and environments.

02/ Fashion: Process, Visualizations, Artifacts and Beyond

While steeped in craft and heritage, the fashion industry is also highly progressive in leading creative innovations in the way we design, create, distribute and consume tangible products, augmented reality designs and non-tangible services. Contemporary consumers consider purchasing opportunities in both physical situations and virtual landscapes. The gap between fashion and digital technologies is closing fast and this has led to radical transformations in all facets of the industry; from fundamental creation through enhanced production to virtual presentations. The conference invites papers that investigate all aspects of fashion impacted by technology. The aim is to open up and explore new arenas in aesthetics, functionality, process, manufacturing and retailing, and how these contribute to a fashion eco-system that straddles both physical and digital realities.

03/ Innovation in Product and Service Design

The rapid development of digital technologies has brought about innovations that enable users to participate in the evolution of a wide variety of products during their entire lifecycles. This participation facilitates strong interaction between designers and customers. Such communication helps both industries and non-commercial organisations to mine invaluable sources of information, and in doing so has proved vital in innovative and sustainable product design. We seek contributions that advance our knowledge in theories, methods and artefacts for product and service design.

04/ Wearables and Alternative Skins

Wearable tech and recent investigations into soft systems have shone new light in the area of alternative skins and interactive materials, enabling technology to gain closer contact with the physical body for aesthetic and functional purposes. The market for wearable tech and alternative skin is projected to grow exponentially in the coming years. The miniaturization of components, the rise of IoT and advances in conductive materials and design structures, are all factors contributing to the improvement of usability and comfort. Designers are specialists in their fields, but the emergence of tech-enabled products and materials, has opened up myriad opportunities for interdisciplinary collaboration and application. We are seeing a seismic shift in the ways that designers create and the way in which users interact with conventionally passive products. The transcendence of distinct discipline areas has led to the creation of alternative platforms for communication, well-being and play. We invite submissions that explore new concepts, practices in development, emerging fabrication technologies and approaches that contribute to the design of wearables, materials and systems.

01/

Form, Interactivity and The Human Experience

A-Vibe: Exploring the Impact of Animal-form Avatars on Students' Connectedness and Social Presence through Delivering Honest Signals in Live Online Classes

Tianqin Lu, Jun Hu

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Abstract. The outbreak of the coronavirus pandemic has made online video conferencing a common delivery method of education worldwide. Research has shown that students in online learning environments often experience isolation and alienation, a situation which can be improved by increasing their social presence. In this study, A-Vibe, a non-real-time animal-form avatar system has been created to transform the user's current honest state into a customised animal form, thereby contributing to the user's social presence and connectedness in the online learning environment. The results of this study provide important insights and ideas on the impact of introducing animal-form avatars on students' connectedness and social presence in live online classes.

Keywords: Avatar, Live online class, Honest signal, Connectedness, Social presence

1 Introduction

The coronavirus pandemic has made online video conferencing a common mode of education delivery worldwide [42]. While e-learning platforms like Microsoft Teams or Zoom have provided useful advantages, the shift to online education has posed several challenges, e.g., the loss of structure and routine, as well as changes in social connections [36]. The occurrence of online learning instruction results in students missing out on opportunities to interact or share their backgrounds with the teacher and other students [12]. In the USA, a majority of undergraduate and graduate students identified the absence of peer interaction and communication as the primary challenge in adapting to online education [44].

Compared with physical face-to-face interaction, communicating through video conferencing-mediated tools is an artificial experience [22]. The physical separation creates a barrier to communication as these mediated systems lack "media richness" and support for both verbal and non-verbal communication [5].

Research [40] suggests that increasing social presence, the level to which one is perceived as "real" in mediated communication, can address the isolation and detachment experienced by learners in online learning environments. Rourke et al.

[38] further identified the importance of developing social presence to establish online learning communities. Learners' ability to establish satisfactory a social presence is crucial in the online learning environment [8]. However, limited empirical evidence is available on learners'

connectedness within their communities [41], highlighting the need for further research on connectedness and presence in online learning environments.

In this study, A-Vibe, a non-real-time animal-form avatar system, was introduced to video conferencing communication. It transforms the student's current honest state into a vivid, customised animal form, thereby attempting to amplify subtle physical and non-verbal signals. An experiment was conducted to explore and evaluate connectedness and social presence using A-Vibe. The objective of this study is to investigate the impact of animal-form avatars in the live online class environment on students' connectedness and social presence through the delivery of honest signals. As such, the following research question is proposed: What are the effects of introducing animal-form avatars that can transmit honest signals to live online classes on students' connectedness and social presence?

2 Related Work

2.1 Online Education

Online education in higher education has experienced exponential growth recently [30], yet it may not be a complete substitute for the face-to-face mode [16]. Learners have to interact with other learners and experts in online education. This presents one of the challenges of online education: the lack of real-time interaction, which can negatively affect students' basic psychological needs [9], [23]. Research shows that computer-mediated communication creates a time-space shift that reduces communication, weakens social connections, and increases isolation [6-7]. Software that facilitates real-time online video connections is constantly developing, allowing teachers and students to conduct live online classes.

2.2 Social Presence

Social presence, as described by Short et al. [43], refers to the degree of salience of the other person in the interaction and the interpersonal relationships that ensue. Short et al. [43] observed that computer-mediated communication fails to relay vital audio and visual cues from face-to-face communication, leading to reduced potential for developing a high level of social presence. According to this view, the social presence in an online learning environment is less than that in a traditional face-to-face classroom. Short et al. [43] identified intimacy and immediacy as the two core components of social presence, which are closely related [31] and determined by both verbal and non-verbal signals [20]. The ability of a medium to convey information about these cues affects its degree of social presence [11].

Garrison et al. [17] have extended the traditional definition of social presence to "the ability of participants in a community of inquiry to project themselves socially and emotionally, through the medium of communication being used". This social presence can be developed and fostered as individuals in the mediated environment are able to "make up" for lost social cues [45], e.g. expressing moods by using emoticons and displaying humour can affect the perception of social presence [39], [45]. Importantly, social presence is the result of interactions among social participants (i.e. students-students, student-instructors) in an online learning environment [18-19], [33]. The study by Liu et al. [28] presented evidence which showed that social presence is vital to maintaining

a high degree of online social interaction as a significant predictor of course retention in the online education environment.

Social presence is closely related to “connectedness”, which has been classified as a form of psychological involvement by Biocca et al. [3]. Ijsselstein et al. [25] have shown that these two concepts are complementary in the awareness system. Rettie [37] pointed out that connectedness’ is potentially useful in the analysis of communication. In this study, connectedness is studied together with social presence as a related concept.

Networked Minds Measure. Biocca et al. [4] identified three essential dimensions of social presence, which they term “Co-Presence”, “Psychological Involvement”, and “Behavioral Engagement”, with corresponding empirically-determined factors. The Networked Minds Measure of Social Presence (NMMSP) questionnaire consists of multiple items for each of these three factors. It proposes a rough hierarchy among the dimensions of social presence and measures the extent to which individuals feel interconnected through networked mediated interfaces [4]. This approach is consistent with other conventional subjective measures of social presence but promises a relatively high degree of reliability in cross-media comparisons.

2.3 Honest (Unconscious) Behaviour

The unconscious mind was defined by Freud [14] as a pool of thoughts, memories, urges and feelings outside of human consciousness. According to Hua and Fei’s [24] study of behaviour on interaction design, unconscious behaviour is the representation of unconscious needs based on long-term life experience, psychology, instincts, and emotional influences. Unconscious behaviour may therefore be an important factor in determining demands [26]. Honest signals are considered those that are not processed consciously or are not controllable [30]. Pentland’s study [35] focused on “influence, mimicry, activity and consistency” as honest human signals measured by the timing, energy, and variability of the interaction. The experiment observes that people use combinations of honest signals in real life rather than using them individually [35]. In this study, the honest signals served as part of the system design rather than the objects being measured.

3 A-Vibe Design and Experiment

3.1 Design

Platform overview. Microsoft Teams has been chosen as the reference live online class platform for the study as it supports both synchronous and asynchronous online learning [34], providing a well-integrated educational space.

The animal models used in this study were launched by Live2D and PrprLive. Live2D is a software technology that creates dynamic expression into an original 2D illustration and is utilized for a wide range of applications [47]. PrprLive is a Live2D live broadcast support software. It enables high-frame-rate Live2D animation with high-performance facial capture [1]. Open Broadcaster Software (OBS) Studio, a free open-source broadcaster software, was used in this study for creating scenes made up of multiple sources as a virtual camera. Specifically, it allows the animal models to be layered on top of the webcam source and then displays the designed scenes. Lastly, Face Analysis (Visage|SDK live), a software development kit developed by the company Visage Technologies AB [13], was used as one of the criteria for assessing participants’ emotions in the experiment.

A-Vibe system. Humans can usually explain the emotions of both themselves and animals through the study of facial expressions, gestures, and postures that share a common origin in life [24]. Previous studies suggest that human empathy for animals can transfer to empathy for other humans [46], leading to increased engagement in social interactions when using animal-form avatars. Taking these findings into consideration and inspiration from the theory of “Honest Signals” [35], the A-Vibe system was built. It is important to note that “Honest” state refers to inner real emotions rather than the emotions displayed and observed directly. The use of animal-form avatars is intended to preserve privacy while conveying the individual’s honest state, thereby raising the issue of the relationship between the avatar and the learner’s sense of self. It should be noted that these animal avatars utilize sample data owned and copyrighted by Live2D Inc., and is created at the authors’ sole discretion in accordance with Live2D’s terms and conditions [29].

When the user starts the system and chooses one avatar, it presents an idle state. Apart from the real time facial tracking output, seven different moods of the avatars are animated: idle, laughing, sweating, questioning, surprising (shocking), nodding, and clapping. Each animation is triggered by manually pressing the corresponding key on the keyboard. The animation time lasts about three seconds. Pressing the “1” key on the Numpad returns the avatar to the default state immediately.

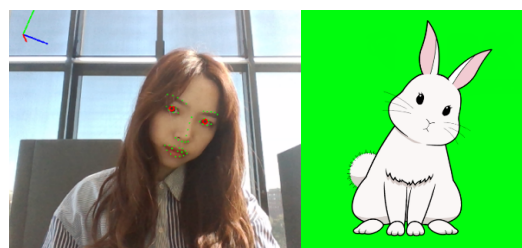


Fig. 1. Examples of interaction with users: (a) tracked face, (b) animated avatar

In OBS the different video sources are combined into one cohesive scene, which is turned into a virtual camera so that Microsoft Teams can use it as the input for the camera. Two scenes were created in OBS, which can easily be switched between: (1) Live video output and avatar (LA), and (2) avatar (AO).

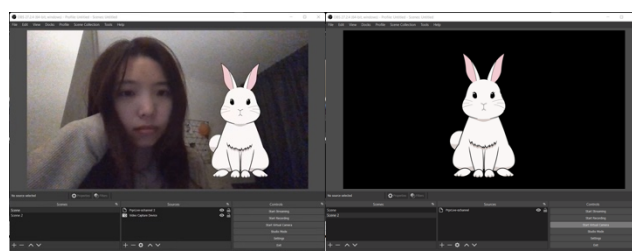


Fig. 2. Two scenes in OBS: (a) LA, and (b) AO (idle/default status of one of the avatars)

3.2 Participants

The participants of the study comprised a total of 16 master’s students (mean (M) $\pm$ standard deviation (SD) age 24.3 ± 1.40) experienced in online education and studying at Eindhoven University of Technology. The sample was equally divided between males and females. Participants’ ages ranged from 22 to 27, with four individuals in the 22-23 age group, six individuals in the 24-25 age group, and six individuals in the 26-27 age group. Purposive sampling, a non-probability sampling

method, was used in the study since it allows researchers to decide which samples will best represent the main audience based on their prior knowledge. Purposive sampling is “used to select respondents that are most likely to yield appropriate and useful information” [27].

3.3 Procedure

The experiment took place in a room with a pre set-up A-Vibe system. Prior to the experiment, participants had received a digital consent form and were briefed on the purpose of the study and the experimental procedures involved. Participants also completed a brief demographic survey that included a question on their level of cooking experience on a scale of 1 to 5 since the class was about cooking.

The experiment consisted of sequential steps: Preparation, Tutorial, Trial 1, Trial 2, Trial 3, and Post-questionnaire. Each participant spent about 50 minutes in total. Participants first selected a preferred avatar from ten options and completed a 3-minute tutorial. They then participated in three trials, one for each situation: face-to-face (FtF), Avatar (AO), and Live Avatar (LA). In the FtF situation, the participant and the experimental assistant were in the same room, while in the other two, they were in separate rooms connected via the online video conferencing interface in Microsoft Teams.

The study was designed as a within-subject experiment, and the order of the three experimental conditions was randomly assigned. In every trial, there were common steps: “Watching video” - “Performing task” - “Survey”. Participants watched a 5-minute instructional video about cooking with the experimental assistant. Immediately after the video, they had 2 minutes to describe the steps in making the dish taught in the video with the assistant. At the end of each trial, participants completed a survey, and after all three trials, they filled out a post-questionnaire.

In the AO and LA conditions, participants were in the same room as the experimenter when “Watching video”. The experimenter manipulated the participant’s avatar based on human observation and Face Analysis results. The participant’s inputs had priority over the experimenter’s in controlling the animations. During the “Performing task” and “Survey” steps, the experimenter left the room.

3.4 Measures

The survey conducted after each of the three trials consisted of three self-report instruments: (1) The Inclusion of Other in the Self (IOS) Scale [2]; and (2) Semantic differential questionnaire (SDQ) [43]; (3) the NMMSP [3] to measure participants’ degree of connectedness and perceived social presence. To minimize the possibility of response bias, the order of the questionnaires for each participant was randomised. The experiment concluded with a post-questionnaire consisting of two general and three open-ended questions aimed at assessing potential customer acceptance of the A-Vibe system and gathering qualitative data, respectively.

The Inclusion of Other in the Self Scale. The IOS scale [2], is a seven-step, interval-level scale used to measure “a person’s sense of direct interconnectedness with another”. It is a reliable measure of the subjective closeness of a relationship in psychological terms [15], which is used to evaluate the level of closeness of the participant with the experimental assistant after each round of test. In the

IOS scale, participants select the picture that best describes their relationship and each diagram represents a different degree of overlap between two circles (see Figure. 3 below).

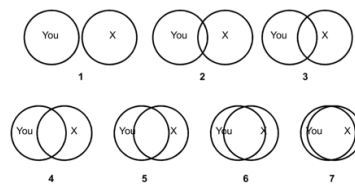


Fig. 3. The IOS scale [15]

Semantic Differential Questionnaires. Short et al. [43] suggested that the semantic differential technique [32] is the primary subjective method used to measure social presence using seven-point bi-polar scales. Eight bi-polar pairs were selected from Short et al.'s SDQ to measure participants' perceived social presence. Four bi-polar pairs were used to measure the presence of social richness. Another four were used to measure the aesthetic sensibility of the media.

Networked Minds Measure of Social Presence. All thirty-eight items of the NMMSp were used in the study to detect the difference between face-to-face and mediated interactions in the level of perceived social presence. The items target the experience of the mediated interactions as the main criterion [3].

4 Results

4.1 Reliability Analysis

A reliability statistical analysis of all items was performed using Cronbach's coefficient alpha. The alpha scores for the factors in SDQ were found to be sufficient (> 0.6). However, for both "Corrected item-total correlation (CITC)" and "Cronbach's alpha if item deleted", "Impersonal-personal" obtained a failing value and therefore was removed. In the NMMSp, the factors "Mutual awareness", "Mutual assistance" and "Dependent action" reached an insufficient alpha score (< 0.6) thus being excluded from further analysis.

1.1 Means Comparison

The mean value and standard error of the degree of connectedness, measured by the IOS scale can be seen in Fig. 4(a) below. The mean values of every condition were compared in an analysis of variance with the FtF, AO, and LA situations as a within-subject factor. The main effect of the situations was significant for connectedness ($F=3.634$, $p=0.034<0.05$). ANOVA post-hoc tests were then performed for multiple comparisons. The connectedness mean score for FtF ($M=6.25$, $SD=1.00$) was significantly higher than that for LA ($M=4.92$, $SD=0.87$, $p=0.035$). No significant differences could be found between FtF & AO and LA & AO.

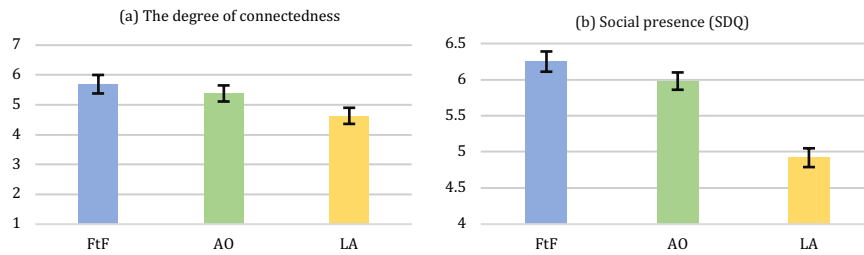


Fig. 4. (a) Mean differences and standard errors in the connectedness factor, measured by the IOS scale (Y-axis starts at 1); (b) mean differences and standard errors in the social presence factors, measured by SDQ (Y-axis starts at 4)

The mean values and standard errors of social presence, measured by SDQ, are shown in Fig. 4(b). The mean values of all situations were compared in an analysis of variance with FtF, AO, and LA as a within-subject factor. The main effect of situations was significant for social presence ($F=16.219$, $p=0.012$). ANOVA post-hoc tests were then performed for multiple comparisons. The social presence means score for FtF ($M=6.25$, $SD=1.00$) was significantly higher than that for LA ($M=4.92$, $SD=0.87$, $p=0.017$). Measured social presence for AO was significantly higher than that for LA ($p=0.038$). No significant differences could be found between FtF and AO. The results show that social presence is higher in the FtF situation than in the video conferencing situations. The avatar alone supports a higher sense of social presence than when the real-time video and avatar show up together.

The mean value and standard error of social presence-aesthetic appeal, measured by SDQ, can be seen in Fig.5 below. No significant differences could be found in any of the factors of NMMSP. Therefore, no conclusions can be drawn from this questionnaire.

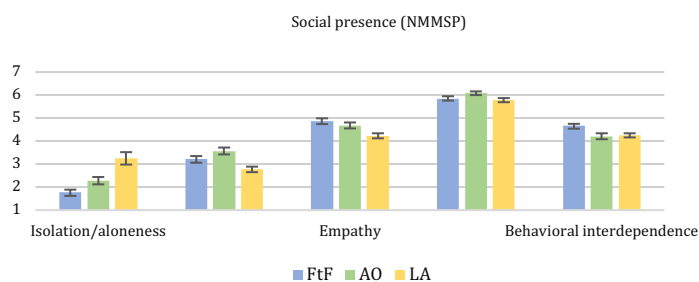


Fig. 5. Mean differences and standard errors in the social presence factors, measured by NMMSP

4.2 Analysis of Variance

To assess whether these differences were due to the group means differences related to the topic of the video (cooking), a one-way analysis of variance was chosen to analyse the impact of prior cooking experience ($M=3.1$, $SD=0.68$) on mean values of the IOS scale and SDQ. The results of this analysis ($p>0.05$) showed that the samples with different cooking experiences do not show significant differences for all group mean differences. This implies that the volatility of the data from the samples shows consistency and no variability. It can therefore be inferred that the results of connectedness and social presence measured in this study were due to the different experimental situations.

4.3 Potential Customer Acceptance

A-Vibe gained positive responses in terms of the participants' desire for future use, highlighting its potential. Out of the 16 participants, 14 (87.5%) responded affirmatively, while 2 (12.5%) responded negatively to the question: "Would you use or utilize the system in the future? And why?" Participants who answered "yes" generally mentioned the cute animal forms, which positively impacted their learning and increased their interaction with peers. However, Participant 8, who responded negatively, pointed out the system's occasional distractions. Participant 15, another negative respondent, explained: "I feel like it is more engaging than just voice, but it could not replace seeing someone's actual face for me". This is asking for richer information to be provided by the system. Overall, the system achieved a good grade: 7.4 (M) $\pm$ 1.20 (SD) (on a scale of 1–10).

4.4 Insights into the Avatar System

Understanding of the avatar. Ten participants (62.5%) saw the avatar as themselves in the experiment as the representation of the avatars matched their changing moods. Participant 2's answer noted that the avatars of the experimental assistants conveyed emotions well, which brought about the feeling that "the avatars were representing us to communicate to each other." Four participants (25%) identified the avatar as their pet. Interestingly, Participant 1 said: "I have a cat at home, so I always relate this cat avatar to my own cat when I interact with it." Another participant who also chose the cat avatar thought it is just a "cat" and wrote, "I really like cats so in my eyes it is a really cute 2D cat." Participant 15 thought the avatar was "just a cartoon character" and did not feel a connection to it.

Privacy aspects. The answers to the question, "Do you think the animal avatar format protects your privacy? And why?" provided the following results: nine (56.25%) yes and seven (43.75%) no, along with reasons. Those who agreed stated that the anonymity of the avatar in the AO situation protected their privacy while still enabling interaction. However, Participant 7 noted that "it's fun to see my 'honest' state in the form of an animal but at the same time I can say it's not me". Regarding the participants who answered no, some said they did not care; some raised doubts about it. As they pointed out, in the LA situation, the live video is still presented, so there is no perceived protection of privacy in essence. In addition, Participant 12 felt that using multiple cameras and facial analysis software in a real online classroom setting was intrusive. Participant 22 reported feeling uncomfortable, even with their real state was represented through the visual language of the animal avatar.

Richness of content. The last optional question was: "Is there anything else you would like to share?" A number of comments were made about the content presented by the system. Participant 4 proposed incorporating personalized text for speech bubbles to integrate text-based messaging. Participant 12 suggested adding a frame between avatars and live video in the LA situation, while another participant desired a background for the avatar, such as grass or sky. Customisable avatar backgrounds were also preferred by participants in the AO condition. Participants 1, 3, 4, 9, and 10 expressed a desire for more emotionally expressive animations. However, one participant noted that the current honest design could be confusing and suggested that conveying real-time emotions would improve communication.

5 Discussion

Considering the difficulty of detecting honest signals and reflecting them to the avatars, the alternative chosen for this study differs from the detection of unconscious signals in the original definition. Assessing the degree of honesty of honest signals was not included in the measurement of this study. The value of this study lies in the measurement of the connectedness and perceived social presence, rather than in the deep analysis of honest signals. However, this does affect the user experience as the response to the question about “privacy” and the participants’ understanding of the avatar shows that the avatar system did not really raise the issue of the relationship between the avatar and the self.

The IOS scale measured results showed that connectedness was the gold standard in the face-to-face situation, while it was not significantly associated between AO and LA. However, participants reported a facilitative effect of this system on interaction, which further promotes connectedness.

By using SDQ, it has been successfully found that differences not only between the face-to-face and the LA situation but also between the two mediated situations themselves in terms of the social presence scale. This result supports one of the hypotheses in Christie’s study [10] that the social presence dimension can distinguish between different variations of the same mediated system, which in this study is videoconferencing. The semantic difference measures also suggest that the AO situation is more capable of supporting an elevated sense of social presence than the LA situation in video conferencing. The concept underpinning AO videoconferencing was confirmed as it also had positive effects on the user’s social presence in terms of aesthetic appeal. Overall, the experiment result shows that this avatar system can potentially influence the degree of connectedness and social presence. However, NMMSP did not elucidate how social presence was influenced by different situations. Future evaluative studies should be carried out by trying other questionnaires, as well as adding some objective or physiological measures.

Limitations and Future Work. The current study had a small sample size of only 16 participants, and so results are not generalisable. Future work should recruit more participants and further explore the interactions between lecturers and students by applying the designed avatar system to real online lectures. Comparing the proposed AO and LA situations with real-time video only is also a direction for future research.

Additionally, the results were subject to the human factor. The performance of the experimental assistant who repeatedly participated in the experiment (whose performance was not considered in the data analysis) was not guaranteed to maintain the same level every time, and both proficiency with the content of the experiment and his fatigue level could affect participants’ experience. The way of capturing and transmitting “honest” state output in the experiment should be improved in the future, for example, by using tools like biosensors or sociometer-like sensors to sense the real states and reflect them to the avatars [21], [35]. However, privacy and ethical aspects must be kept in mind when deciding what tools to use, and they should be easy to use and accessible from the user’s perspective while maintaining the suitability and marketability of the system.

It is worth noting that while animal forms were chosen as the preferred design option in the current study, other possibilities should be considered in future research, such as abstract or humanistic representations, to provide a more comprehensive understanding of how different avatar designs affect user engagement and emotional expression. Additionally, a comparison with

other visual aids such as emojis as an expression of emotion could be an interesting avenue for further research.

6 Conclusion

The results showed that the degree of connectivity and social presence increased from the mediated communication LA situation to the AO situation and face-to-face communication. Although face-to-face was rated the highest in the IOS scale and SDQ, AO showed excellent performance, and participants reported that the animal-form avatar increased their enjoyment and encouraged interaction. However, further investigation is needed of the definition and transmission of honest signals in the system.

A-Vibe was well-liked by participants and gained good potential customer acceptance, but some criticism was noted. The introduction of the animal avatar in live online classes may lead to distractions for students, and the non-real-time presentation caused confusion for some users. Importantly, the system design and functionality leave much room for improvement.

Overall, it can be claimed that the research and development of animal avatars in live online classes are of great value for the students' connectedness and social presence. This study confirms the potential for video conferencing-mediated communication to perform at a good level of social presence compared to face-to-face communication, which is in line with Swan's [45] findings. It is hoped that this research can bring meaningful insights to researchers in the field of remote education, and contribute to more enjoyable video conferencing communication in future live online classes.

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An exploration UX Automotive in the 5G era: New interaction processes through gesture control and haptic feedback.

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Abstract. Cars are becoming smart devices with intelligent interfaces that fit into the smart driving environment, able to connect and coordinate with each other to ensure seamless user adoption. This is the context for the BASE5G project, a multidisciplinary project that aims to harness the potential of 5G connectivity to design adaptive urban environments in which cars are part of complex, infrastructure-integrated systems. The proposed work recounts the experience of designing the interior of a shared self-driving vehicle, with a focus on interface design. The interface design explores a touchless user interaction model involving a gesture-based control system implemented by haptic feedback. The project aims to explore a design scenario for an experiential car interface and interior that considers new visualisation and interaction paradigms in future mobility.

Keywords: User Experience, Sharing Mobility, Autonomous Driving, 5G Connection, User Interface

1 Introduction

The world is witnessing disruptive transitions in the automotive industry. With the rapid development of artificial intelligence and the Internet of Things (IoT) technology, the European Commission has suggested that automated mobility be deployed on a large scale and the full potential of data unleashed by 2030 by [1]. Furthermore, the notion of Mobility-as-a-Service (MaaS), which is often described as a one-stop platform digitally unifying trip creation, purchase and delivery [2] has been raised. MaaS changes the existing concept vehicle ownership and indeed the business model of the mobility industry. In summary, the automobile world is going through four main trends:

1. **Electrification:** reducing the dependence on fossil fuels and switching to battery-based vehicles.
2. **Autonomous Driving:** (semi-)autonomous cars are becoming more available.
3. **Connectivity:** with the increase in car connectivity, a car links not just to other cars but also to the wider online world.
4. **Shared Mobility:** in urban areas, the needs of mobility can be satisfied by shared mobility services.

2 Future of Mobility

According to Coppola and Silvestri, an extensive use of Electric Connected and Autonomous Vehicles (CAVs), i.e., future cars embedded with the latest technologies, along with accommodating infrastructure, characterise the mobility of the future [3]. And it has been suggested that future mobility needs should be considered in both physical and virtual forms [4], wherein the physical mobility represents “*a form of bridging distance to achieve connectivity*” [4], while the virtual form emphasizes the telecommunications aspect. Cars have already become highly complex with interconnected systems [5] consisting of various electronic control units [6]. In the future, this systematic tendency will be apply to all aspects of vehicle usage with the deeper integration of ICT technologies such as ubiquitous computing [7]. The high-level CAV can be recognised as a smart car which is part of the IoT and the Internet of Vehicles thanks to fifth-generation (5G) communication [8].

Cars are becoming smart devices with smart interfaces moving in an intelligent driving environment. Car will be able to connect and coordinate with each other in a decentralized proactive manner to synchronize traffic and driving behaviour [7]. Such a huge increase of automation and connectivity of cars promotes more diverse behaviour and events of users in/with cars. Drivers will have more need for non-driving-related activities with CAVs [11]. As such, the in-vehicle information and infotainment systems and the way people interact with these systems will also see a huge change [12][13], incorporating multi-sensory (including voice, tactile, olfaction, and somato-sensory [14] and multimodal [7] natural interaction for a comprehensive driving experience based on multi-channel user interface (UI). The gradual digitalisation and intelligentisation of cars and the car industry would, in a bigger picture, drive the business model in the automotive industry to shift from a physically-oriented one to a more digitally-oriented one [15]. Automotive companies are recommended to increasingly rely on the integration of attractive value-adding services into value propositions [16], such as offering additional subscription services. For instance, Tesla offers its Advanced Assisted Driving feature as a subscription service to customers who have purchased a specific model [18]. Mercedes-Benz has also recently announced an accelerated subscription service for the *Mercedes-EQ* range of electric vehicles in North America [19].

Moving beyond seeing the car as a digitalized product-service system [20], Mobility as a Service (MaaS) has also been widely discussed as a future context of urban mobility, and is often described as “a one-stop, travel management platform digitally unifying trip creation, purchase and delivery” [2, p. 6]. Shared vehicles in MaaS are recommended to offer a personalized service and a diverse interior layout based on expected UX [21]. Future mobility also plays a critical role in constituting the future smart city. Here, the smart city can be taken as the intelligent driving environment for electric CAVs, and is defined as a city environment where “*investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance*” [22].

Smart mobility is considered to be an important pillar of the smart city concept, which consists of various digital solutions focused on optimizing mobility problems, including traffic congestion, parking, pedestrian safety and urban sprawl [24] [23]. In the future mobility context, the future electric CAV can be taken as a main ICT resource of smart cities [25]. While accessing the vehicular network, cars act as mobile base stations which can be accessed by people inhabiting smart cities via smart devices. In addition, the capabilities of future cars of processing and storing data and

information plus their ubiquity in the city can build a network to enable a multitude of services in future cities [25]. Specifically, future cars can outsource part of their computation over neighbourhood resources in cities and this depends on technologies such as the edge computing paradigm, which is supported by 5G mobile networks [26]. As discussed earlier in this paper, we can envision how future mobility boosted by future vehicles would make significant impacts on future living, which can be taken as a sociotechnical system transformation of mobility [27]. There are already several practical commercial projects that explore the implementation of these disruptive technologies. Starting from a self-driving car project in 2009 by Google, *Waymo* has launched the *Waymo One* service in Phoenix, Arizona and San Francisco, California in the USA [29]. Such exciting and anticipated future mobility scenarios cannot be realised without the in-depth integration and use of communication technologies, including 5G [29]. In this paper we explore the innovative design scenarios and challenges that arise from the use of 5G technology in smart vehicles, based on a real-life BASEG project. This name derives from *Broadband interfaces and services for Smart Environments, enabled by 5G technologies*.

3 Project Framing BASE5G

BASE5G was a multidisciplinary research project exploring the different applications of 5G technologies, such as health, didactics, sports, and mobility. *Regione Lombardia* selected this EU-funded project to understand and study the application of 5G technology in the short term. Our research group explores a new hyper-connected urban mobility within this more extensive project. The design team collaborated with the Department of Mechanical Engineering (DMEC) and the Department of Management, Economics, and Industrial Engineering (DIG) of Politecnico di Milano. Company partners are Vodafone, a leading company in communication technologies, and Akkodis, an innovation accelerator company working on automotive design projects. Our research group has identified new urban mobility scenarios and applied some of these to two prototypes (physically and virtually developed). The research presented in this paper focuses on the virtual interactive prototype by redesigning the user experience (UX) in an electric autonomous driving vehicle.

More precisely, the research intends to explore a new interaction process through gesture control and haptic feedback.

3.1 The BASE5G project scenario

The design of the BASE5G car refers to a hyper-connected mobility system that experimentally investigates a new shape and configuration of the car itself. The project framework assumes that the connectivity of 5G and the integration with IoT platforms will transform cars from a means of transport into authentic digital platforms [30]. As noted earlier, products are blurring digital and physical boundaries, and cars are increasingly digitised and connected, which involves a change in product configuration and user interaction. Therefore, the BASE5G car is to be considered part of an integrated communication and data exchange, usually referred to as "*Vehicle-to-Everything*" [8], which involves not only the exchange of data between vehicles but also communication with infrastructure and people's devices [3]. It refers to a seamless experience where multi-device systems dialogue and smart cars become part of the user's device ecosystem [31]. The BASE5G car exchanges dynamic information between people, vehicles and roads and the user's devices are

integrated with and connected to cars. The user is at the centre of a mobility ecosystem that can connect to the decentralised and proactive data exchange to personalise the driving experience.

Upon entering the car, users find an environment connected to their digital identity that brings in all their information. The latter may change according to the terms and consents provided by the user on personal data sharing and may include information on likes and dislikes, medical conditions and job positions. With their digital identity, users will bring their data into the vehicle and facilitate integration with personal devices and cloud space, allowing the vehicle's interior to be hyper-personalised (see Fig. 1 below for the aesthetic concept of the BASE5G car).

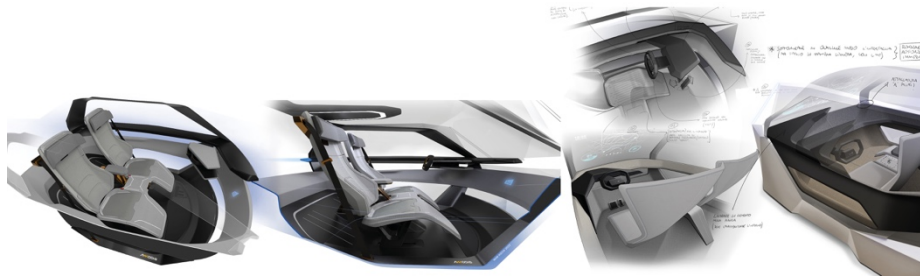


Fig. 1. Aesthetic concept of the BASE5G car with renderings of the car's interior and exterior

The car thus becomes a *Smart Bubble*, a personal and customised space for the user, which communicates with the outside environment to enrich the in-car experience. According to research, future car use will be more than just a means of transport. The vehicle will become an environment in which users can carry out activities, whether work or leisure. The car can become a *Smart Office*, which isolates the user from the outside environment by creating an ideal working environment, or it can become a *Smart Infotainment* space that interacts with the outside world in an integrated and personalised way, providing information from the surrounding environment using augmented reality. These assumptions will inevitably change the car's interior and the cabin's layout. This leads to a new dashboard model in which the steering wheel is hidden, not eliminated, but appears automatically based on the level of autonomy or specific user requests in shared driving control or co-piloting involving the car and the driver. The cockpit will be transformed into a comfortable space and will house the haptic gesture controller. The seats will become cosy armchairs, and the windscreen the communication channel between the car, the user and the city. In the BASE5G car, the interface is projected and visible directly on the windshield using the full-screen Head-Up Display (HUD), which can be interacted with through a gesture-based control system implemented by haptic feedback.

3.2 Driving Simulator Prototype.

The project scenario provides a broad view of the idea. An interactive prototype realised as the project outcome was scaled down to meet time and technological constraints but the result of the research was a driving simulator reproducing the vehicle's interior environment and driving experience.

The interface design explores a touchless user-interaction model involving a gesture-based control system implemented by haptic feedback. The interface incorporates natural multisensory interaction involving voice and touch and is multimodal for a complete driving experience. Since the design process refers to shared mobility designed during a pandemic, it was decided to eliminate all physical control systems and touchscreens in the cockpit.

Moreover, the haptic feedback system aims to improve efficiency and reduce the user's cognitive load during interaction with the interface [31], providing a "touch" feeling even without physical elements. The team of engineers was responsible for the technical realisation of the prototype. The prototype was realised in the IDrive Lab of DMEC (Politecnico di Milano), a car simulator that reproduces the windshield using three screens that communicate with a *Stratos Explore from Ultrahaptics* to generate haptic feedback through the controlled emission of ultrasonic waves (see Fig. 2 below).



Fig. 2. IDrive simulator during a demonstration event of the BASE5G project.

In recent years, the automotive industry has started to use the windshield as a media to convey information about the vehicle, giving it an active function [32]. Examples of HUDs have recently started to spread in the automotive sector and can be found in several types of vehicles, such as the Mercedes S-Class.

There are conflicting studies on the subject; according to some, the application of the HUD system can reduce the driver's response time to emergencies and make speed control more consistent, while according to other research, the HUD is an obstacle to driving [33] because it is located right in front of the driver's point of view, interfering with the road view. The centrality of the viewpoint, however, is also an opportunity when exploited to display valuable and timely information because it reduces the distance the driver's eyes have to travel to see essential information.

Aware of the current technological limitations, the design choice was to reduce the complexity of fragmented information on multiple screens in the car [14] by focusing information and user attention on the windshield that communicates with the external environment.

3.3 Gesture Interaction Model

The design and engineering teams developed three different haptic interactions, using *LeapMotion* and *UltraHaptics* devices, corresponding to different visual feedbacks within the UI. In this way, users interact with the HUD of the driving simulator prototype.

The three types of haptic gesture interaction and the feedback on the UI are:

1. The first "finger interaction" involves using individual finger movements to activate the interface's main menu functions. When the selection is made, a vibration on the fingertip notifies the user of the activation, and the desired menu opens.
2. The second "swipe interaction" allows users to interact using simple aerial swipe gestures. When the user's hand "touches" two vertical virtual walls, one on the right and one on the left, the user perceives haptic feedback. The interface comes alive by scrolling the menu to the right or left depending on the surface touched; once the desired menu item is reached, it can be selected by simulating a "grab" (closing the hand into a fist), and the interface reacts by opening the chosen section. *UltraHaptics* and UI give feedback each time the gesture is executed correctly.
3. The third "grid interaction" allows users to select information on the windscreen by moving their hand over a virtual grid. Some sub-menus on the interface are designed to maintain a correspondence between haptic feedback and the position of elements on the UI. Users will feel the feedback in their palms and feel that they are touching the various menu icons in grid mode.

3.4 User Interface

The interface was developed considering the three-gesture interaction models the engineering team had implemented. The menu is presented inline and has five items for better finger interaction. Navigation of internal pages is possible thanks to the "swipe interaction" facilitated by the interface UI that suggests the gesture. In more complex cases, such as document selection, document icons are arranged in a grid layout on the screen to match the "grid interaction".

One of the first design challenges was to organise the information that would usually be spread across several screens in the car on a single screen. Different information architecture and UI hypotheses were tested to define the optimal location and most coherent stylistic layout of the information on the windshield. This phase determined the type and flow of information and denoted the proactivity of the interface. Moreover, the opportunity to iteratively test the interface enabled an accessibility analysis with colour and contrast tests in the virtual environment. The information on the screen was clustered into distinct groups: the ones referring to the *Driving Info*, which include information on speed, driving mode and vehicle status, were designed to be close to the field of view. The *Navigation Info* was placed to reassure the user by showing the route and situation, with an interactive map and traffic information. Finally, there is the *Advanced Control* which, through an exploratory menu, allows navigating all the car's other functions, from HVAC (heating, ventilation, and air conditioning) to the communication system and Infotainment.



Fig. 3. User Interface of driving simulator showing active communication with the city through augmented reality in a partially immersive experience

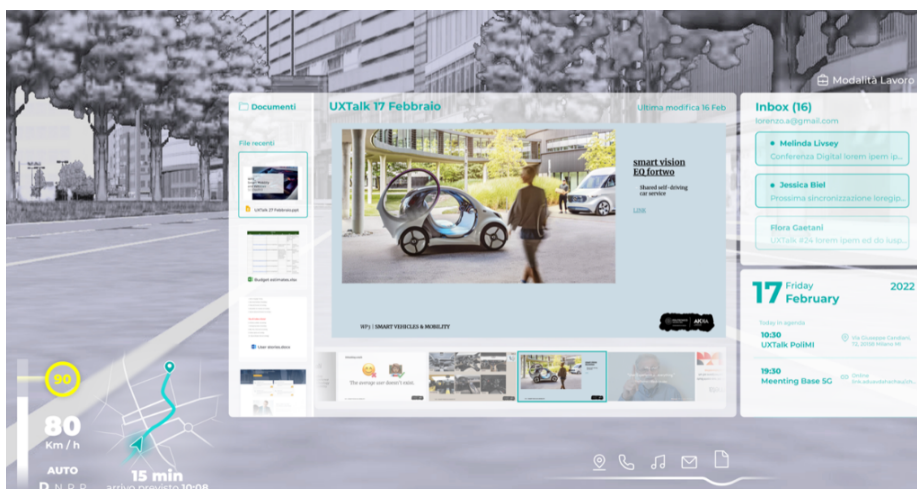


Fig. 3. User Interface of driving simulator showing the immersive experience

A 3D representation of the vehicle is projected onto the interface, allowing the user to proactively control the state of the car relative to the external environment. Augmented reality is also used to increase the immersive dimension with types of experience:

- A partially immersive experience (see Fig. 3 above) in which the interface proactively integrates with the city by giving information about the surrounding buildings (Smart Infotainment).
- A fully immersive experience (see Fig. 4 above) with protection that obscures the external environment and allows complete privacy for or concentration from the user (Smart Office).

In conclusion, the interface is proactive and adapts to different driving situations to reduce the cognitive load on the user and ensure that only the necessary information is displayed on the interface at the appropriate time. The interface design emphasises communication with the external environment and connecting the car with the city.

4 Pilot Test Findings and Conclusions

The research team is working on a series of tests with the virtual prototype to validate the iteration model, better understand the limitations and functionalities, and improve the UX by collecting direct feedback. The test will consist of a simulated walkthrough in which the user can interact with projections on monitors simulating the most realistic scenarios possible. A series of pilot tests were performed, which showed preliminary results that will be validated and further explored during the upcoming user tests.

The results of the pilot tests also showed that gesture control is possible even if a complete dematerialisation of the interface is not feasible. Touchless control needs specific feedback; in this case, haptic feedback improves usability, and the UI can help guide user interaction. In general, the pilot tests showed that touchless interaction requires a preliminary learning moment for the user; during the first tests, we realised that it is necessary to provide an onboarding moment to allow the user to become familiar with gestural interaction.

Three main critical issues emerged concerning the relation between gesture interaction and the HUD interface:

1. Need for contextual feedback notifying the position and presence of the hand: the interface must vary its state by showing clear feedback, e.g., by increasing the brightness of the menu to help the user understand the correct hand position.
2. The most difficult interactions are those that do not map natural user behaviours: "*grid interaction*" is the least natural gesture and, therefore, the most complex to learn and apply correctly, unlike "*swipe interaction*", which is the most intuitive, also because of its obvious parallelism with the interactions we are used to with digital devices.
3. The UI is most helpful in understanding the interaction model: "*finger interaction*" has led to the need for the menu to have an icon layout directly associated with the five fingers of the hand that act as selectors during the gesture.

This research has made it possible to work experimentally by focusing on the interior of the vehicle instead of concentrating on the exterior and power to create an environment that makes driving more productive and enjoyable. The automotive field allows for the practice of a strategic methodological approach, capable of predicting and describing future scenarios, supporting radical innovation processes while at the same time working and stressing design limits, and experimenting and testing design dynamics that lead to radical innovations. Multidisciplinary collaboration in such complex contexts as automotive UX redraws disciplinary boundaries and highlights how specific professional profiles can mutually benefit from cooperation.

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Comfort Between the Top and Bottom: A Cost-Effective Ergonomic Monitor Stand with Automatic Height Adjustment Based on Machine Learning

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Abstract. Prolonged use of poorly designed monitors that induce incorrect posture harms human health. This paper presents a machine learning-based design approach to an automatic height-adjusting ergonomic monitor stand which offers significant advantages in terms of cost-effectiveness and non-destructive modifications compared to currently available solutions. The research described here includes details of model training, data collection, programming, and mechanical construction in the design of the stand. The work also optimises the training set in an innovative manner by reusing two machine learning models. A tentative approach is proposed in this paper, which may verify the accuracy of the model training method, the improvement of the user experience, and the simplicity of non-destructive modifications by inviting users to replicate the retrofit under the guidance of the researchers. This research contributes to the adoption of relevant artificial intelligence ergonomic devices, reflecting the user-friendliness of human-computer interaction and the inclusiveness of intelligent technology.

Keywords: Machine Learning, Ergonomics, Cost-effectiveness, Monitor, User Experience

1 Introduction

1.1 Reasons for Choosing the Topic

The development of digital office work increases the amount of work time when employees are in front of monitors, and this leads to health problems, including musculoskeletal complaints and fatigue [1] [2]. To alleviate these problems, experts advise users to adjust the height and angle of their monitors to the "proper desktop position" [3]. Marcus et al. [4] propose that encouraging "specific seated postures" may reduce the risk of musculoskeletal disorders and symptoms.

The overriding point is that the poor design and layout of the workstation is a significant factor in causing adverse effects on health [5]. In a less ergonomic computer application, repetitive movements and static posture causes musculoskeletal complaints [6]. Therefore, users should consider adjusting their sitting posture while using the computer at the appropriate time.

However, once the users have switched to another posture, it is common for some to forget to adjust the height and angle of the monitor, which causes a relapse to poor posture relative to the screen. For example, it is possible for the user to look down at the screen when switching to a more comfortable position. Hansraj [7] found that as the head of an adult bends forward, the weight on the spine increases dramatically. These excessive pressures may result in premature wear, tearing, degeneration, and potential surgeries.

The current study sought to design an ergonomic device that automatically adjusts the position of the monitor screen, based on an artificial intelligence model that recognises posture changes and adjusts the monitor screen to the proper position to optimise users' experience and facilitate the matching of industrial design with human-computer interaction.

1.2 Previous Studies

In 2015 Wei [8] applied for a patent for an *automatically height-adjustable monitor stand*, which implements face recognition technology to control two complex robotic arms moving horizontally and vertically to adjust the height of the mounting panel.

LG demonstrated the *ULtrafine Display Ergo AI 32UQ890* at Internationale Funkausstellung Berlin 2022. The Consumer Technology Association awarded the 2022 International Consumer Electronics Show Best of Innovation Award for it and described it as "the first monitor capable of automatically detecting the posture of users and adjusting its display position accordingly" [9]. This monitor also won the 2022 Red Dot Award for providing users with a guided way to maintain appropriate posture through optimised real-time AI analysis algorithms. It appears that display devices with intelligent position adjustment are worthy of prospective development.

1.3 Background

Although the patent for the automatically height-adjustable monitor stand was published in 2015 [8], only one prototype was exhibited by LG in 2022 [9], and it will possibly take a long time for the technology to be widely used in product development. The reasons why this intellectual property has been so delayed in its application should be considered.

The patent mentioned above has a precise mechanical structure, and the device uses a laser camera to improve face recognition accuracy [8]. These are its remarkable advantages. However, for consumer-level users, the expensive laser camera may prove to be an obstacle. Buying a stand that is more expensive than a monitor seems to lack appeal to them.

LG *32UQ890* monitor is a top-of-the-line product. Its price may not be very acceptable, and no consumer-grade counterparts exist on the market [11]. Therefore, a simple and inexpensive solution that can optimise the experience of consumer-level users by modifying the display without damage should be considered.

The International Data Corporation [12] indicates that most monitors sold in the last three years have height-adjustable swivel stands. While using such a monitor, a force applied in the vertical direction can move the screen up and down. Therefore, in the study, two stepper motors are installed below the screen to drive a series of mechanical structures to achieve screen height adjustment. A machine learning model that can classify face information and output signals is adopted to control the motors. A camera outside the monitor is responsible for capturing face information.

In addition, having no built-in camera monitors does not affect data collection. Users can utilize their phone or tablet as a webcam for monitors with APPs like *DroidCam* [13].

This study aims to achieve a simple and non-destructive retrofit. The research shows that users only need to install a few devices outside the monitor to access automatic adjustment. Therefore, parameter adjustment of the screen rotation angle is not considered because it would require removing the pivot, which increases the risk of damage when making modifications. Hence, the current solution considers improving the user experience through height adjustment only.

2 Methods

2.1 Machine Learning and Face Recognition

Classification and Algorithm. Supervised learning classification algorithms are applied in the study. The camera captures two categories of head-related information. Head height is collected to confirm the distance from the intersection line between the horizontal plane where the geometric centre of the head contour is located and the screen to the bottom of the screen. The Convolutional Neural Networks Algorithm is executed to classify the head contour features from captured information to estimate head position. Meanwhile, with the captured face information, the angle between the sight line of users and the normal vector of the screen is measured to detect the level of cervical spine flexion. These two types of information are used to train two classification models.

In the design assumption of the first model, called *Model_H*, the user follows the suggestions from Microsoft and adjusts the position of the device and body posture to the "proper desktop position" by looking horizontally at a given reference Point A (Fig.1 shows its position) on the top of the screen to ensure comfort before the formal experiment [3], with recommendations for maintaining the centre of the screen in the range between 15 and 25 degrees below eye level [14]. Therefore, multiplying the tangent of the above angle by the distance between the monitor and the eye may yield an appropriate value for the eye height relative to the midpoint of the monitor. According to Rempel et al. [15], setting this distance at 60 centimetres is acceptable for health reasons in work environments with fixed character sizes. The calculation reveals that the acceptable range of the distance between head height and screen centre height is between 16 and 28 centimetres. The minimum value of 16 centimetres is selected to accommodate small screen monitors with widths of less than 28 centimetres. Consequently, the height of Point A is equal to $y+16$ centimetres, where y denotes half the width of the screen. The above calculation is only an example, and the exact location of the reference point should be re-computed in a similar way to suit the practical situation. Table 1 and Figure 1 show the relationship between head height h and the classification of *Model_H*. Reference points in the figure are used in the data collection.

Table 1. The relationship between head height h and the classification of *Model_H*

Condition	Classification	Adjustments
$h \geq y+28$	Monitor position is too	Raise the
$y+16 < h <$	Monitor position is	No adjustment
$h \leq y+16$	Monitor position is too	Lower the
<i>Null</i>	Not in working condition	No adjustment

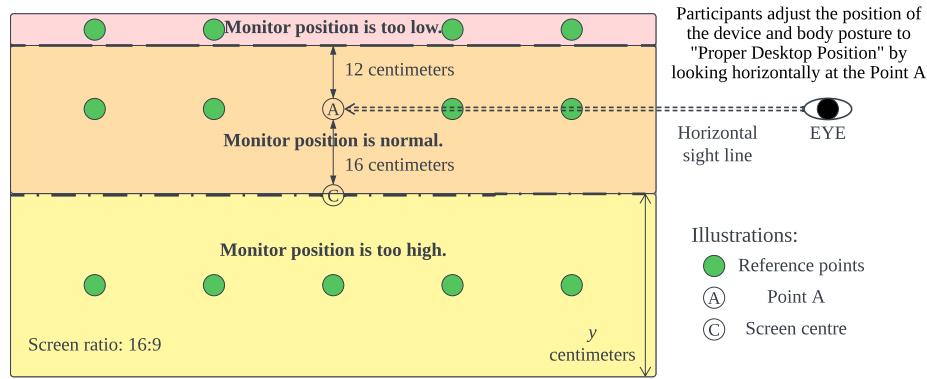


Fig. 1. Classification and reference point distribution of *Model_H*

The second Model, given as *Model_A*, is similar in design to the first. Assuming that the user initially looks horizontally at Point A and then bends the cervical spine downwards by approximately 15 degrees, the line of sight will coincide precisely with the screen centre. Namwongsa et al. [16] suggest limiting neck flexion to between 0 and 15 degrees will help control excessive cervical load and muscle activity. Thus, the intersection of the sight line with the screen below the centre reflects that the user is looking down. Distance from the intersection of the sight line with the screen to the bottom of the screen is h_0 . Table 2 and Fig 2 indicate the relationship between the h_0 and the classification of *Model_A*.

Table 2. The relationship between h_0 and the classification of *Model_A*

Condition	Classification	Adjustments
$h_0 \geq 2y$	Seriously looking up	Lower the screen
$y+32 < h_0 <$	Slightly looking up	Raise the screen
$y \leq h_0 \leq$	Normal	No adjustment
$h_0 \leq y$	Looking down	Raise the screen
Null	Not in working	No adjustment

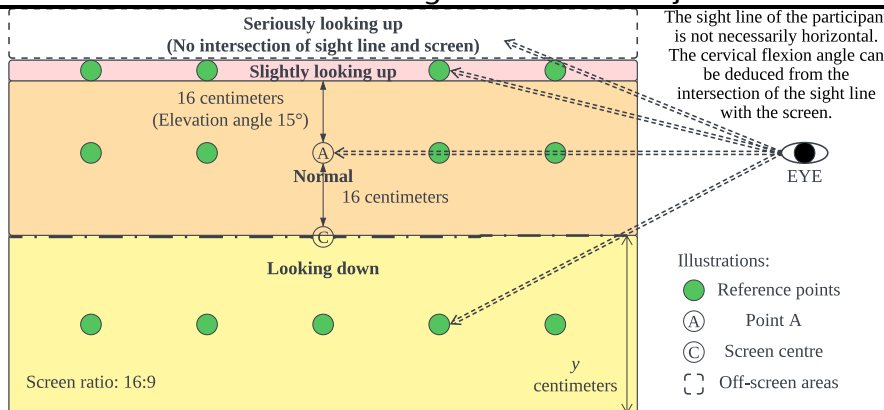


Fig. 2. Classification and reference point distribution of *Model_A*

Figure 3 below illustrates the program in which *Model_H* and *Model_A* are continuously alternated. Whenever a classification is identified, the program ensures the input is sorted into one condition for five seconds before adjusting thus eliminating frequent changes that may affect a positive user experience. The height adjustment is performed until normal conditions are detected or detected to

reach the lowest or highest point. A five-second pause follows to avoid unnecessary height adjustments resulting from excessive testing.

Fig. 3. Program Flowchart

Training Set and Data Collection. Not every monitor has a camera in the same position. Users need to place themselves within camera range and observe a full-screen picture with reference points. *Model_H* training data is captured at a constant rate of five frames per second when Fig. 1 is displayed at its actual size on the screen. In the example of the classification *Normal*, users start by maintaining a horizontal sight line, ensuring that their sight crosses any of the reference points in the interval for classification in Fig. 1. They then hold their head position unchanged and rotate their eyes to scan the other points in turn. By then horizontally rotating the head, simultaneously captured photos will contain cases that happen in practical situations, enhancing the classification accuracy. The above steps are repeated for the other classification.

Training of *Model_A* is conducted similarly. The users ensure that their horizontal sight line passes over any reference point in the *Normal* interval in Fig. 1 as displayed on the screen. Then users turn their necks to scan all the reference points in a given classification interval of Fig. 2, with the camera capturing pictures. Users need only to maintain their eyesight above the top edge of the monitor to access the classification of *Seriously looking up*.

Users could also duplicate the above data collection method by adjusting the subject-monitor distance from 60 cm to 50 or 70 cm to simulate a real environment, with a slight position change to increase the classification accuracy.

Null classifications in both models could apply to the same dataset. Valid data can be generated by showing the actual resting condition of the users in front of the camera. If using one classification model, every possible real-world scenario is considered exhaustively. However, alternating multiple models can create new events through basic events, and so the program in this study has the specific advantage of simplifying the data.

Model Training. This research found that the intensity of ambient light and monitor screen size significantly impact the classification accuracy of deep learning models. Collecting training set data in a multivariate environment seems rather challenging for individual users. Monitors are usually in a fixed position that determines unchanging ambient light and screen size in the workplace. Therefore, deeply customizing a machine learning model for each working environment may avoid numerous data-collection issues. For users who lack AI knowledge, the *Teachable Machine* website [17] can be referenced to generate a machine learning model with just a few minutes of instruction. Jeong [18] found that models trained by the *Teachable Machine* also achieve the level of traditional training methods in certain complex scenarios, such as healthcare. This website assists users with simple training of models.

2.2 Materials

A mechanical structure inspired by *Prusa i3*, which is an extensively implemented open-source 3D printer design solution, is utilized to achieve automatic height adjustment [19]. Open-source firmware *Marlin* is burned to the *Arduino* microcontroller to drive stepper motors conveniently [20]. Figure 4 below describes the materials used for the stand.

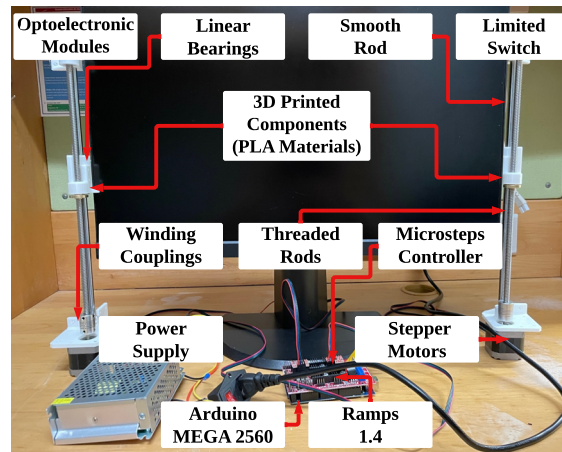


Fig. 4. Construction and materials of the stand

2.3 Parameter Adjustment

The height change of each command needs to be regulated for smoother adjustment. F denotes the number of steps the motor needs to run for every 1 mm rise of the threaded rods.

$$F = \frac{360^\circ \times m}{s \times p} \quad (1)$$

Where m represents the microsteps of the stepper motor driver, s is the Step anglemar of the stepper motor, and p is the pitch of the leadscrew. The stepper motor in the stand executes 1600 steps for every 1 mm rise. For a 24" monitor, the number of steps measured optimally in this study is 4800. However, the screen size, weight, and coefficient of friction between the height adjustment components can impact the result.

The practical application involves friction or slippage between components, where the height adjustment of the left and right sides is not synchronised. Defining the positive value for the number of steps executed when the motor is rotated clockwise and negative for counter-clockwise. The summed final value can be used to calculate the displacement x relative to the starting point. Comparing it with the actual value measured by the photoelectric sensor, the error can be adjusted in time.

$$x = \sum_{i=1}^n \frac{F_i}{f} \quad (2)$$

Where F_i is the number of steps in each executed producer of the stepper motor driver, and f is the number of steps executed of the 1 mm descending clamps.

Parameter *System Uptimes* in *Arduino* functions as a timer in the design model. The microcomputer starts to run with the number of *System Uptimes* increasing from 0 and vibrates when the number gets up to an integral multiple of 5,400,000, 45 minutes long, to alert users. If they refuse to break, the monitor will slowly move to guide them to adopt alternative proper postures.

2.4 Evaluation

A possible evaluation method of inviting participants to construct this monitor stand under the guidance of the researchers is proposed in this section. The criteria for the recruitment of participants could cover people of different ages, genders, professions, heights, and vision conditions without neck and shoulder pain for the universal design and the objective experiment. The feasibility and simplicity of the solution are considered to be evaluated by the assembly time of the stand, recognition accuracy of the model, and the psychological expectations and health improvement of users.

Experience feedback may implement a matched degree of expectational results and real outcomes of AI recognition. In this assumption, the participant pretends to make the wrong move and holds it for about 5 seconds after being explicitly informed of the correct sitting posture. It is recorded as a pass if the adjustment matches their expectations and guides them to adjust their posture correctly. The pass rate reflects recognition accuracy and design feasibility.

Considering the health of users, the experiment should be repeated a reasonable number of times to ensure the sample adequacy while ensuring that participants would not feel fatigue or discomfort. The influence of the device on the shoulder and neck movement frequency, muscles and tissues of the user also needs to be assessed.

3 Result

Table 3. below demonstrates that the approximate cost of stand assembly is HK\$232.2. It seems evident that this stand is more cost-effective than a top-of-the-range monitor with automatic height adjustment.

Table 3. Cost of the components in the stand

Object name	Number	Unit price	Cost(HKD)
100W Power supply	1 pc	HK\$28	HK\$28
3D printed PLA materials	110	HK\$0.4	HK\$44
A4988 Microsteps	2 pcs	HK\$3.5	HK\$7
Arduino MEGA2560 R3	1 pc	HK\$60	HK\$60
Bearing LM8LUU	2 pcs	HK\$3.8	HK\$7.6
Limit switches	1 pc	HK\$0.4	HK\$0.4

Optoelectronic modules	2 pcs	HK\$4	HK\$8
Ramps 1.4	1 pc	HK\$18	HK\$18
Refurbished stepper	2 pcs	HK\$12.5	HK\$25
Smooth rod D8	2 pcs	HK\$5.6	HK\$11.2
Threaded Rods T8	2 pcs	HK\$8	HK\$16
Winding couplings	2 pcs	HK\$2	HK\$4
Wires and Screws	N/A	N/A	HK\$3

The preceding section presents a preliminary idea for a feasibility evaluation of the low-cost machine learning-based ergonomic monitor stand design. This hypothesis still needs to be explored by further research.

4. Discussion and Conclusion

This section discusses the potential for enhancement of the study and provides a conclusion.

Although switching two AI models has reduced information in the training set and the optional use of *Teachable Machine* decreases training complexity, more advanced algorithms are still needed to reduce time consumption. The experiment in the assumption is conducted face-to-face, and remote instruction of the stand construction and model training may require more time. The feasibility of live or video mentoring still requires exploration. Reducing the complex steps involved in the installation may optimise time consumption.

Mechanical structures causing noise and vibration disturb users. Vibration damping devices and sound insulation materials may reduce negative impact. Replacing stepper motor controllers with more subdivision or adopting brushless motors may also decrease noise generation. However, these potentially increase costs. The figures in Table 3 show that the cost of 3D printing represents 18.95% of the total expenditure. The cost issue may be alleviated by lowering the print fill level or by using stamped plastic parts. Nevertheless, these changed components' compatibility and structural strength still need to be tested.

The monitor used in the experiment was 24 inches. The stepper motor power may need to be increased to adjust all variety of monitors with large screens. Improving device compatibility is a potential research direction.

This cost-effective ergonomic monitor stand with automatic height adjustment based on machine learning optimises user experience in an economical and simplified way. Future research will lead to further development of intelligent ergonomic design that reflects the inclusiveness of technology and its potential to enhance the quality of human life.

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Giving Form to the Invisible: Can we make in-home network data traffic tangible to users?

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Abstract. Most people now connect to the Internet of Things (IoT) through a number of devices within the privacy of their homes. The data traffic generated by smart home and other connected devices remains invisible and intangible to everyday users. Is it possible to make these complex data flows somehow visible, and with that also accessible and graspable for users? Is there a path for everyday users to participate in desirable future developments, meaningful services, and relevant policies? If so, how do we go about conducting such user research? In this paper, we report and reflect on an experimental study conducted by an interdisciplinary research team with these questions in mind. We explore the possibilities and limitations of a non-intrusive, plug & play network monitoring device. Our findings point to opportunities for empowering participants in sensitive environments like the home and produce insights into how designers may collaborate with researchers in data analysis to make the invisible visible.

Keywords: User research, smart home, designing in the digital age, data visualization, user empowerment

1 Introduction and Background

For most people, the potential opportunity to participate in the evolution of the digital technologies and AI services they use in the privacy of their homes stretches beyond a strong interaction between designers and customers. The aim of designers here can no longer be to merely 'mine invaluable sources of information'. Rather, it is increasingly a task for designers to make the invisible visible and to make concepts graspable, so that users can engage in the discussions and developments, thereby giving them a voice in how, where, when and why products and services based on these technologies benefit them. But how might designers trained in products and services, but in hardly any of the new technologies, fill this role, or even approach the task? We provide an example of collaboration among designers, computer scientists and network data analysts looking to make an in-home data network accessible to users.

More and more people are installing smart devices in the sanctity of their homes, effectively connecting them to the IoT and exposing them to new vulnerabilities [1, 2, 3]. Most of the data-gathering activities of devices remain largely undetected by their users. Researchers have established that end users lack mental models when it comes to new IoT technologies, and so may fail to grasp their complexities and the attendant risks to privacy and security. Absent mental models, what do people make of the many devices they have in their homes? How may we arrive

at user-friendly, easy-to-use, and meaningful ways for non-expert users to learn about the network traffic in their homes? What would products and services that enable them to monitor and interpret in-home data traffic look like [2, 4]? How could we support them in taking deliberate actions and making informed decisions about their data sharing?

The quest for such products and services poses new demands and challenges because such user research depends on a combination of technical, quantitative, and qualitative methods. The user perspective so far has not received much attention. Answers to date involve elaborate, lab-like set ups in users' homes that constitute major intrusions of living spaces [4] and are highly impracticable. Most are so complicated as to limit studies to a few households and participants who are technically sophisticated [4, 5]. These studies have proven significant and insightful but have done little to explore what kind of information may be helpful to everyday users or how such information could be made available to lay people within the (data) confines of their homes. Furthermore, they cannot be scaled-up or replicated easily as they are costly. This paper reports on a pilot study that experimented with a non-intrusive, scalable approach to the capture of in-home data traffic.

1.1 Background

A recent review on definitions of the smart home by Marikyan, Papagiannidis & Alamanos [6] explains that the term 'smart home' is reserved for homes equipped with 'smart devices and sensors that are integrated into an intelligent system, offering management, monitoring, support, and responsive services and embracing a range of economic, social, health-related, emotional, sustainability and security benefits.' Such definitions may mislead users to assume they only need to be concerned about security and privacy risks in their homes if they consciously install advanced smart home devices such as, for example, voice assistants [6, 7, 8]. Given the range of 'smart' sensing and networking devices available today, almost any home network may require a certain degree of control and transparency over the data exchanged in- and outside this network [7, 9]. Lacking an awareness of vulnerabilities, users have even fewer opportunities to mitigate potential risks. The only way to learn about the presence of vulnerabilities is to make them visible in one way or another. Therefore, studies into user awareness of security and privacy risks must account for data traffic generated by an increasing number of sensing 'non-smart' home devices.

Efforts at providing users with the means to monitor their in-home data streams have focused on traffic generated by 'smart home devices' [10] in 'smart homes' [11]. Beyond specifically labelled smart home devices, most modern electronic devices can be equipped with additional functions for recording, receiving, and sending data. While some data needs to be protected from external access, meta-data on data collection and communication activities of home network devices should be available to the home network users in a transparent way. Ideally, users should be enabled to make informed decisions and take deliberate actions to adjust their own network traffic to their own privacy and security preferences. Ideally, information on their in-home data flow should be available in real-time so they can control which data their in-home network will share with specific providers and app services. But as the example of the GDPR shows, it is simply impractical for users to monitor every device activity, i.e., every refrigerator and every toaster. In theory, GDPR provides autonomy and control over data to users. In reality, most people give up on de-selecting the seemingly endless list of permission requests [12, 13].

Conducting research into people's homes and now into in-home networks and data traffic poses new ethical challenges as these are clearly highly sensitive research settings [16, 17]. Such settings even challenge our notion of 'vulnerable' research participants, as those who participate are inevitably becoming vulnerable, sometimes without realizing it until very late in the process. As one participant in this Network Traffic Analysis shared with us: "I realize now that it would be so easy for someone to access my system under the pretense of research." The participant emphasized that having been part of the initial in-home study for our project was a factor for allowing the research team to pursue follow-up studies.¹

Current (in-) home network architectures are optimized for security, efficiency, and flexibility, but not for transparency of data traffic for users. Instead, these objectives often conflict with each other [10]. To change this, data needs to be gathered in an unobtrusive way and aggregated into meaningful information that users can act on. But even to get to the necessary insights poses new challenges for researchers: participants differ in age and technological enthusiasm and trust while the focus, by default, remains on technically literate users who can cope with elaborate lab-like arrangements in their homes for study purposes.

The issue of data legibility is related to but not identical to the challenge of making the intangible tangible and the invisible visible in a way that is meaningful and actionable to non-experts so they can become aware, make informed decisions, and take deliberate actions to minimize their privacy and security risks [10, 11]. Data visualization for users has gained new urgency [16] but presents new challenges. Though data visualizations have changed over time [17, 18], the needs of everyday users have yet to be addressed and considered in information visualizations of Big Data [16, 19].

There is a need for new methods to conduct research in the privacy of the home in ways that are less intrusive and reduce exposure of their data, their homes and their networks. Users also should also not need to adjust their everyday routines and practices around physical technical equipment and its requirements. In this context, limiting research to meta-data presents a way to maintain a high level of user privacy during ongoing research. But few users understand what meta-data is or can reveal. Users, in fact, continue to be treated more like subjects in these studies, with only a few benefitting directly from their participation. The question remains what kind of methods are suitable for researchers and users.

When looking at the IoT from the user perspective, these questions emerge:

Who tells me that the algorithms for filtering potentially sensitive devices ("design IoT Inspector such that it does not upload any traffic from devices that show signs of being general-purpose computing devices") really work?

Maybe I have a different opinion than the algorithm. What is sensitive for the programmer (the project manager/designer/developer) and what for me?

If I can then delete my data on a server (remotely) afterwards because they are too sensitive for me, then they have already been transferred and stored on a drive. I have to trust that, for example, if the data is backed up, the backups will

¹ For more on this follow-up project see: Shorter et al (forthcoming). Lifting the Bonnet on Voice Recognition Technology: Designing the WordCloud, *Designing Interactive Systems Conference (DIS)* 2023.

also be deleted. How is it deleted? Permanent and irreversible (data shredder) or is it just a "deleted" flag set?

I can't control who has access (or had before deleting it). Even if the architecture is broken down completely transparently (if I can remember that), I have to trust the setup.

Due to the great public attention, such projects are always interesting for hackers. What if someone gained unauthorized access or exploited a vulnerability in the architecture and was able to sniff the traffic (without the knowledge of the project team)?

We investigated (1) how to design a plug & play, user-friendly and self-installable data traffic monitoring device; (2) how might a minimally invasive/unobtrusive research approach to reduce the security and privacy risks to participants be conducted; (3) how can we visualize the data captured for users (i.e., non-experts) and make it understandable to them and (4) what insights into privacy and security issues can we gain from a user's perspective by presenting our findings to them employing semi-structured interviews. The study took place during the COVID-19 pandemic and the ability to capture network traffic remotely and without a physical visit turned out to be essential. It was further designed to be minimally intrusive to monitor users' in-home data traffic. We made use of Raspberry Pi 4 devices, compact full-fledged single-board computers, that were configured as network sniffing devices. Our requirements echo those established by DiCioccio et al [20]:

- a. Ease of Use: In our case, the tool had to be simple to install, run and de-install by non-experts.
- b. Portability: In our case, the tool needed to run on all home networks (WLAN and Ethernet).
- c. Respect Users' Privacy: In our case, the sniffing tool does not collect any identifiable information, no data is transferred over the internet, no data is uploaded to an external server.
- d. Light User Commitment: In our case, the installation, configuration, running, de-installation and returning of the device and its components had to be done in little time without drawing on the users' resources. The objective was to provide a plug & play experience.
- e. Incentive for Participation: In our case, user incentives were to learn about what one can see and infer from the data traffic in their home networks and to receive a visualization and explanation from experts on their personal network data.

Method and Approach

To minimize risks of privacy and security for our participants, we opted to store data only locally and to require no personal contact or cloud storage. The approach is one where data is (securely) deleted after local processing. For this reason, we experimented with a remote and non-intrusive set-up.

Our participants self-installed a monitoring/recording device we had prepared and mailed to them together with an illustrated step-by step instruction. There was no change to their living environment. The data sniffing device then recorded the participant's home network traffic for one week and recorded it locally before participants de-installed the device following another step-by-

step set of instructions. The recordings were stored locally on the device without the need for personal contact or sending or storing them in a cloud that could be hacked or accessed by third parties. They then returned their device to the research team in a prepared, pre-stamped and pre-addressed return box. We produced individual charts for each home network as well as a comparison chart with the other participants home networks. From this, we were able to produce insights into individual participants' in-home network data traffic, which we were able to compare and contrast with that of other participants. All data and participants' information were anonymized and recordings were deleted after analysis. Next, we developed a semi-structured interview around our findings for their home using PowerPoint slides. We invited participants to meet with us individually online to share and discuss our findings with them, prompting participants first to estimate what the recordings would reveal about their in-home data network traffic. We recorded their answers before we shared with them the actual data we captured for their home. We chose this approach to get a better understanding of how aware people are of the connected activities in their homes.

This network data traffic study was embedded within a larger study into the user experience of voice assistants in the home, which was conducted with 31 Swiss-German households. Of those, 16 households consented to join the network traffic study. However, four of our participants experienced technical difficulties and one withdrew, allowing us to collect data from eleven households (of the remaining participants three were male, nine female).² Prior to the in-home study, participants were asked to rank their technology expertise on a scale from 1 to 6, where 1 stood for "I am a novice to digital technologies" and 6 stood for "I am an expert, no one fools me." The majority considered themselves as knowledgeable to very knowledgeable (Table 1). Participants were not compensated for this part of our study, which was approved by our university's Internal Review Board. Participants also had to inform and get consent from members in their household, as in-home studies involve everyone in a home. We tested the technical set-up as well as the visualization and presentation of the captured data with two people who were not involved in any part of the study and were non-experts.

Table 1. Participants in the study.

Male Participants	Technical Self Assessment on 1-6 Scale	Participated in Power Point semi-structured interview	Female Participants	Technical Self Assessment on 1-6 Scale	Participated in Power Point semi-structured interview
M1	5	no	F1	2	no
M2	4*	YES*	F2	2	no

² In one household, two people signed up independently; that is how the number adds up to 12 participants.

Male Participants	Technical Self Assessment on 1-6 Scale	Participated in Power Point semi-structured interview	Female Participants	Technical Self Assessment on 1-6 Scale	Participated in Power Point semi-structured interview
M3	5	YES	F3	6	no
M4	5	no	F4	5*	YES*
M5	5	YES	F5	5	no
M6	withdrew	no	F6	3	no
M7	6	no	F7	4	no
M8	5	no	F8	5	no
Total 8			Total 8		

* M2 and F4 shared a household. They did not install the mini-computer but were interested in learning about the general findings. (Data from VA-PEPR).

Key Findings

Our findings go beyond those we mention here. We present here a summary only of those most relevant to the DesForm Community and its conference theme. Overall, the understanding of basic concepts of networks such as ports and packages was low even for people who judged themselves to be experts. In contrast, the forms of visualizations we chose (such as chord diagrams, bar charts, time series or histograms (see Figure 1 & 2 as an example) were intuitively clear.

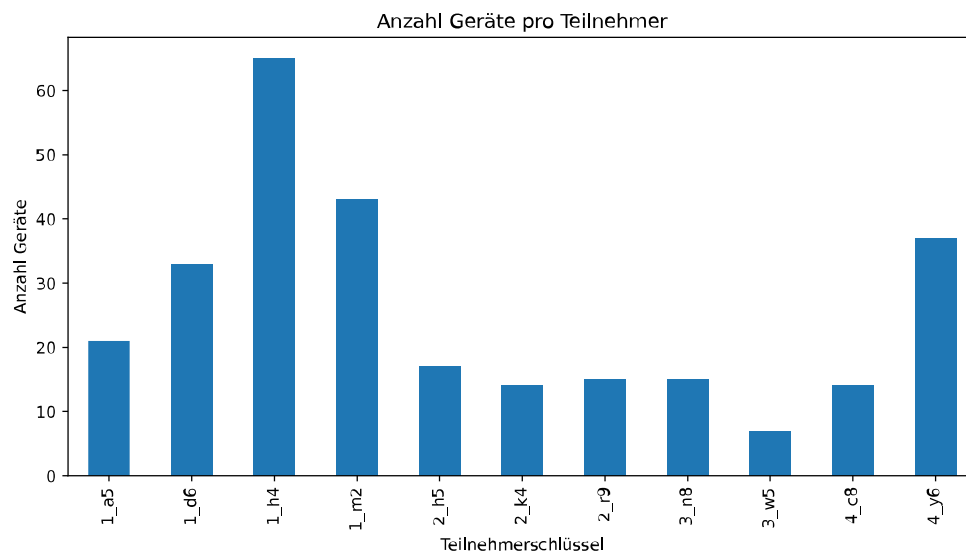


Fig. 1. Number of devices per household for each of the eleven participants: Do I have more or fewer than other participants? (Source: VA PEPR).

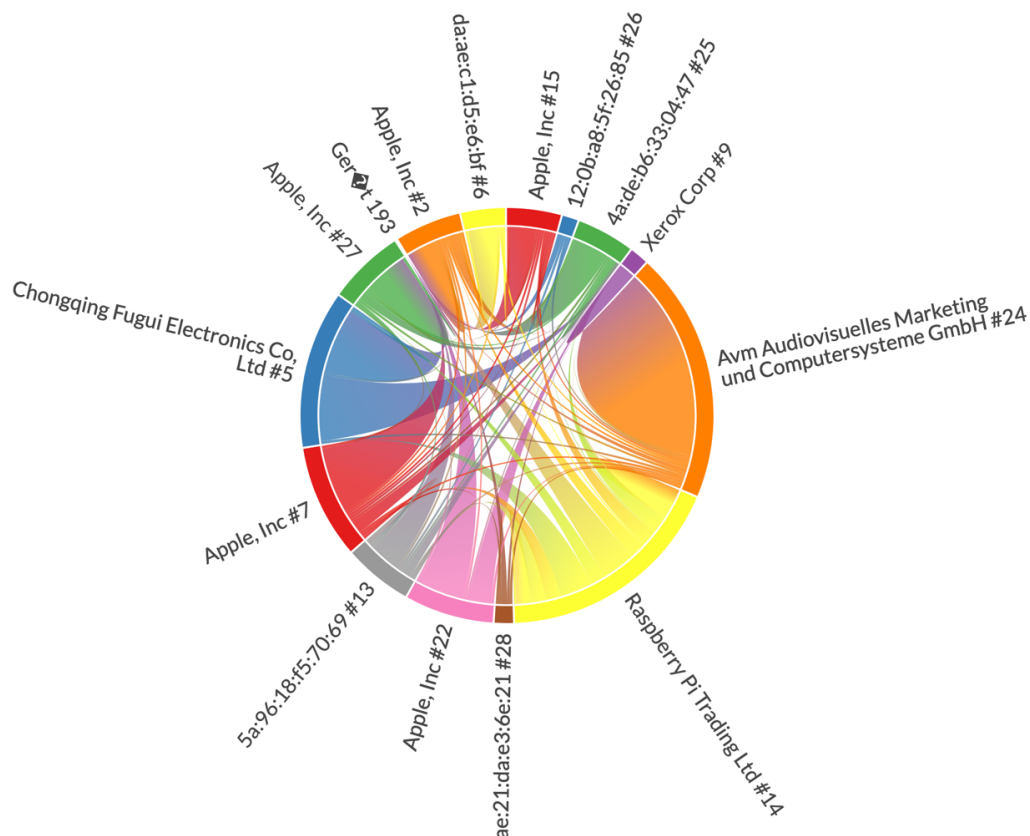


Fig. 2. What devices in your home are sending and receiving – from where to where? (Source: VA PEPR).

Users are looking for comparisons with others: Participants asked for cross-participant visualizations because they felt that this allowed them to compare their own household with others. Lacking mental models and any understanding of what ‘normal’ behavior is, the participants had trouble interpreting and judging the absolute values we presented for their in-home network (e.g., the number of open ports per device or network activity). It emerged that concepts relative to other households were significantly more intuitive than the absolute numbers. (See Fig.3 as an example). A wish for a clear point of orientation was noticeable. Immediate questions that arose were often of the type “Is it good or bad that I have less (or more) of ... than the others?”

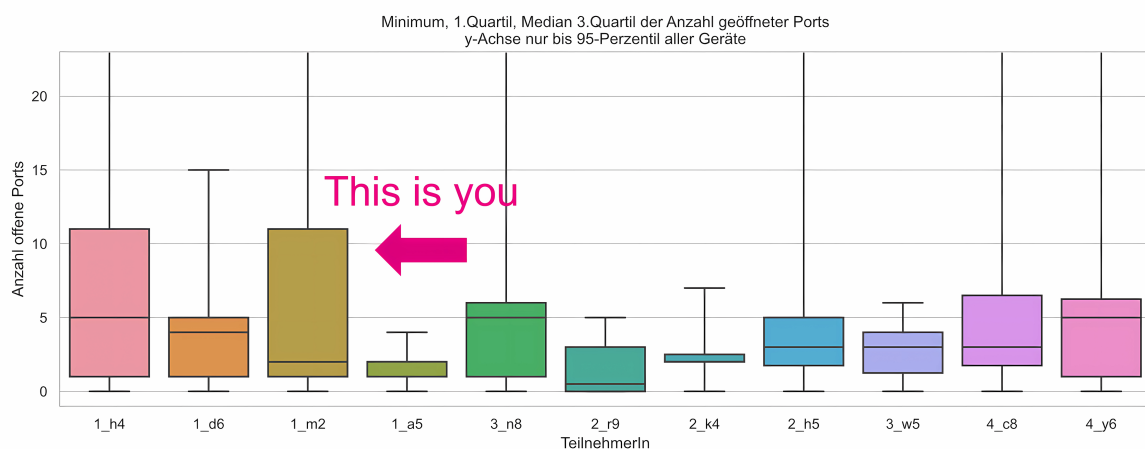


Fig. 3. How many open ports does your household have in comparison to other participants? Participants found it helpful to compare their situation with that of others (Source: VA PEPR).

Though we could not answer these questions in a definite fashion, it underlined the value of such visualizations when the goal is to enable users to frame questions around their own home network and the attendant privacy and security risks. This aligns with the study by Krsek et al. [21], which explored the social influence personal and non-personal on the behavior of users in best practices around security and privacy. They suggest that the difficulty of gathering the meta-data that is needed to show end-users personalized peer recommendations might be overcome by deploying non-personal social influence suggestions into 'existing or fabricated privacy setting interfaces.'

Our interviewees struggled to account for all the devices in their home networks the data sniffer picked up. They had either under- or over-estimated the number of devices, by 30-50%. In our view, this is linked with the concepts users have of a smart home as outlined by Marikyan et al [6]. Once they sat down with us, they realized that their children's iPads and the phones used by guests logging into the home network were all part of it, too. Unlike Huang et al. [4] who consciously excluded some devices in the home out of concern for abuse and ethical violations, we think that users need to be able to account for all the devices in their home network. This would give all household members a much better picture of their privacy and security risks. Homes are co-lived, co-shared and co-worked in, they are the best places for open data. Yet, the social aspects of the smart home have not found their way into services and applications yet. Applications are still built around one-user, one-password per account. Our study shows that everyone (or at least every adult) in a home should have the ability to see all the devices in the network to have a chance at transparency. This may require a rethinking along with new technological and regulative approaches.

Discussion

Our findings indicate that there is no normal for users when it comes to their in-home traffic. Yet, they are eager to understand what a normal network state is in terms of their usage of data, data traffic flows, number of connected devices, and risks they take with respect to their privacy and security. When we were able to present the findings for an individual household, the bars, levels, and numbers meant little to our participants until we were able to show them how they compared to the other 10 participants in the study. This points to an opportunity for home networking providers to improve their products by providing users with such orientation and baselines.

When participants were able to see visualizations of their own network traffic – the number of devices they had in their homes versus those of others; the level of data traffic activities; the days their data networks and/or individual devices were most active; the actual devices (i.e., partner's iPhone; Airbnb guest's phone) that contributed to their data traffic; the open ports of their devices, etc. they started to ask questions and reflected on their in-home networks. They affirmed our hypothesis that when we make the invisible visible, we provide people with the means to engage in the conversation around these new technologies. This outcome resulted despite our admittedly clumsy and rather basic visualizations. We consider it a key challenge for the DesForm Community to engage in further research and development of user-friendly, appropriate visualizations that consider the human experience. At this point, no such visualizations exist, or at least are not readily or easily available to non-expert users.

Data collection needed only a minimal support effort, and where we received any data, it was mostly complete and extending over the full data-gathering period. This indicates that our

single-board computer might scale well to tens of participants. Most of the participants did not experience any technical difficulties with our single-board computer and the self-installation procedure, but we did not receive data from 4 out of 11 participants. We do not know if these four tried the installation but were not able to provide data, or if they simply were no longer willing to share. We will follow up on this. The research team was able to reduce exposure risks of participants to privacy and security during this research by avoiding any ‘middling’ technology, i.e., external server, or internet transfer.

Conclusion

As reported above, research into user homes and home network data inevitably involve sensitive research settings. We run into the issue of privacy in the home because making network traffic transparent possibly exposes people in a household to different privacy risks. Our effort to test the potential for a remote and non-intrusive plug-and-play data monitoring solution still generated ethical questions. In these sensitive settings, new methods are needed to generate relevant and meaningful information for users who ultimately need to be able to assess and manage their privacy and security risks. One challenge we find emerging here is the tension that arises in the hands-off approach by researchers that leaves participants in control of their data and insists of a non-intrusive research method. The method entails participants never even meeting the researchers in person (though they are in contact online, via Messenger app and email) and it is difficult to engage users in such a way as to enable them to contribute to future desirable outcomes for their home networks. In the latter, participants take on a more active role and that role in turn requires closer engagement with the researchers, possibly limiting the ability to be non-intrusive.

Our approach and methods depended on interdisciplinary collaboration. We would not have been able to conduct this experiment within any one of our disciplines and depended on this collaboration that brought together data analytics, network analysis and human-centered design. Our methods allowed us to get a basic understanding of how home network users think of their data streams. We found that from a user’s perspective, an analytical approach is not sufficient to explore the possibilities and opportunities for how users may engage in security and privacy risk assessment and risk management. Instead, a more cultural approach is needed [22, 23]. Here, we see a greater role for speculative design and the use of *provotypes* as methods to explore meaningful and user-friendly monitoring solutions [24, 25]. These may also be able to point to alternative business models to those that exist today. Research into smart home devices – which are more like consumer products – has embraced methods of co-designing [11]. But so far, few studies into the privacy and security risks of home networks and home network traffic involve such methods. This, we argue, is also owing to the fact that the design and computer-human-interaction research communities are not yet collaborating often enough. Users tend to be at a loss when confronted with data visualizations (of packets and ports) generated from the transport layer. We are still lacking suitable truly informative visualizations for the non-technically, non-data inclined. We did not have enough time in our project to get to these. Nevertheless, discussions with users about privacy, data protection and device activities were easily initiated based on our data presentation. We are thus encouraged and not as pessimistic as Forget et al. about engaging users [27].

6 Limitations of the Study

As pointed out by DiCioccio et al. (2013), it is difficult to get representative results from a few homes. Our participants were also part of a voice assistant study and smart speakers may have different preferences and attitudes to privacy [20]. Nonetheless, with eleven participating households, we have begun to identify measurement points inside the homes that are meaningful to home network owners and users. And with only three completed semi-structured interviews, the findings must remain preliminary. Nonetheless, we were still able to get thick data [26] and with that, glean important insights relevant to privacy and security issues from a user perspective. An important factor was that the one-week data network analysis was embedded within a four-week ethnographic in-home-study, which was also conducted remotely.

Acknowledgments

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K-means based group clustering approach for Group Recommender Systems in a metaverse environment

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Abstract. In recent years, digital technology has developed rapidly. The importance of hyper-personalization and marketing automation has been elevated due to the rise of online, virtual shopping environments, spurring the development of intelligent recommender systems. To provide insights for the design and marketing of decision-making in such environments, a clustering method based on K-means is proposed for group recommender systems (GRSs). The proposed method is demonstrated on furniture products, where users are segmented into groups according to product preferences and demographic characteristics. Results show that out-group heterogeneity in terms of demographic variables and product attributes can be identified among user groups. Such information is crucial when implementing targeted marketing campaigns. In addition, the results can provide designers with insights about the most preferred design attributes.

Keywords: Recommender System; *k*-means Clustering; Group clustering; Product design, Personalization

1 Introduction

Due to the rapid rise of digital technology and the Internet of Things (IoT), such as the metaverse, blockchain, and artificial intelligence (AI), many economic activities are relocating online or going virtual [1]. Particularly beneficial in tackling these difficulties are hyper-personalization and marketing automation [2]. Specifically, recommender systems (RSs) facilitate the decision-making process for customers through individualized product recommendations [3]. In addition, information regarding individual customer's preferences is crucial for improving the design of product attributes. However, it is expensive to tailor market and design activities to each individual consumer. It is more efficient to offer products to different user groups, thereby reducing marketing and design expenses without sacrificing customization. To this end, Group Recommender Systems (GRSs) were created to deal with recommendations in a constrained situation [4] [5]. GRSs cluster users into groups according to similarities of taste, thereby creating standardized user recommendations and building group preference models [6]. GRSs automatically identify user communities [7] and display a list of recommended items for each group via aggregation techniques [4], which is key in e-commerce. It is also particularly useful in a metaverse environment.

Understanding group preferences of product attributes is essential for effective product design and marketing strategy [11]. Group preference assessment can be aided by identifying the common characteristics of customers via GRSs [10]. When planning and implementing marketing actions for a certain user group, group characteristics such as demographic variables which can influence consumer behavior need to be considered. Identifying the demographic characteristics and preferred product attributes of user groups provides important insights for marketing decision-making to (1) increase the probability of a user purchasing recommended products and (2) optimize customer journey strategies such as relationship management [12]. In addition, the information obtained from GRSs regarding the group preferences for product attributes can be used to improve the overall design of a product.

However, despite the enormous potential for customizing customer experiences, usability of GRSs in a metaverse shopping environment has not been studied adequately. Most previous studies have focused on improving the algorithms used for user grouping [8] and methods for aggregating recommendation lists [9]. Furthermore, previous studies did not investigate adequately key aspects of information provided by GRS. This study overcomes these limitations by incorporating in-group homogeneity and out-group heterogeneity in a GRS in terms of demographic characteristics and preferred product attributes. Therefore, this study aims to investigate the implementation of GRSs for personalized shopping experiences in a metaverse environment by analyzing the demographic disparities as well as the differences in product attribute preferences amongst identifiable user groups. Users' demographic information is collected, processed, and combined into group profiles throughout the data collecting phase. Furthermore, statistical methods are implemented to determine in-group homogeneity and out-group heterogeneity and to profile the groups. The relationship between product characteristics and the preferences of each group is also studied. The clustered groups can then be used to generate additional marketing actions that target certain user groups in order to enhance the sales, shopping experience and the design of products.

2 Methodology

The framework of the proposed group clustering method for group recommender system in a metaverse environment is illustrated in Figure 1.

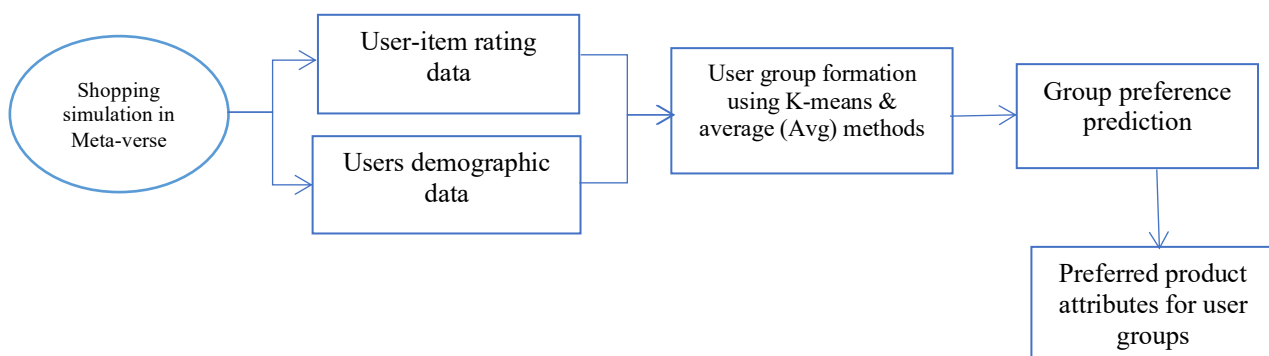


Fig. 1. Framework of the proposed group clustering methodology

First, the demographic information of users and their ratings on the selected set of items are collected. These data are collected via an interactive simulation in a metaverse environment. Figure 2 below shows a screenshot of the metaverse simulation. The simulation consists of sequence of interactive sessions that begin with an instruction page, which briefly describes the simulation, followed by the consent form. Next, a demographic profile of each participant is collected. Finally, item rating data are collected for each user.

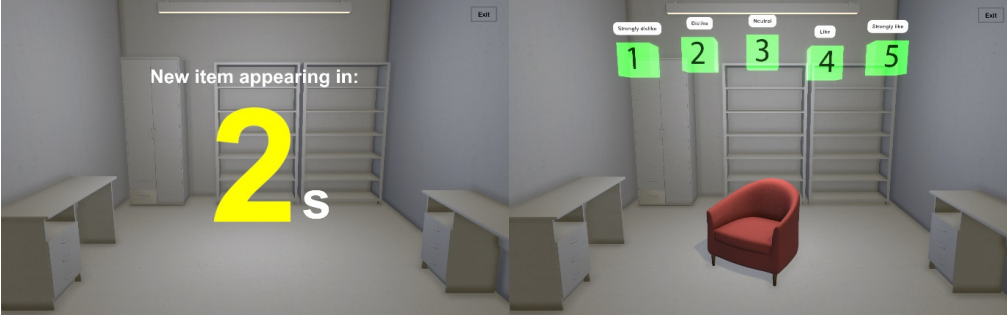


Fig. 2. Screenshots of the simulation of the shopping experience in a metaverse environment

After collecting user-to-item rating data, users are divided into groups using K-means and average (Avg) methods based on aggregation of similar ratings. K-means seeks to classify objects, which are users in this case, into a certain number (k) of clusters based on their characteristics, which in this case are their ratings for the given set of items. The formula for the objective function J of K-means clustering is given in Eq. (1) below. Moreover, the groups are evaluated using two metrics: normalized Discounted Cumulative Gain (nDCG) and precision.

$$J = \sum_{g=1}^k \sum_{u=1}^N \left\| x_u^{(g)} - c_g \right\|^2 \quad (1)$$

N denotes the sample size, $x_u^{(g)}$ denotes the case of user u and c_g denotes the centroid of group g to which user u belongs.

The chi-square test and one-way analysis of variance (one-way ANOVA) tests are utilized to determine differences in categorical and numeric variables among independent groups. In addition, after determining the form styles of the selected items and the group ratings of each item for each group, the Pearson correlation coefficient is utilized to assess the relationship between form styles and group ratings. The Pearson correlation coefficient is a standardization of the linear correlation between two data sets. With regard to the association between a given form style and a user group, there are two sets of data: (1) the scores for the form style of all items and (2) the group ratings of all items calculated using the Avg method for the group. The average method assigns scores to items by averaging the scores given by all users in a group as given in Eq. (2) below.

$$G_x^i = \frac{\sum_{u \in G_x} r_u^i}{|G_x|} \quad (2)$$

3 Results

3.1 User grouping

Furniture products are chosen as a case study to demonstrate the proposed GRS. Furniture products possess attributes that can be highly customized and are suitable for evaluating various design forms in a VR environment. Users were asked to evaluate furniture items in various forms ranging from chairs, desk lamps, book shelves and tables. K-means clustering was used to categorize users into groups ranging from 2 to 10. Each value of k is used to calculate the nDCG and related accuracy. According to different sizes of the recommendation list (M equals 1, 3, or 5), Fig. 3 illustrates the change in nDCG and the change in precision with the number of groups produced. Observing the graphs, we infer that $k = 4$ is an acceptable option because the nDCG and precision values for $k = 4$ increase dramatically from $k = 3$, but decline significantly after $k = 4$. This tendency is also apparent for the accuracy metric, where increasing k from 3 to 4 results in a significant increase in precision, while the increase diminishes as the value of k grows further. This demonstrates that if the users are separated into four groups, each group will have enough members (at least 11), and all users will be generally satisfied. This k value is subsequently utilized in further phases, such as user segmentation of product subcategories.

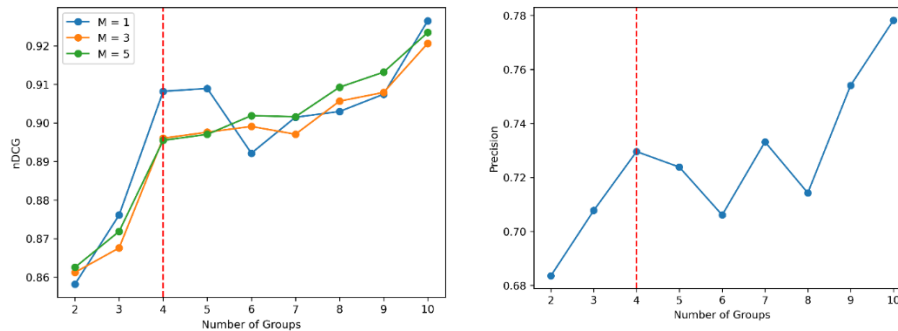
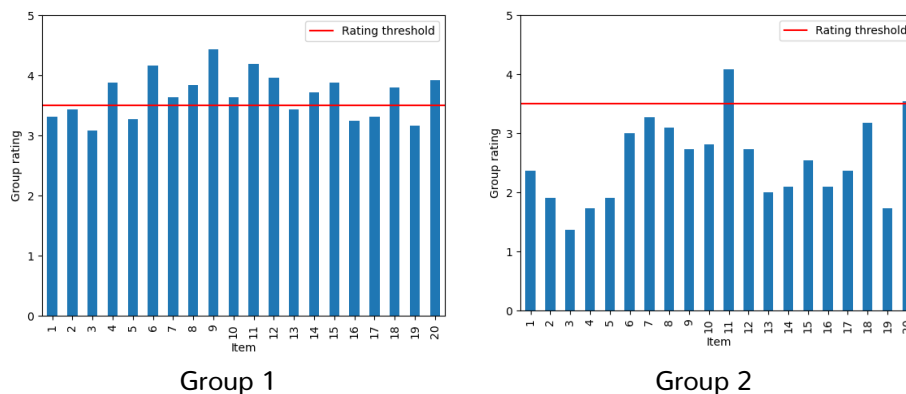
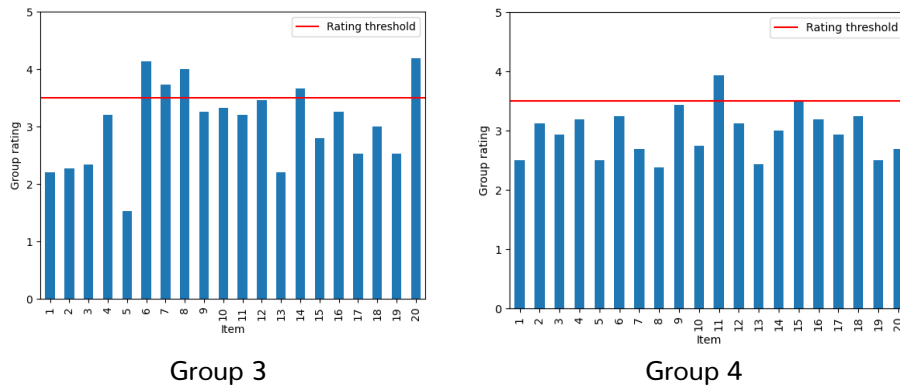


Fig. 3. nDCG and precision with different values of k

The group ratings of all items in each group are plotted in Fig. 4. As can be seen, each group has distinct product preferences. Group 1 has greater average group ratings, whereas Group 2 shows the opposite. There are also noticeable distinctions between the groups in terms of the items they like and dislike. Notable is the fact that with a rating criterion of 3.50, items with sufficient group ratings to qualify as "liked" are in the minority. Specifically, 12 things are favored by Group 1, 2 items are favored by Group 2, 5 items are favored by Group 3, and 2 items are favored by Group 4.





Group 3 Group 4
Fig. 4. Group ratings of the user groups

3.2 Demographic characteristics of user groups

According to results of the chi-square test on gender, gender differs significantly ($p < .05$) between the four user groups. Results of the pairwise comparison using the chi-square test are shown in Fig. 5 below, which indicate that Group 3 (12/15, 80%) and Group 2 (7/11, 63.6%) have a larger proportion of males. In contrast, Group 1 (17/25, 68%) and Group 4 (10/16, 62.5%) have more females. In terms of age, a one-way ANOVA test was conducted to compare the user groups, and the results showed no significant differences. The mean age of each group was in the range 21.04 to 23.91.

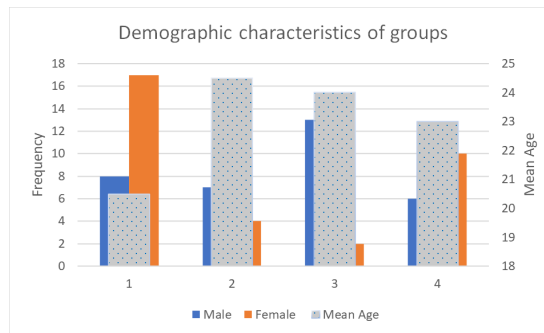


Fig. 5. Demographic characteristics of groups

3.3 Extraction of product attributes and identification of preferred product attributes of user groups

Seven experts in product design were requested to assess the form styles of the selected items, assigning ratings to each of the 20 items based on the six form types. The five items with the highest group ratings are featured in each group's list of recommendations. Fig. 6 depicts the means for the form styles of the recommended products for each group.

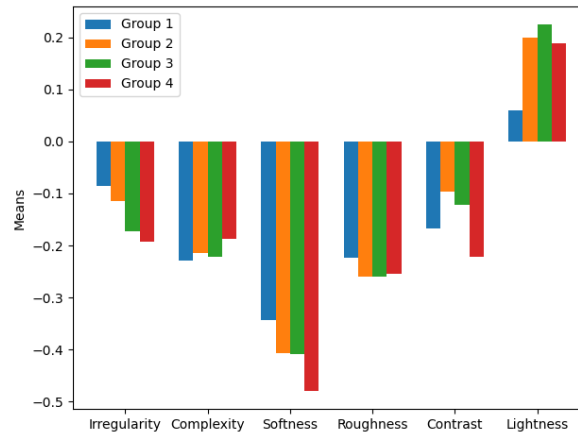


Fig. 6. Form styles of recommended items for each group

The Pearson correlation coefficient reveals a significant positive link between form style irregularity and Group 1's group assessments ($R = 0.56$, $p = .01$). This suggests that members of Group 1 have a distinct preference for irregular shapes over geometric ones. Even though the association is not statistically significant, both Group 1 ($R = 0.41$; $p = .070$) and Group 3 ($R = 0.41$; $p = .076$) demonstrate a marked preference for soft over rigid objects. There is no other correlation that is statistically significant.

4 Conclusion

This paper proposes a group clustering approach for user groups in GRSs, taking demographic factors and product attributes into account. As a case study, a GRS is created utilizing K-means clustering and the Avg aggregation approach for furniture products. User groups were subjected to group profiling in order to statistically identify the group's characteristics in terms of demographic data, such as age and gender, and preferred product features related to form styles. This study outlines the function of GRSs in e-commerce and lays the framework for future research in this area by balancing the cost and effectiveness of personalization and establishing the link between intelligent recommender systems and marketing automation.

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Interstitial Diagramming: Mapping Temporal Experience

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Abstract. In the following paper the authors argue for a renewed attention to all time-based interactions focused on the emergent interstitials of experience. Rather than codifying all services and experiences via static touchpoints, the investigation argues for attentions to focus on “the space between” these touchpoints as the actual space of emergent interaction. Presented here as Interstitial Diagramming, this renewed focus on the dynamic and emergent qualities of unfolding experience highlights a need for new tools to record/predict/plan for service or any interaction that occurs over temporal space.

Keywords: time, experience, embodiment, mapping

1 Introduction

While design for static forms continues to be a robust practice, the “new normal” in design practice is designing in the context of time-based or interactive media. Few images or objects are created today that do not engage with some aspect of a time-based or interactive paradigm, contrasting with the older assumptions that surround the design of 2-dimensional and 3-dimensional artifacts. As technologies and the accompanying modern aesthetics have evolved, it falls to designers to re-envision their media practices and develop new approaches to acknowledge aspects that exist inherently *in time*: participating bodies, the aesthetics of visceral feeling bodies, time and implicated experiences over time, and the traversed spaces between noted moments or touchpoints. As design fields have matured over the past two decades and as technology has allowed for the truly interactive, we note the temporal turn in design — interaction and service exist over time, yet many of our design approaches continue to work with biases informed by static image-making and form-making, obscuring the temporal reality of these experiences.

Current tools for analyzing and designing time-based experiences focus upon the sequencing of events without exploring the experiential qualities of those events over time. Many of these tools amount to little more than elaborate lists or matrices of roughly synchronous sequences. In this paper we present an ongoing theoretical research project informed by research-through-design as implemented in our teaching practices. We present a reframing of the design perspective for temporal practice and offer the *interstitial diagram* — an accompanying tool to address this gap as it pertains to service practice. Inspired from two different perspectives on time, we will discuss how this approach informs a new approach to service mapping, and consequently, a more nuanced understanding of time as a key medium for experiential design practices.

Thinking about different approaches to time seems a philosophical exercise not well suited to the day-to-day work of a practicing designer. However, in the practices of interaction, service, and user

experience design, time is the stuff of which the interaction is made [1]. A dominant metaphor of time in US and European culture as identified by Lakoff & Johnson [2] is “time is money”. Common metaphors of *spending* time, *wasting* time, *investing* time, all share this perspective of an accountancy-based approach to time-units. This framing directs our attention to the chronographic units of time, or clock-time, which can be spent or saved. Yet this same perspective devalues the aesthetics of wholistic time-based experience. Chronographic accounting of time implies that all minutes are worth the value of a minute, but in practice, some minutes are impactful while many others are forgettable. Here we present an alternative framing for approaching time, lest we become, as Henry David Thoreau stated, “the tools of our tools” [3].

1.1 Aion—Chronos—Kairos

The ancient Greeks had three concepts for time. The first is exemplified in the Hellenistic deity Aion (Αἰών), associated with perpetual, cyclic time, as in the ideas of ages, timelessness, or eternity. The second is Chronos (Χρόνος) and refers to clock time — measurable time, as in seconds, minutes, hours, years. The third is Kairos (καιρός) which instead of minutes, seeks to describe moments or more specifically, the opportune or ideal moment.

Where the long time of aion is central to all discussions surrounding Transition Design, [4, 5] design for interaction or service exists somewhere between chronos and kairos. Current attention to touchpoints, or the “points of contact” between customer and service, amount to instants in time, snapshots or freeze-frames of time, and can be recorded as timestamps on a chart of minutes and seconds — notable chronos attentions. When discussing touchpoints in service design practice, these ordered lists of contact instants are commonplace. Touchpoints summarize or reduce service experiences into clear linear points easily pinned to specific instants on the stopwatch.

However, it is notable that the dimensions of human experience in any interaction cannot be contained into a pinned timestamp on a chart. All interactions take place “over” time not “at” an instant of time. In this sense, experiences may more accurately be described as gestures or arcs or phrases — moments rather than minutes — and *moments* take us into the realm of kairos. As participants in an experience, we do not aspire to accomplish our objectives in sequence synchronous with a ticking clock, rather, we hope to interact in affective moments of participation — organic, natural, comfortable, (even beautiful) interactions that unfold in time.

The early 1900s were a significant moment in design practice where scientific management practitioners attempted to precisely record and redesign human work using time. Frederick Winslow Taylor’s [6] famous stopwatch mediated the temporal processes of the factory floor. To optimize production, this chronographic solution disciplined workers toward efficiency. Taking this management study a step further, Frank and Lillian Gilbreth [7], focused upon the structure and sequencing of motions (see Figure 1 below), attempting to improve the effort required and reduce the number of motions in a process, seeking the one ideal form that a process might take. The Gilbreths’ work can be seen as an early example of touchpoint accounting, striving to reduce the number of touchpoints needed to complete an action. While not defined via the stopwatch, this management framing continues the chronos approach to the collection/listing of discrete instants rather than centering awareness of the wholistic experience.

Touchpoint-centric journey maps or blueprints are extremely useful at presenting the logic and

directing the designer's attention away from the experiencing of the experience. Wholistic experience cannot be reduced to the touchpoint. Noting this, Jaques-Dalcroze provides us with two accompanying concepts, both of which require time to behold: Anacrusis is the gesture that precedes and drives toward the crusic, and metacrusis is his term for the falling-away-from the instant of the crusic. Where crusic is a noted instant in time, anacrusis and metacrusis direct our attention to experience over time, and truly, experience over time is the only actual happening. One cannot feel or experience a touchpoint, we can only experience the anacrusis and metacrusis surrounding the touchpoint.

The default approach to designing with time has been to create lists of touchpoints, as in orders of events. These lists or maps or flowcharts can easily state the logic of an event and even provide timestamps for the instants when the cruses "hit". However, without a toolbox that includes the anacrusis and metacrusis of an interaction, the kairotic momentum will remain decentered, if not entirely obscured.

1.3 All experience is momentum

The Jaques-Dalcroze lens claims that all lived experience is understood or felt through gestures of momentum toward and away from crusic points. We see the same attention to kairotic experience practiced in the actor training of Konstantin Stanislavsky (1863–1938), the Russian actor, director, and founder of the Moscow Art Theatre. Rather than accepting punctuation as the overriding organizing tool for an actor's spoken lines, Stanislavsky instructed his students to discover the motion of the words noting how, when spoken, groups of words formed mini arcs of intention, or beats ("bits" in Russian, *кусок*) [9, 10]. The understanding of the beats or gestures inside of the script can propel the action forward by acknowledging the inherent motion in the experience. Seen through Stanislavsky's framing, the script is not a series of critical instants in time (touchpoints), it is an invitation to a series of moves, an array of connected gestures. The attention to *beats* exemplifies the anacrusic and metacrusic nature of all interactions. Acting for the stage is not a task of delivering a memorized script or hitting all the dramatic touchpoints in the correct sequence. The goal, not unlike in the best examples of service, is to carry the audience along on a continuous ride. This continuous ride requires an attention to the accumulating and decrementing emotional trajectory between the cruses. Theater occurs between the touchpoints and is not the touchpoints themselves.

The current investigation seeks to capture the aliveness of any interaction, in both the designing and in analysis stages. In order to accomplish this, we first need a new ontology (experience is gesture, noted as anacrusis/crusic/metacrusis) and then we need new tools.

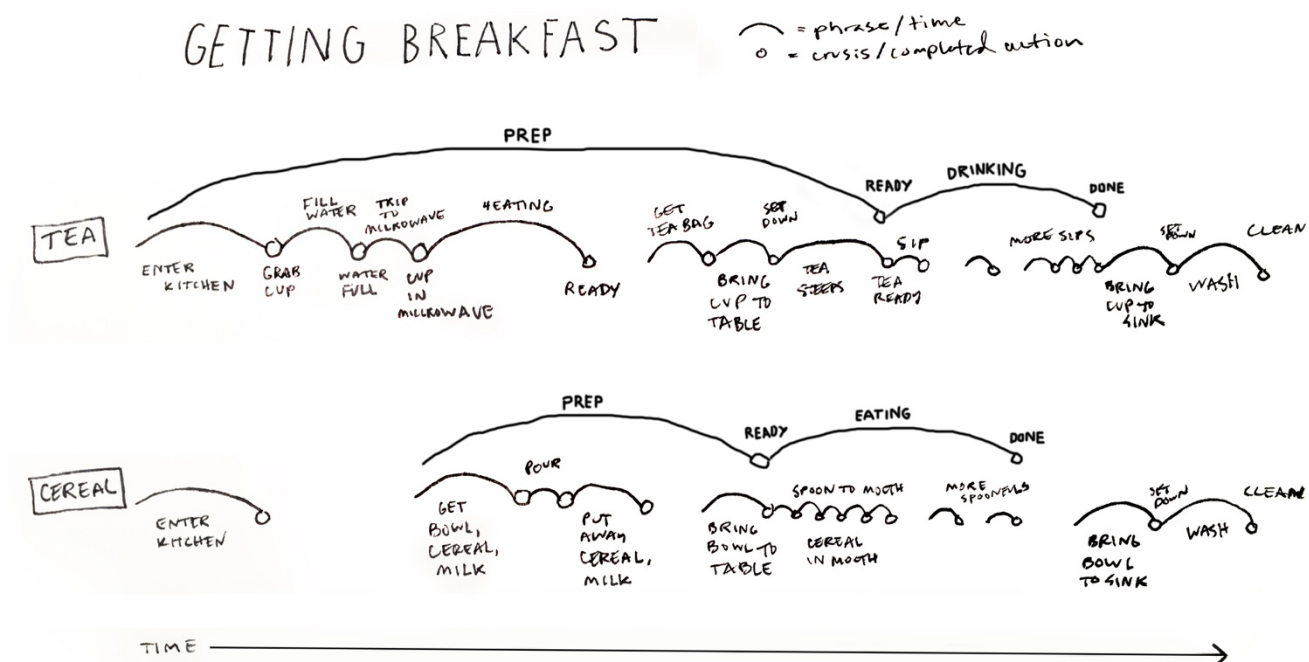
2 Interstitial Diagramming

In coursework led by the authors, students were asked to engage with these concepts of time, to note the embodied engagements in service and to test different ways of depicting the interstitial

time of a service graphically. In the following project examples, students explored different ways to represent the experience of beats and kairotic time. In these examples, students approached the challenge of a food service design. Food service was chosen because there are many nuances and subtle variations, yet the base schema of the food service experience is similar across many offerings. Most students in contemporary contexts have many personal experiences of food service to draw on. Further, food service experiences are accessible to most students and can be investigated within the context of the course itself

Fig. 2. Nested arcs of experience, Lily Fulop, 2017

The student sketch shown in Figure 2 investigated the preparation of two foods at the same time. The student depicted the experience, representing nested levels of felt time. Rather than merely listing the touchpoints of the studied interactions, students completing this project were asked to document the temporal experience, consider which moments were most salient, and what moments



were of secondary and tertiary relevance. Students were asked to make value judgements about the various *moves* in the design — a very different mindset compared to more common chronos attentions. The students then considered the full arcs of experience that created these various gestures and represented those time arcs in multiple levels of resolution. Two concurrent processes are represented, each with its own sets of cruses that are not necessarily congruent.

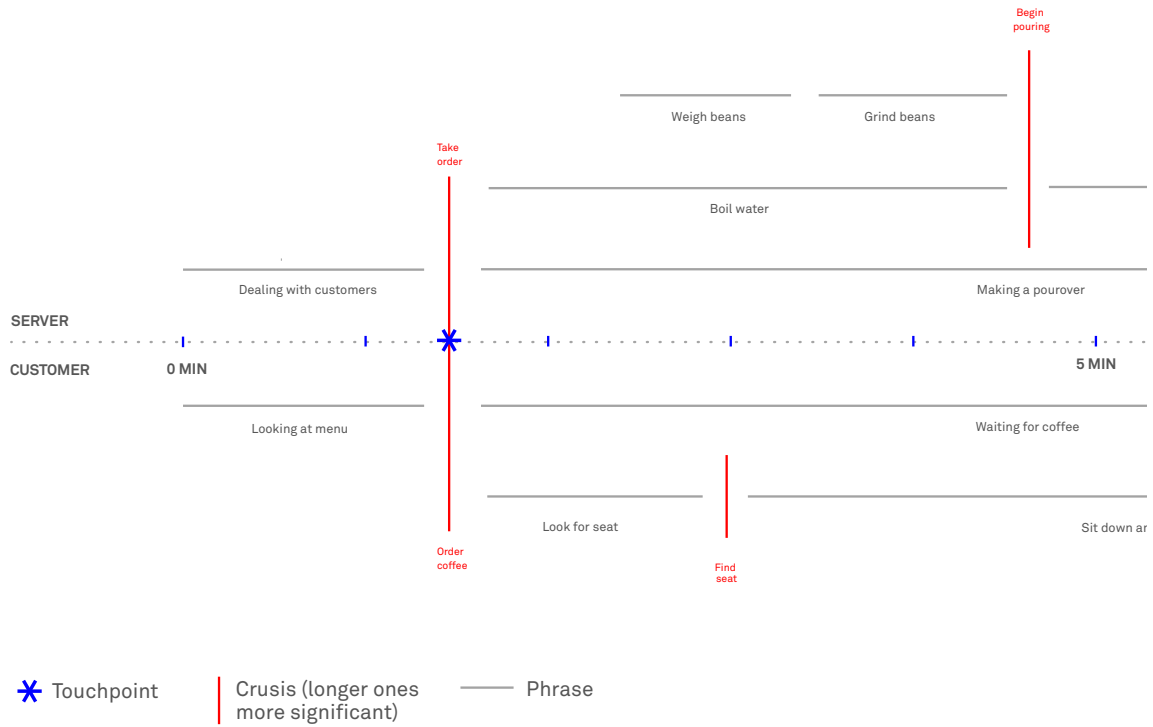


Fig. 3. Concurrent cruses in a service experience (excerpt), Anqi Wan, 2017

In a second example, Figure 3 above shows the order and fulfillment of a coffee order — a choreographed service experience with a service-literate customer. While both schematic and abstract, this kind of representation depicts the service in a way that reveals the specific temporal profile of the service as a simultaneous gestalt. While this approach is not the *only* way to represent the temporal experience of services, one can see how a similar form of language might be used to represent a variety of services. Doing this would reveal the uniqueness of the temporal profile and concurrent cruses for each set of interactions. Here also, the chosen visual language reveals the



structural proportions of the service choreography.

Fig. 4. Current State Customer Journey Map (excerpt), Shipra Shah, 2021

The process depicted in Figure 4 above shows the ordering and delivery of food structured as arcs and cycles of experience. The diagram shows dips of low energy, phases through use of color, as well as significant crusic points. Contrasting the journey map in Figure 4 to the standard touchpoint-centric journey maps, we can see that this revised form contains similar data but is arguably more

affective. Here the designer can present a unique visual form that is unique to each service experience, allowing one to speak to the situated nature of each customer's experience.

3 Discussion

We acknowledge that there is great value in the chronos-based tools (journey maps, service blueprints, etc.) the design community continues to use. As any series of actions can be recorded as a list of touchpoints occurring at specific moments in time, these timestamps are useful to critique the logic of events and can serve as useful data when deciding on cost-benefit analysis, etc. However, "None of the existing tools really matches the need of representing what a service is into a synthetic and unique view (such as the sketch of any tangible products does)" [11]. Rendered with the grammar of a customer journey map, the experience of a banking service is visually quite similar to the service of train travel, which also looks like the experience of a food service. A service experience described with these tools looks more like an implementation of the tool than a representation of a specific, dynamic, and affective experience.

Human experience is not felt in seconds/minutes/hours/etc. Neither is human experience built simply through sequential touchpoint structures. Reframing time as anacrusis–crusis–metacrusis from the work of Jaques-Dalcroze [8] and through the beats of Stanislavsky [9, 10] helps us to see lived experience as either driving toward or away-from the instants of crusis. If one is involved in any experience, there can be no true stillness. We pass through the events of our lives in kairotic gestures toward and away-from instants of significance. Stealing from these philosophies, we offer *interstitial diagramming* as a new tool to recenter the continuity of unfolding gestures in aspired-to service.

Interstitial diagramming re-envision our customer experience as always in motion, either toward or away-from the significant touchpoints. It is an attempt to flip the script and create journey maps that center the space between the touchpoints as more valuable than the touchpoints themselves. Here we foster services that aspire to keep the customer engaged — realizing the motion toward and away from the desired touchpoints. Interstitial diagramming provides a new set of biases where we can ask: Where in our designs are clients feeling still? Or stuck? Or bound (rather than freely empowered to drive toward the next crusis)?

4 Conclusion

In this paper we argue for an enhanced perspective when designing for and representing time in design practice. Instead of continuing to map our services using tools that center touchpoints and simple narratives, we suggest that there are opportunities to organize experience through the valuing of temporal gestures. If we aim to give participants in a service an experience [12], we should center this attention in the way we represent the service in our design planning and analysis. We designers are obviously working with more than touchpoints. The mapping and journaling tools in current practice are highly effective at describing and analyzing the ordering and logic of our various interactions and initiatives, yet without noting the space between the cruses/touchpoints, and without recognizing the dynamic quality of these spaces (always aspiring to incline toward or away from the crusis), our tools continue to devalue critical design opportunities. Of greatest concern for the practicing designer should be the biases our current tools create, amplifying distinct cruses of our events, while decidedly hiding, ignoring, or dismissing the actual experiencing of the experience.

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Big Data Analytics for Marketing Strategy

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Abstract. The advent of advanced information and communication technologies have boosted the customer-brand interactions. This study utilizes big data in investigating how social media activities affect customer engagement in brand communities. As initial criteria to evaluate subscribers' emotional reactions, we used the Feedback Ratio and the Gross Positive Feedback Ratio. A web crawler was then applied to obtain data-driven insights on real-time emotions and behaviors of customer engagement on social media using data containing 4.39 hundred million video comments and the "likes" captured from the top 12 YouTubers in various fields. The results indicate that social media marketing activities help improve customer engagement within brand communities. This paper also examines how brands may encourage long-term customer relationships through social networks.

Keywords: Customer Engagement, Brand Communities, Big data Analytics, Sentiment Analysis

1 Introduction

Recent breakthroughs in Internet technologies and social networks have enabled greater customer engagement [1]. Customers are voicing opinions and sharing information across different channels and social networks. These actions allow brands to engage with their customers more effectively so as to leverage the potential of co-created innovations in brand communities. [2]. However, the vast quantity of data provided by mass-media platforms makes it challenging for brands to interpret or analyze effectiveness. Opinionated data that can be used to influence products or services in marketing strategies is crucial for both individual and organizational decision-making.

Advances in big data analytics technologies have contributed to fill in this gap in customer engagement. The main characteristic of big data is its unrestricted capability of computational information and enormous exchange of data recorded in various forms on customers' engagement responses and brand marketing activities via social networks in real-time [3]. These contribute to developing data-driven insights on real-time customer-brand interactions that lead to innovations both for customers and brands.

This study seeks to assess the impact of social media marketing activities on customer engagement in brand communities by utilizing big data. We first introduced the feedback ratio and the gross positive feedback ratio as our criteria to measure subscribers' emotional responses to YouTubers. A data set containing 4.39 hundred million video feedback was collected from the most popular 12 YouTubers in different categories by using a web crawler. Sentiment Analysis was also applied to gain data-driven insights into real-time emotions and behaviors of customer engagement in social

networks. Finally, the research findings provide insights for brands to facilitate long-term customer relationships.

2 Literature Review

2.1 Customer Engagement within Brand Communities

Previous research has explored the antecedents, consequences and evaluation metrics of Customer Engagement (CE) in some depth. For instance, Bowden [4] and Brodie et al. [5] identified customer engagement as a multi-dimensional concept comprising cognitive, emotional, and behavioral aspects. Bowden et al. [6] demonstrated that customers perform various brand-related behaviors which include positively or negatively valenced engagement during customer-brand interactions. Dhaoui [7], Pentina, Guilloux, and Micu [8] further measured the customers' behavioral engagement.

Research on customer engagement has evolved with the development of associations through information technology and social networks. Brand Communities (BCs), which serve as important platforms for online customer engagement [9], make customer-brand communications more effective with the aid of mass-media platforms. The increasing popularity of brand communities on social media has resulted in a huge amount of opinionated data recorded in unstructured form that traditional approaches are unable to interpret and analyze, which offers opportunity to discover valuable and subjective information utilizing big data.

2.2 Sentiments Analysis

In the age of big data, sentiment analysis may be applied as an efficient data mining technique to identify and classify various opinions and feelings expressed in social media so as to ascertain general customer attitudes towards brands.

Sentiment Analysis (SA), also referred to as Opinion Mining, is the process of detection, extraction, and classification of subjective information from text, speech, and database sources with systematic and algorithmic approaches [10]. The polarity of sentiments encompassing emotions, beliefs, perceptions, behaviors, decisions, and feelings can be categorized as positive, negative, or neutral [11]. The essential methods for sentiment analysis include lexicon-based, supervised machine learning and a hybrid approach [12]. To create meaningful lexicons for 136 multiple languages, Chen and Skiena [13] used a range of diverse linguistic resources. Rambocas and Pacheco [14] proposed that machine-learning sentiment analysis should combine more manual analysis into sentiment classification to include contextual information more effectively.

Although researchers have investigated the conceptualization, characteristics, and behavioral manifestations of customer engagement, there are still discrepancies between theoretical approaches and operational implementations of customer engagement. There is also a research gap of examining engagement's relation to customer experience management and performance implications. Meanwhile, most studies have concentrated on evaluating emotional responses and behaviors for customer engagement on Twitter, Facebook, or Snapchat, but less research has been conducted on YouTube. As a result, this paper aims to investigate the online customer engagement in brand communities based on the data collected from YouTube.

3 Methodology

3.1 Design and development of big data analysis framework

We designed and developed the framework of big data analytics and it is illustrated in Fig.1 below. In this paper, we adopted a web crawler to extract the text and conduct text classification. With polarity and subjectivity, sentiment analysis is conducted. YouTube was selected as a source to investigate social media sentiments and customer responses. It is a widely used social network and its rapid information-spreading potential could offer enormous real-time data on customers' emotions and reactions during YouTuber-subscriber interactions.

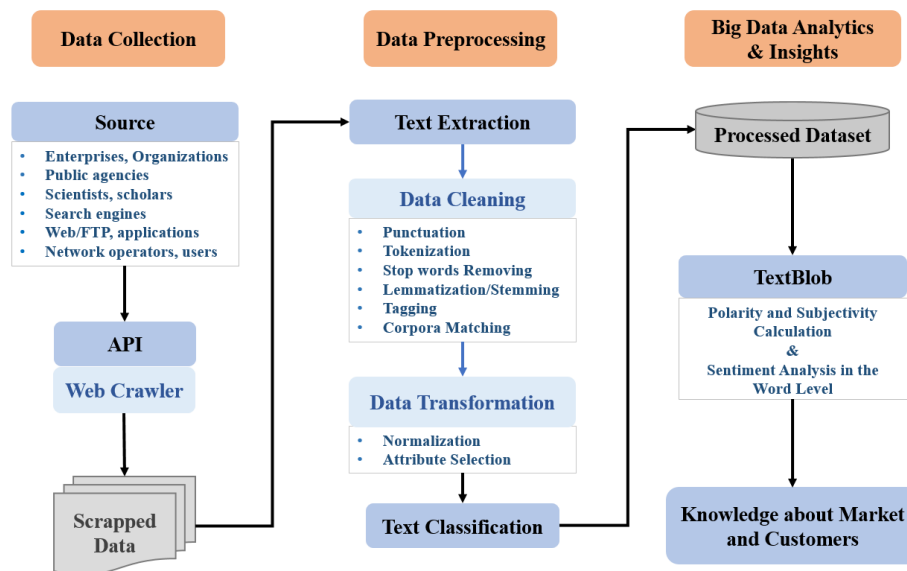


Fig. 1. Design and development of the framework of Big Data Analytics for Marketing Strategy

The most popular 12 YouTubers from different domains encompassing Technology, Car, Lifestyle, Beauty, and Fashion were chosen as research samples. A total of 4.39 hundred million items of English feedback on videos including comments and likes were extracted and parsed from these 12 YouTubers through programmatic access to Youtube comments API¹ using web crawling techniques.

A web crawler is a tool to detect syntactical structure and semantic relations to retrieve content from textual information. TextBlob² is a Python open-source software package built for handling text-based data. The crawlers' automated process of TextBlob can gather massive volumes of data through mass-media channels to extract keywords, and conduct sentiment analysis using Natural Language Processing (NLP) method [15].

¹ YouTube comments API provided by Google (<https://developers.google.com/youtube/v3>)

² TextBlob is a Python's open-source software package, called text blob automatically score (<https://textblob.readthedocs.io/en/dev/>)

We analyzed emotions at the word level by counting and tabulating words that contained various discrete emotions. Then, data pre-processing (tokenizations, punctuations, lowercase conversations, etc.) was carried out by applying Python and the TextBlob to quantify the unstructured data for sentiment analysis on customer engagement via social networks. The information about 12 YouTubers including the number of subscribers, the number of videos posted, the number of views of posted videos, the number of comments of posted videos, as well as the number of the “likes” of posted videos is summarized in Table 1.

Table 1. 12 YouTubers and their summary of YouTube activities.

Youtuber	Catagory	Subscriber	Videos	Views	Comments	Likes
Geek Street	Technology	264,000	1,034	97,868,721	41,150	720,132
Nastazsa	Lifestyle (Design)	626,000	651	59,507,663	94,414	1,588,178
Hoovies Garage	Car (Family Style Car)	1,400,000	522	350,000,000	1,239,000	10,561,000
Jeff Nippard	Lifestyle (Sport)	3,280,000	441	361,591,368	295,294	9,781,570
PatrickStarr	Beauty	4,300,000	548	372,351,236	452,872	8,554,723
Carli Bybel	Fashion (Women Fashion)	6,120,000	636	651,053,360	1,103,996	14,448,975
alpha m.	Fashion (Men Fashion)	6,570,000	1,785	1,171,075,297	3,639,852	32,668,462
Supercar Blondie	Car (Supercar)	8,590,000	513	1,249,000,000	1,071,000	32,028,000
Mrwhosetheboss	Technology	11,200,000	1,437	1,815,230,272	1,216,368	60,590,979
Marques Brownlee	Technology (3C)	15,900,000	1,456	3,090,705,616	1,007,139	60,590,979
Natalies Outlet	Fashion (Consumables)	15,900,000	1,456	1,570,489,967	1,722,657	40,848,652
James Charles	Beauty (Make up)	23,900,000	408	3,692,791,855	1,021,916	154,023,982

Note. Information updated as of August 18th, 2022

3.1 Measurements

Customer engagement is measured as the responses of subscribers towards YouTubers’ activities including video comments and “likes” in this study. The Feedback Ratio is used to assess the engagement quality of social networking activities on the YouTube channel. The equation of the Feedback Ratio is listed below.

$$\text{Feedback Ratio} = \frac{(\text{Overall comments} + \text{Likes})}{\text{Views}} \quad (1)$$

A corpus of 4.39 hundred million video feedback items with 12.9 million comments was formed. Word count analysis was conducted on the targeted corpus to determine which keywords were most frequently used to express customer emotions. The top 17 most frequently occurring keywords including nouns, verbs, adjectives, and adverbs were chosen to denote positive, negative, or neutral words to demonstrate the emotional aspects and behaviors that customers engaged with (Table 2).

Table 2. Words used to identify video comments related to positive valenced engagement and negative valenced engagement

Catagory	Key Words
Positive Words	Best, amazing, awesome, love, wow, like, good, great, glad
Negative Words	Hate, shit, down, sick, wrong
Neutral Words	Buy, Purchase, Pay

The Gross Positive Feedback Ratio is adopted to assess the positive emotion aspect of customer engagement on the YouTube channel. The equation of the Gross Positive Feedback Ration is listed below:

$$\text{Gross Positive Feedback Ratio} = \frac{((\text{positive word related comment} + \text{likes}) - (\text{negative word related comment}))}{(\text{overall comment} + \text{likes})} \quad (2)$$

3.2 Sentiment Analysis

The results from the Average Feedback Ratio of 3% show that social networking activities have a substantial impact on customer engagement within YouTube Channel, where the negative ratio of 0.72% is much lower than the positive ratio of 5.57%, indicating that subscribers would experience more positive emotions during the social networking interactions, and customer engagement behavior tends to be positively influenced by social media marketing activities (Fig. 2).

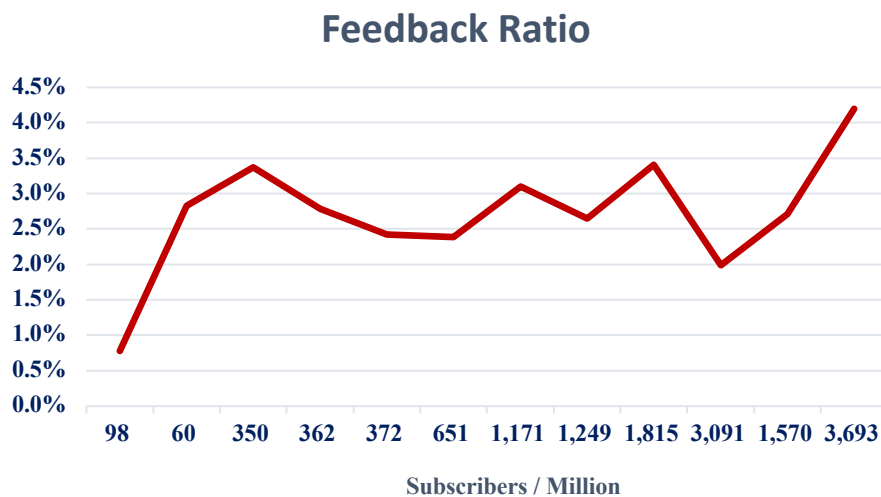


Fig. 2. The Results of Feedback Ratio

The Average Gross Positive Feedback Ratio of 4.84% demonstrates that positive emotions and engagement behaviors of customers are commonly observed on YouTube. In addition, YouTubers with subscribers in the middle range have the highest gross positive feedback ratio, such as Patrick Starr, who has 4.3 million subscribers and 548 videos, earning 14.72% gross positive feedback ratio. This suggests that subscribers' positive emotions for Patrick Starr are more frequently detected than other YouTubers (Fig. 3).

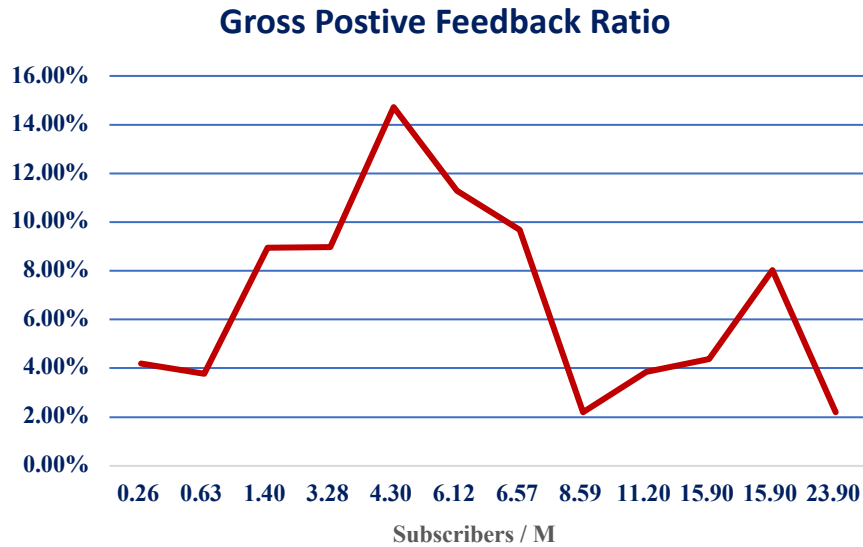


Fig. 3. The results of Gross Positive Feedback Ratio

The findings also imply that the gross positive feedback ratio fluctuates across categories. For example, the fashion and lifestyle categories had the highest gross positive feedback ratios of 5.08% and 5.14% correspondingly. In contrast, the gross positive feedback ratios for the technology and beauty categories were both less than 2%, which is considerably lower than the average gross positive feedback ratio. This highlights that the fashion and lifestyle categories may effectively stimulate the interactions between YouTubers and subscribers to foster the development of new idea generation and value co-creation (Fig. 4). Therefore, the sentiments of youtubers Carli Bybel and Nastazsa from Fashion and Lifestyle categories are further discussed below.

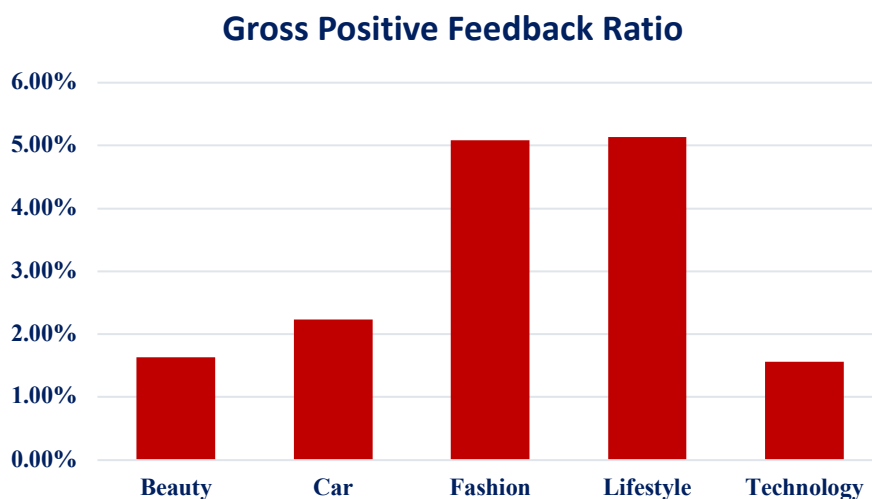


Fig. 4. Gross Positive Feedback Ration in Different Categories

The sentiment is a named tuple that the sentiment property returns (polarity, subjectivity). The polarity of sentiments indicates how strong the positive or negative emotion portrayed in a text is.

The negative words are classified as notwords and assigned a value of “-1”, and positive words are also classified as sentiwords and assigned a value of “1”. The sentiment score of video comments is calculated by summing the sentiment values of keywords in each sentence. The polarity score fluctuates between [-1.0, 1.0]. The subjectivity rating is indicated by a float within [0.0, 1.0], with “0.0” denoting very objectivity and “1.0” denoting high subjectivity.

The sentiment polarity distribution of Carli Bybel’s video comments from the fashion category has shown that she receives diverse feedback on her social media activities, and subjectivity is the most objective among these 12 YouTubers (Fig. 5). Meanwhile, the sentiment polarity distribution of Nastazsa’s video comments from the lifestyle category has concentrated within [0.0, 1.0], suggesting that she receives high positive feedback of her social media activities, and customer engagement on fashion brand communities typically results in positive emotions and behaviors (Fig. 6).

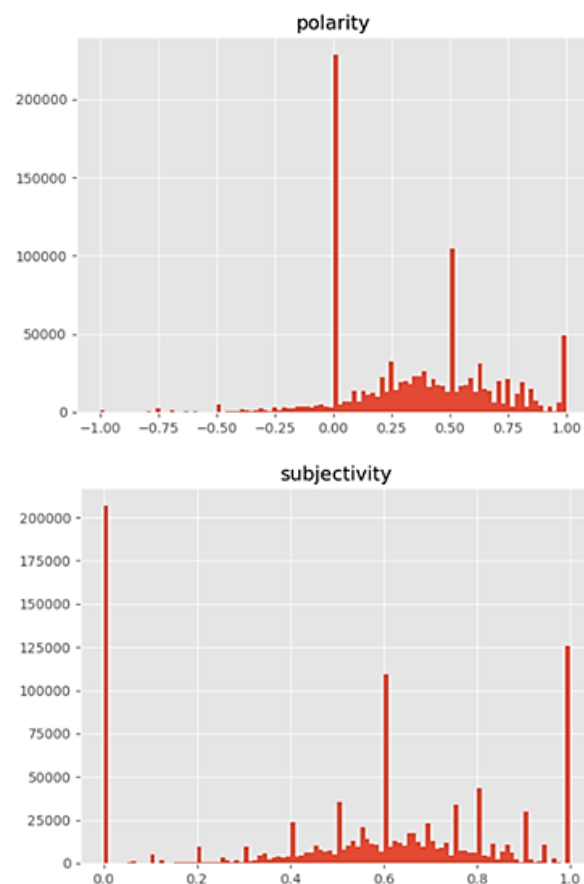


Fig. 5. The polarity and subjectivity distribution of Carli Bybel (Fashion)



Fig. 6. The polarity and subjectivity distribution of Nastazsa (Lifestyle)

4 Conclusions

To summarize, this study evaluated the effects of social media activities of the most popular 12 YouTubers using big data on the investigation, measurements, and sentiment analysis of customer engagement in brand communities. Our findings suggest that customer-brand interactions benefit a lot from social media engagement efforts in brand communities. In addition, YouTube is an effective customer engagement channel with an average feedback ratio of 3.0% to enhance brand reputation and value building.

Therefore, future studies are required to explore what type of Key Opinion Leader (KOL) or YouTuber that brands can choose to work with to get the most benefits in online communities. Furthermore, it is encouraged that the fashion and cosmetics industry can increase social media marketing budgets on YouTube as there are more customer engagement activities compared to other sources.

Acknowledgement

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02/

Fashion: Process, Visualizations, Artifacts and Beyond

Deep Fabric Print Generation for Fashion

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Abstract. Extracting feelings from the mood board is a necessary step for designers to create new illustrations. However, the process of feature extraction from the mood board and obtaining a new print is both time-consuming and creatively challenging. A style transfer process based on a deep neural network is described here to solve this problem by creatively generating an entirely new print. In this paper, the **AAST (Aesthetic-Aware Image Transfer)** method is utilized to extract the color and texture features from the mood board and transfer it into the content images. This algorithm can generate numerous results, fusing content and mood board at high resolution. Unlike other previous style transfer methods, which transfer the style and color features simultaneously, a novel style transfer block, i.e., Aesthetic-Aware Image Transfer divides the color and texture features into two independent feature maps, thus creating a preferred print. Specifically, colors and textures extracted from multi-images are two instinct paths in the training section from which the generator obtains and transfers color and texture separately. Compared with the filters in Illustrator and Photoshop, this method can extract the feelings of arbitrary images as filters and generate prints from them. Extensive experimentation has demonstrated the feasibility and effectiveness of the method.

Keywords: Deep Neural Network, Generative Adversarial Network, Feature Extraction, Style Transfer, Image Rendering

1 Introduction

Creating an outfit with the inspiration of a mood board is a key process in fashion design. Usually, designers carry out creative design by using the feeling of the mood board and the colors it proposes. Specifically, designers extract the features from the color and texture of the mood board with their own understanding. Combining the conditions of creativity with personal inspiration ensures the creation of a unique print but can take up a great deal of time. Besides, the new print pattern can only be drawn one by one, which leads to even less efficient use of time. It is effective and efficient to adopt style transfer techniques to generate new fabric print patterns based on the original designer's inspiration. Compared with the filters in Illustrator and Photoshop, the advantage of this method is that the arbitrary images can be extracted as filters to generate prints that capture a designer's inspiration.

Studying the influence of color on the expression of emotional styles in a statistical way has long been discussed. A number of studies [1] illustrate that feelings can be conveyed by the color combination of the patterns. Several methods based on these results change the color distributions of the images, thus manipulating the feelings of the original images. However, these classical methods edit feelings in terms of color only, while texture and content remain unchanged.

Figure 1. The result of prints generated from AAST.



The style transfer model is a deep neural network which can generate new images with reference to content images and carry the features of the style images. As one of the specific scenarios in the task of Image-to-Image translation, the style transfer generators generate final images that are full of detail and have high resolution. Gatys et al. [2] first applied the Gram-matrix as constrained functions in training the deep neural network and obtained the output images with the color and textures from the style images. Based on this research, several methods [3] [4] explored different solutions to better match the second-order statistic. However, these methods can only transfer the style of a single reference image from color to texture. Furthermore, the elements of the reference image are bundled together, and thus it is not easy to separate them using these methods.

Several methods have been proposed to disentangle the features in the perceptual layer to overcome the bundling of the color and texture. [5, 6] and [7] split the style features into different sub-features, such as style of the brushstroke and color, etc. However, it is still challenging to disentangle the color and texture of the reference image since color is the most significant element that needs to be disentangled. Color and texture are significant elements in constituting a pattern, and successfully disentangling color and texture to facilitate the task of neural style transfer and its application to fashion and design. The AAST [8] method proposed here can extract both style information like brushstrokes and emotions represented by color information. Deep neural networks can effectively generate inspired delicate patterns in batches with high resolution.

In this paper, AAST [8] is applied to generate more patterns with novel feelings while preserving the spatial structure of content images. Samples are shown in Figure 1 above. Specifically, the pre-trained model proposed by the authors is used to transfer the color and texture information. Two reference images are considered to manipulate the color and texture features of the final image separately. The LAB channel is utilized instead of the normal RGB channel to disentangle the color and texture information. The L-path of the LAB channel is applied to control the color features more and the AB-path handles texture features, which generates the new print design better in terms of texture details. Extensive experiments were conducted to test the effectiveness of the AAST in a new print generation. Compared with other style transfer models, not only can a high-quality print be generated, but also the texture and color can be successfully manipulated according to the multi-reference images. In summary:

1. We utilize the deep neural networks-based method, namely AAST, to realize style transfer to assist designers in generating new inspired patterns.
2. AAST is applied to generate new patterns; it can not only successfully transfer the style of the reference images, but also independently manipulate the reference images' color and texture.
3. Extensive experiments demonstrate that the AAST can generate high-quality new fabric print images.

2 Related Work

2.1 Generative Adversarial Network

The core of image generation involves learning the statistics matrix of the reference images and reconstructing the images with desired deep neural networks. Two main methods of image reconstruction are Variational Auto-encoders (VAEs) [9] and Generative Adversarial Networks (GANs) [10]. Since methods based on VAEs learn the representation of the images in the latent space, they are limited to defining the hypothetical prior probability of all images. GANs avoid this problem in the Nash equilibrium, where a generator, namely G, and a discriminator, namely D, are embedded in the whole model. The G can generate images better than a discriminator, and the discriminator can classify the image as real or fake. In this way, the generator can synthesize an image with vivid patterns. However, the unsupervised generator limits the application. Based on this observation, methods have been developed to improve the capability of plain vanilla GANs. For instance, Conditional Generative Adversarial Networks [11] are proposed to constrain the direction of generated images.

2.2 Style Transfer Model

The concept of Style transfer was first proposed by [2], which fuses the content image with the style image and synthesizes a new image that preserves the content image's texture information and the style image's emotional feeling. Gatys et al. [2] accomplished the task with statistic matrix similarity. However, the difficulty is that this method involves minimizing the style and content loss iteratively. To overcome the high computational cost of the optimization-based methods, feed-forward methods have been proposed to improve efficiency. For instance, [12] [13] [14] methods utilize a single-forward strategy to improve efficiency. However, the drawback is that these models can only generate images of a single style. AdaIN [15] transfers the style through mean and standard deviation to content images for arbitrary style transfer. WCT [16] matches the co-variance matrix of content and style images extracted from the deep neural networks.

These style transfer methods transfer the style of the reference images to the content images. However, the color and texture information are bundled together, which limits the application to texture-only transfer.

2.3 Color Feature Control

Color information is one part of style features that can be transferred with texture and stroke by statistic matrix analysis. Several methods provide effective global style transfer. [6] extracted the style features with multi-layers and reconstructed images by different sizes of strokes. However, the color information is difficult to disentangle from other features. AAST [8] disentangles the color and texture features with multi-reference images, and so can be applied widely to inspire print generation.

3 Methodology

3.1 Image Representations

In normal style transfer methods, the color and texture information are bundled in the RGB channel, and this means that it is difficult to extract and disentangle the information using normal deep neural networks. Since images in CIELAB [17] color space represent color and texture better, the L-channel in CIELAB space illustrates luminance while the AB-channel demonstrates color distribution (see Figure 2 below).

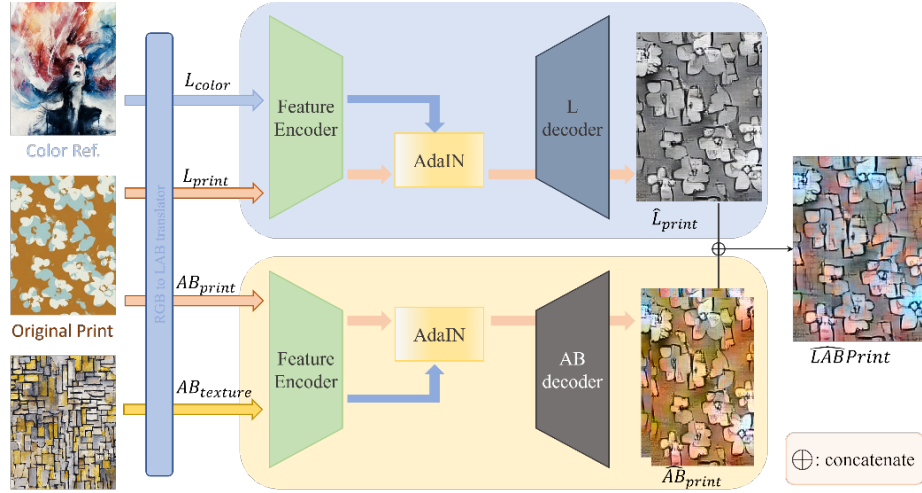


Figure 2. The architecture of the style transfer generator. In this architecture, two independent transfer modules are included. The L-path generator and AB-path generator synthesize the color and texture transfer respectively.

3.2 Feature Encoder

The pre-trained VGG-19 model is utilized as the encoder to extract the high-level information of the input image and release the computational cost during style transfer. The formula is:

$$f_{LAB_x} = En(LAB_x, \theta) \quad (1)$$

where LAB_x is the input images x in CIELAB space translated by the original images and $En(\cdot)$ is the pretrained encoder.

3.3 Style transfer modules

The novel style transfer module AdaIN, which is used to manipulate the mean and standard deviation in the channel-wise maps, is applied to fuse the style of the content image and reference images. The format is written as:

$$AdaIN(x, y) = \sigma(y) \left(\frac{x - \mu(x)}{\sigma(x)} \right) + \mu(y) \quad (2)$$

where $\sigma(\cdot)$ denotes the mean calculation and $\mu(\cdot)$ illustrates the function of standard deviation calculation. In the process, two hyperparameters α and β are applied to control the degree of color and texture translation with the format:

$$\hat{f}_{AB_{result}} = (1 - \alpha)f_{AB_{content}} + \alpha AdaIN(f_{AB_{content}}, f_{AB_{color}}) \quad (3)$$

$$\hat{f}_{L_{result}} = (1 - \beta)f_{L_{content}} + \beta AdaIN(f_{AB_{content}}, f_{AB_{texture}}) \quad (4)$$

where $\hat{f}_{AB_{result}}$ and $\hat{f}_{L_{result}}$ denote the AB channel and L channel of the result images respectively.

During style transferring in both AB channel and L channel, the color and texture feature maps are decoded by upsampling and convolutional layers. The final results in RGB channels are obtained by the LAB2RGB space translator.

4 Implementation

In this section, the full implementation process is described. The pretrained model is with weight from [8]. Images from the MSCOCO dataset [18] are applied as content images, and images from the WikiArt dataset are regarded as color and texture references to obtain this weight. In the implementation, the pattern prints sampled from the website are applied as content images. Nvidia 3090 GPU is utilized to accelerate the generation speed of the new print. Texture-only style transfers are implemented to change the feeling of the original print.

5 Results

5.1 Arbitrary Style Transfer

Figure 3 below illustrates the samples of the new print generated by content print and style images. Prints in the same row denote the same print in different styles, while prints in the same column have the same style but in different prints. The generated prints demonstrate that the generator can synthesize high-quality images and transfer the style of the reference images successfully. Taking the first column of generated prints as an example, it is clear that not just the color but also the texture features are well transferred.

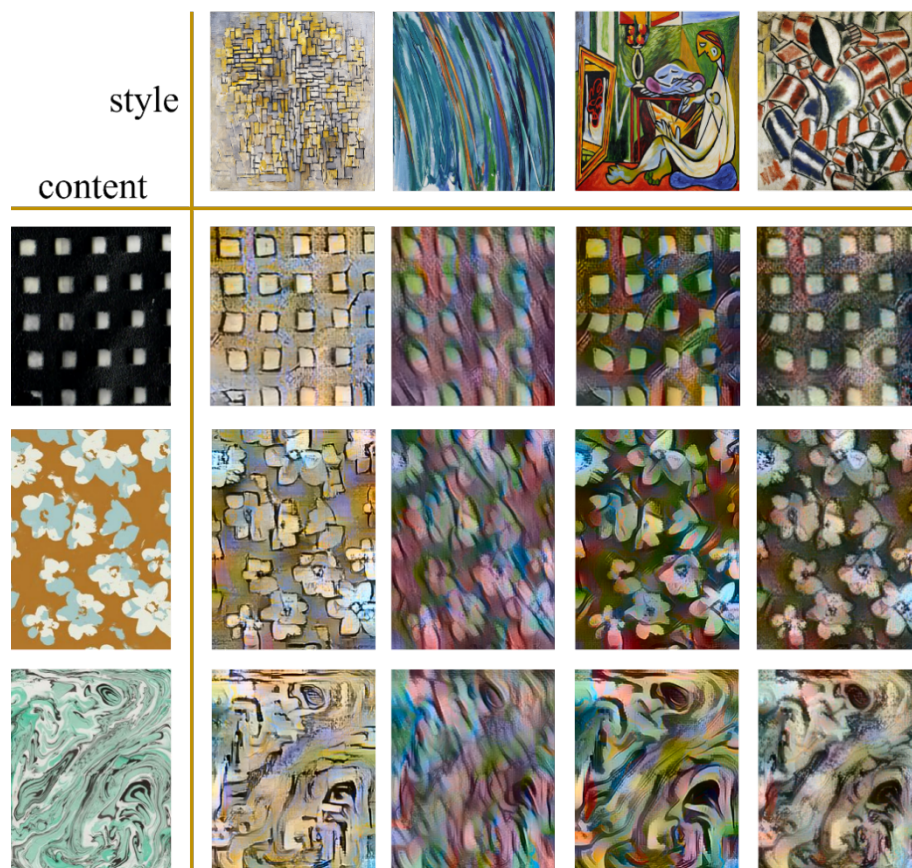


Figure 3. Samples of generated print from content print and style images. The generated prints on the right-down side inherit the specific content print fused with style images

5.2 Similarity Control

Figure 4 below shows that the model is able to control texture and style similarity between texture reference and style reference. From left to right, the transferred results carry the information of the style reference step by step. The texture information is gradually represented from top to bottom in the figure. This performance demonstrates clearly that the model can disentangle and control the color and texture of the reference images.

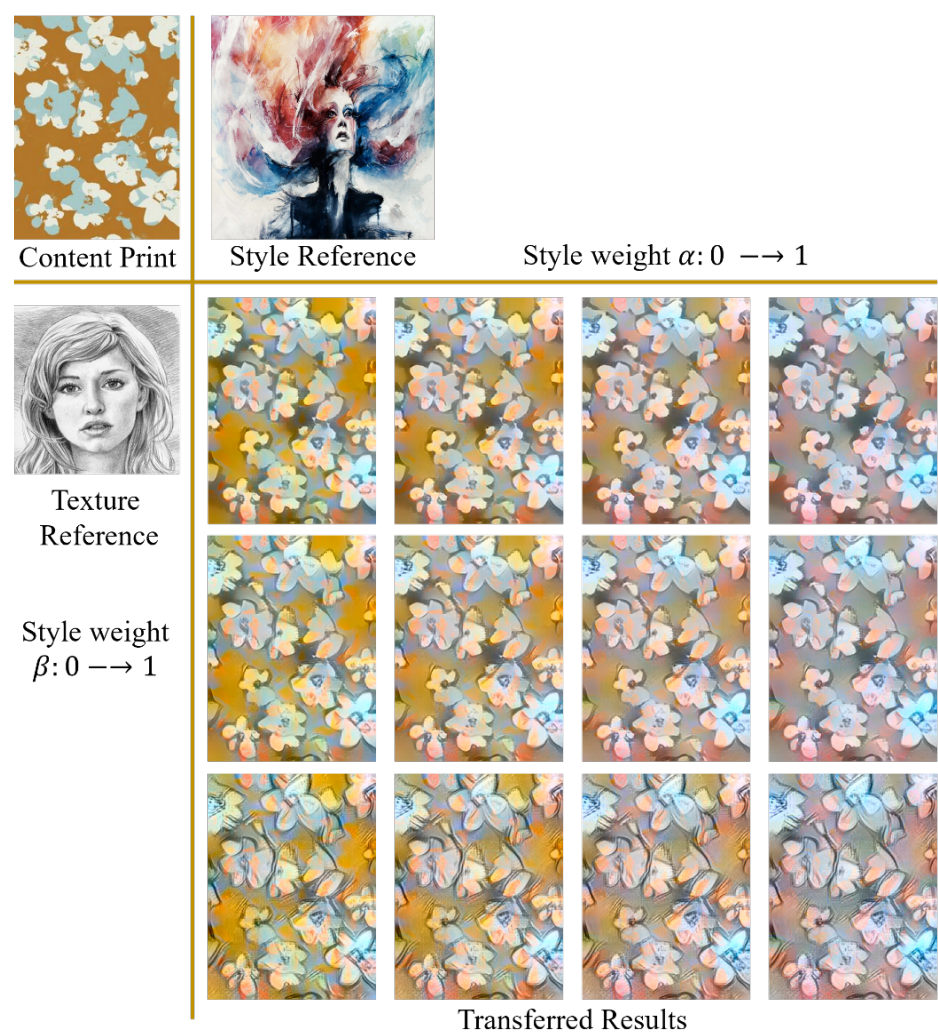


Figure 4. Samples of generated print from content print and style images. The generated prints in the Transferred Results denote the content print fused with style reference and texture reference with different weights.

5.3 Qualitative Comparison

The comparisons are shown in Figure 5.

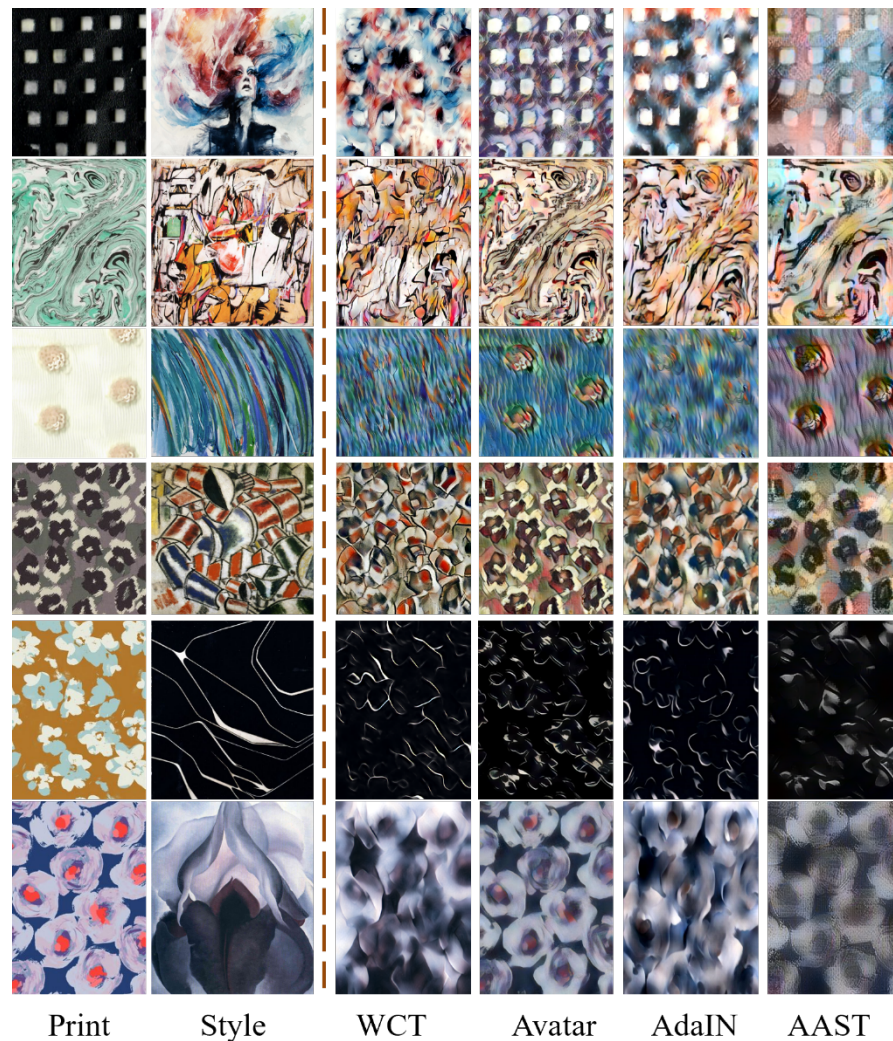


Figure 5. Comparison of prints generated by different methods. Print and Style in the Figure denote the content print and style reference. Prints generated by WCT, Avatar, AdaIN, and AAST are illustrated on the right side.

From this figure, all four methods transfer the style images into the print. Unlike WCT, Avatar-net [19], and AdaIN, the prints generated from AAST are better representations that preserve details and textures in the patterns due to the reduced influence of luminous distribution. The textures in the prints generated by AAST are clear and preserve elements of the content.

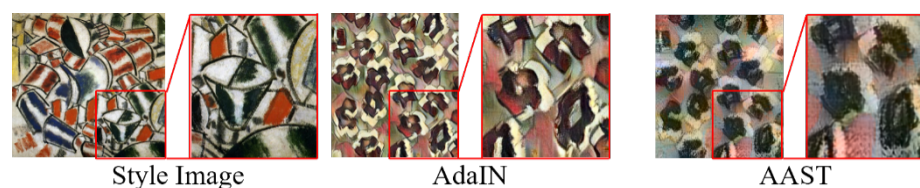


Figure 6. Comparison of details in generated prints and the style image. AAST outperforms in detail since the oil painting style in the style image is well transferred to the print

Figure 6 shows details of prints generated by AdaIN and AAST. It can be seen that prints generated by AdaIN limit the texture style when applied for style transfer. The print generated by AAST has the feeling of an oil painting, and thereby reflects the style image.

6 Conclusion and future work

In this paper, a new method is proposed to generate patterns with new feelings while preserving the spatial structure of content images. The new method, AAST, is applied to generate new prints effectively. In this method, the content and style features of normal images in RGB space are extracted during RGB2LAB translation and deep neural network learning. In this way, the method generates new prints by fusing the content and style features from different images. Moreover, color and texture in the style features are disentangled into two independent paths to generate new prints, which can provide designers with greater inspiration in print and outfit design.

Creating different repeats of the print is currently limited, and adjusting the scale is challenging since the work so far has focused on color and texture transfer from the mood board to the print. Future work will address these limitations.

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The Effect of Heel Base Design on Plantar Pressure and Wear Comfort of Healthy Females

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Abstract. As one of the most popular and desirable fashion items, high heels with a pointed heel base are particularly popular with women. Despite the foot problems induced by ill-fitting designs of high heels, many women neglect their foot health, which results in foot discomfort and even pain. The aim of this study is to investigate the effect of heel base designs with a classic pump style on the plantar pressure, walking stability and perceived wear comfort using a classic pump style. Heel base designs have a major influence on the maximum peak pressure and shifting of the centre of pressure trajectory. In this study, a wedge heel design which provides more plantar support is perceived as the most desirable footwear for walking stability and comfort. As compared to the trapeze-heel, the cone-shaped heel is perceived to be more stable, although it has a small contact area. The trapeze-heel results in the highest peak plantar pressure and thus causes walking instability and discomfort. In addition to the height of the heel, shoe designs should also consider the contours of the heel base to improve wear comfort and reduce pressure during walking.

Keywords: heel base design, plantar pressure, comfort, high heels

1 Introduction

High heels have become one of the most important fashion items in women's wardrobes. High heels are considered to increase the attractiveness of women and enhance their femininity [1]. Women wear high heels not only for aesthetics but also for career or social purposes [2]. In some industries, such as the hospitality and corporate industries, high heels are an essential element of business attire. Shoe designers continue to create fashionable high heels with captivating designs or decorative additions. Due to the influence of social norms, it seems that women continue to wear high heels every day without concern for their foot health even though elevated heels make walking inconvenient and uncomfortable, as well as cause a variety of foot problems.

High heeled shoes are not considered to be comfortable footwear mainly because of their elevated heels and the shape of the toe box. Although high heels can increase the attractiveness of women mainly because heels change their physical profile and stride [1], the adverse impacts and discomfort caused to the feet should not be neglected. Elevated heels shift most of the pressure forward on the feet and the pressure is unevenly distributed, thus creating pain and discomfort in the forefoot area. Prolonged and frequent wearing of high heels may lead to forefoot pain, hallux valgus and ankle sprains [3]. The American Podiatric Medical Association (APMA) [4] reported that nearly half of the American women (49%) in their study own 9 pairs of high heels on average, and 71% of the respondents who wear high heels experience pain. Despite the fact that high heel wearers disregard foot health and comfort, societal customs and fashion trends have encouraged the continued use of high heels.

Given the large number of high heel wearers, comfort is a very important consideration. Since serious foot problems may arise from improper high heel design, the majority of studies reported in the literature have evaluated the factors that lead to discomfort and even foot pain while wearing high heels. These studies, however, mainly focus on the relationship between comfort and heel height, as well as the effectiveness of shoe inserts in improving the comfort of high heels. Few studies have investigated the influence of heel base designs on plantar pressure distribution and wear comfort. Studying the influence of different high heel characteristics on comfort can provide the basis to improve high heel construction and thus improve footwear comfort.

Methodology

1.1 Subjects

A total of five female subjects between 21 and 24 years old (mean $\pm$ SD: age $22.2 \pm$ years old, BMI 20.0 ± 2.4) were recruited for the study (see Table 1 below). The inclusion criteria were that subjects should have no history of serious foot problems such as hallux valgus, flat foot, etc. and have suffered no foot injuries within the past 3 months. All subjects reported that they did not usually wear high heel shoes, except for special occasions. That is, they did not wear heels very often, or less than twice a month. All subjects signed a written consent form agreeing to participate in the study, and verbal instructions on the wear trial were provided to them upon their arrival in the testing venue.

Table 1. Descriptive statistics of participants (n=5)

Variable	Mean	Standard Deviation	Maximum	Minimum
Age (years old)	22.2	1.2	24.0	21.0
Body mass index (kg/m ²)	20.0	2.4	23.4	15.9
Shoe size (EU)	36/37			

1.2 High Heel Conditions

Three experimental high heel types were adopted in this study. High heels made of synthetic materials in a standard almond shaped classic pump style with a heel height of 5 cm. The heel bases include the wedge, trapeze and cone types, as shown in Fig. 1 below, and specifications are presented in Table 2. An almond shaped toe box is typically adopted in high heels with pointed and round toe designs. This combination provides a perfect match for a contemporary look while keeping a comfortable aesthetic, offering a glamorous effect with relatively spacious room for the toes to move. It is noted that the trapeze heel has a large contact interfacial between the ground and the heel base, while its heel connection with the outsole is relatively small as compared to the other heel types. Stimpert [5] advised that wearers unused to high heels should keep the heel height to a maximum of 5-6 cm. Since all subjects did not usually wear high heels, a heel height of 5 cm was chosen for safety purposes. As compared to experienced high heels users, the less experienced wearers find that functional mobility and perceived stability are relatively low when heel height increases [6]. The use of 5cm heel height in this study enabled wearer to walk comfortably and safely throughout the experiment, with minimal forward shifting of the body weight. The subjects were given the opportunity to walk on a concrete surface for no less than 15 minutes. The concrete floor surface allows the subjects to have a sufficient reaction force for easy movement control in each test to become habituated to the sample high heels [7].



Fig. 1. Three experimental high heel types

Table 2. Specifications of heel bases

Variable	Type of heel		
	Wedge	Trapeze	Cone
Heel height	5cm	5cm	5cm
Heel base area (cm ²)	55.5	16.2	6.1
Upper heel contact width (cm)	Full	3.5	5.5
Lower heel contact width (cm)	Full	4.5	1.5

1.3 Experimental Protocols

A total of 10 trials were carried out to obtain the walking speed of each participant. To minimize the effect on the plantar pressure due to the different walking speeds, walking trials that exceeded 10% of the predetermined speed of 1.27 m/s were rejected [8-9]. The plantar pressure of the 3 types (3 high heel types × 3 trials) while walking was collected by the in-shoe Pedar® system, with its 99 sensors (Novel GmbH, Munich, Germany). The capturing frequency is 50Hz per second. Calibration was conducted according to the manufacturer's instruction before each trial. The subjects were instructed to walk a distance of 6 m on a concrete surface for all of the trials. Each experimental type was recorded three times and the three types were randomized to minimize possible order effects.

The plantar of the foot was mapped into 7 regions for analysis: hallux, lateral toes, forefoot medial, forefoot, forefoot lateral, midfoot and heel (see Fig. 2). The dominant foot was determined to be the foot that is used to kick a ball. The peak plantar pressure (PPP) in kPa and center of pressure (COP) in mm for the 3 experimental types are reported as follows.



Fig. 2. In-shoe Pedar® system and seven anatomical divisions of the foot: (1) hallux, (2) lateral toe, (3) forefoot medial, (4) forefoot, (5) forefoot lateral, (6) midfoot and (7) heel.

Subjective perceived comfort after the walking trials for each of the three different high heels worn was measured as follows. After each walking session, the participants rated the overall, forefoot and heel comfort, heel and arch stability and overall control respectively [10-11]. The visual analogue scale (VAS) is 15 cm long with a scale of 0-15, on which 0 represents “not comfortable at all”, and 15 represents “the most comfortable condition imaginable”. Each grid in the VAS is 1 cm wide.

Results and Discussion

1.4 Peak plantar pressure (PPP)

Table 3 and Fig. 3 show the PPP obtained with the various heel base conditions. The highest PPP is found in the hallux for all 3 heel base types (306 kPa or higher). The increase in heel height shifted the peak pressure over the forefoot, midfoot and rearfoot to the hallux. It is interesting to observe that the heel base designs show a major influence on the trend of pressure changes. Wearing the shoe with a trapeze heel resulted in the highest maximal peak pressure at the hallux (334.5 kPa) and lateral toe (123.3 kPa), even though the heel height of the three footwear types was kept constant at 5 cm. Despite the fact that the cone-shaped heel has the least interfacial contact with the ground, its maximal peak pressure at the hallux (315.9 kPa) was lower than that of the trapeze-shaped heel. Note that the PPP should be kept at less than 200 kPa to avoid foot pain and related foot deformities due to excessive high pressure [12]. In this study, regardless of the heel base design, the PPP obtained at the hallux, forefoot and heel regions was consistently higher than the threshold of 200 kPa, and reached 300 kPa or higher during walking with a heel height of 5 cm.

Table 3. Mean and (SD) of peak plantar pressure for 3 heel types (unit: kPa)

Region of plantar of foot	Type of heel		
	Wedge	Trapeze	Cone
Hallux	306.0 (120.8)	334.5 (111.3)	315.9 (97.3)
Lateral toe	80.5 (45.4)	123.3 (76.2)	82.8 (47.5)
Forefoot medial	209.0 (47.9)	187.6 (31.4)	251.2 (49.5)
Forefoot	268.4 (42.2)	292.6 (61.6)	234.5 (38.8)
Forefoot lateral	106.9 (29.5)	109.1 (28.9)	95.2 (15.8)
Midfoot	40.0 (18.4)	75.2 (13.9)	60.8 (14.4)
Heel	246.2 (27.9)	286.6 (28.8)	248.8 (16.5)

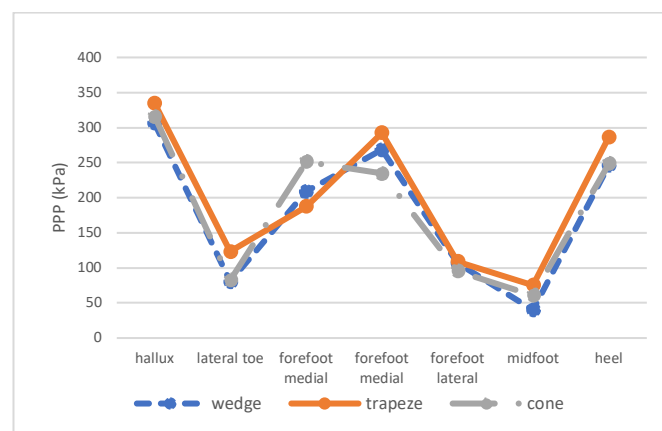


Fig. 3. Peak plantar pressure of three high heel types during walking

1.5 Centre of Pressure

The COP locations (i.e. COPx and COPy) in the medial-lateral (ML) and anterior-posterior (AP) directions were further investigated so that the walking stability associated with various heel base designs could be identified and compared. As indicated by Luximon et al. [13], COPx values decrease as the heel height is increased; that is, the COP shifts to the medial direction with increased heel height. As shown in Figs. 4 and 5 below, the cone-shaped design has the lowest mean COPx value (37.6 mm medially) among the 3 heel base designs. The subjects tended to sway when they wore the shoes with a cone-shaped heel as compared to the wedge and trapeze shaped heels with a mean COPx of 40 mm medially. Regarding the mean COPy, the wedge heel best preserves walking stability with the lowest mean COPy (99.8 mm), while the trapeze heel tends to shift the COP forward (110.9 mm).

Amongst the 3 heel base designs, the cone heel is more unstable in the ML direction, while the trapeze heel results in forward shifting with excessive high pressure at the hallux and lateral toes. The wedge heel tends to show the best walking stability in both the ML and AP directions, which may be attributed to the large area of interfacial contact between the heel and the ground, which provides better support for wearers. It has also been noted that dynamic stability is maintained by the loading response and mid-stance in a gait cycle [14]. The full contact design of the wedge heel allows a higher loading response for improved walking stability. Apart from the contact interfacial between the ground and the heel base, consideration should also be given to the heel connection with the outsole. It is noteworthy that the trapeze heel has a relatively small interface in connection to the outsole. The results align well with the finding in Zhang and Li [15]; that is, inadequate support from where the heel is connected to the outsole tends to inhibit the function of the heel rocker and impair weight bearing stability during walking.

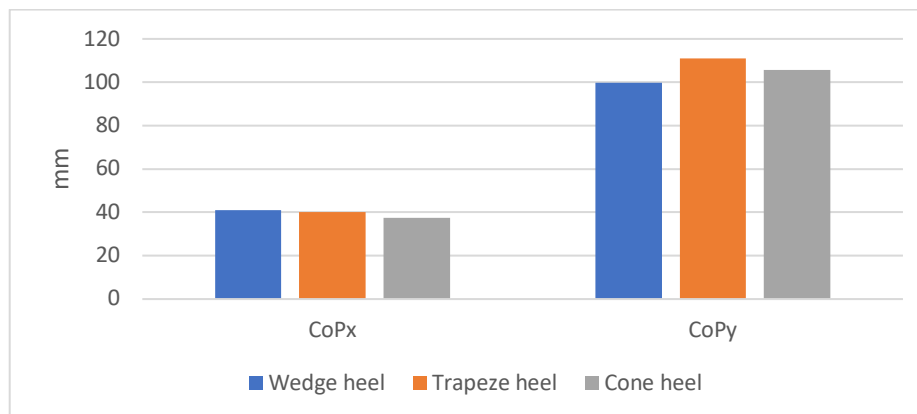


Fig. 4. Mean COPx and COPy of the 3 heel based designs during walking

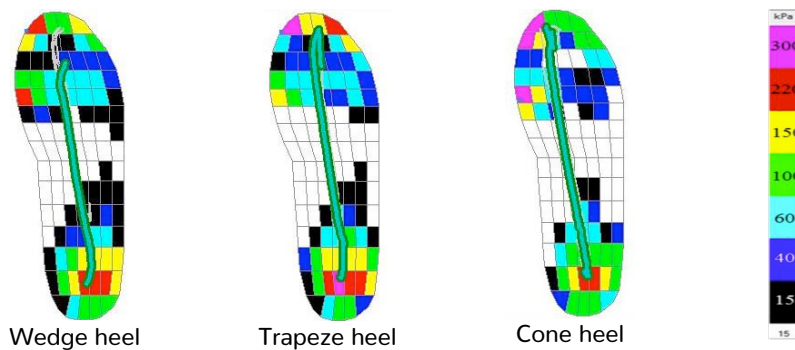


Fig. 5. Pressure maps of three high heel designs during walking

1.6 Wear Comfort

The wedge heel has the highest mean scores in all aspects of the subjective assessments for walking comfort and stability, including overall comfort (14.3), forefoot comfort (13.3), heel comfort (14.0), heel stability (14.3), arch stability (13.5) and overall control (14.3) respectively. The mean scores of the other heels range from 8.5 to 10.0. It is interesting to note that the cone heel yields a higher score (9.5) for heel stability than the trapeze heel (8.5), despite the medial shift observed from the cone-shaped design. The subjects tended to be sensitive to the small difference in the COP_y between the cone-shaped (105.8 mm) and the trapeze-shaped (110.9 mm) heels.

2 Conclusion

Walking in high heels may be associated with instability and a high risk of falls and foot injury. The influence of heel base design on the plantar pressure, the change in COP and subjective wear comfort has been investigated in this study. Results reveal that when the heel height is fixed at 5 cm, the heel base designs show a major shift of the PPP to the hallux and lateral toes. The COP measures in the AL and ML directions also show that the heels shift the foot forward and medially, which lead to walking instability and swaying, thus adversely affecting wear comfort. It is recommended that a full contact heel base might increase stability during walking which is consistent with participants' perceived stability.

Acknowledgements

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M-VTON: Multi-layer Virtual Try-on System

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Abstract. Fashion recommendation is an issue of considerable importance in the fashion e-commerce industry. The essential part of the recommendation task is how to represent outfits. We propose a multi-layer try-on system (M-VTON) based on deep learning methods. M-VTON can generate vivid try-on images to represent an outfit using its separate product images. It includes a fashion keypoint detection model and a semantic segmentation model. The detection model aims to estimate the keypoints of garments in order to calculate an item's scale and position. The segmentation model serves to separate garments into front and back pieces, which are used to generate the multi-layers of outfits. We conducted experiments on two mainstream fashion datasets and results support the effectiveness of our proposed approach.

Keywords: Fashion recommendation, virtual try-on, keypoint detection, semantic segmentation, fashion compatibility learning

1 Introduction

The fashion e-commerce industry has maintained a strong growth momentum in recent years according to Statista¹. The fashion recommendation, as a core task of the fashion e-commerce industry, contains two important sub-tasks: fashion compatibility learning [4, 5] and fashion cognitive learning [1, 6]. Both have received significant research attention. The former studies the relationship between items of an outfit, while the latter focuses on modelling the relationship between an outfit and human physical attributes. Although the research aims of these two tasks are different, their essential problems are the same, *i.e.*, how to meaningfully represent an outfit.

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Fig. 1. Illustration of a try-on image. An outfit consists of fashion items with different scales and spatial positions. The layer orders between items should also be considered when representing an outfit. For example, the blue skirt is covered by the sweater, part of which is covered by the skirt.

Most studies [7-9] consider an outfit as a set of separate fashion items. However, they neither respect the scale of fashion items nor their spatial position. As illustrated in Fig. 1 above, the product images of the skirt and shoes are of comparable size, but their sizes in the try-on image vary considerably. In addition, the try-on image accurately reflects the spatial relationship between fashion items. Some researchers have examined the feasibility of evaluating outfits from a try-on angle, but their results are less than satisfactory. [10] employs a generative model while suffering from poor try-on image quality. [11] suggests learning try-on representation from real try-on images in an unsupervised manner, however, the research could not produce try-on images based on discrete item images. In addition, no research has investigated the problem of item overlap. As shown in Fig. 1 top left, the shirt is mostly covered by the sweater.

Based on the above analysis, in this paper, we aim to develop a multi-layer try-on system to facilitate fashion recommendation. However, developing such a try-on system is challenging for the following reasons. 1) Accurate fashion keypoint detection is essential; however, the keypoints of fashion items vary markedly between fashion types. How to determine the scale and spatial position for each item with different fashion types poses a significant challenge. 2) How to precisely present the multi-layer relationship between fashion items poses another challenge. 3) The current fashion parsing task concentrates on classifying items in terms of fashion categories. Lack of an available segmentation dataset focusing on the front and back pieces of clothing is the third challenge.

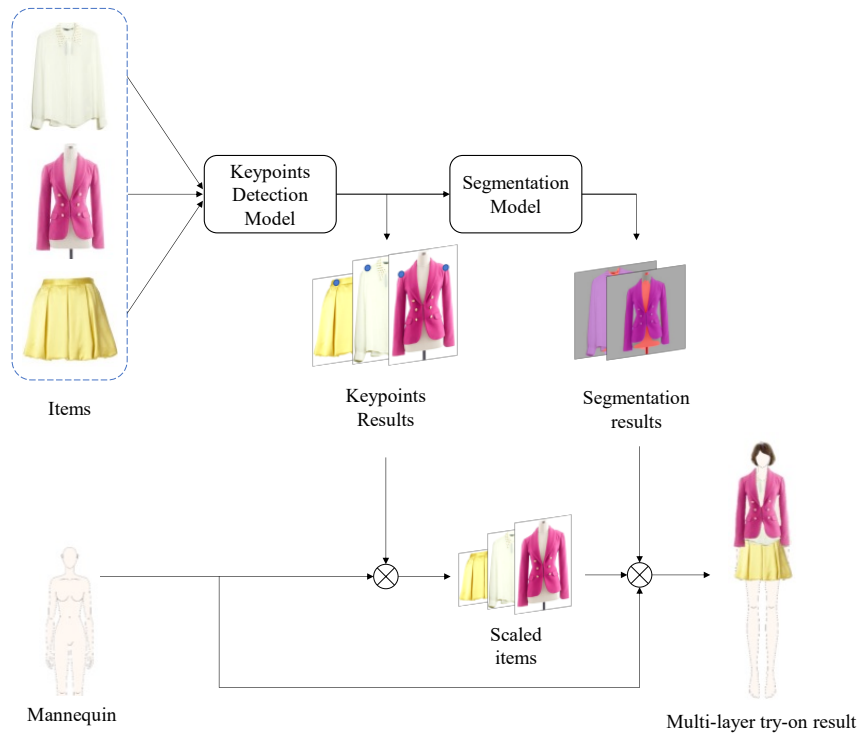


Fig. 2. Overview of a multi-layer try-on framework. Each fashion item will first be sent to keypoint detection model to estimate fashion keypoints. The estimated keypoints are used to calculate scales and positions for garments. Then segmentation model separates images into front and back pieces. Finally, the segmentation results are applied to scaled items to generate the try-on images.

To tackle these challenges, we devised a Multi-layer Try-on System, M-VTON, and the pipeline is shown in Fig. 2 above. Firstly, an efficient pose estimation model ViPNAS [2] estimates the keypoints for each fashion item of an outfit. Secondly, we perform semantic segmentation on the fashion items to obtain their front and back pieces. Object-Contextual Representation (OCR) [3] is utilized as the segmentation model in this project. The third step involved calculating the scale of items by aligning the keypoints of the mannequin and garments. Finally, the semantic segmentation results are applied to the scaled item to generate the final multi-layer try-on image.

We tested our M-VTON on two mainstream fashion datasets to demonstrate its practicability. Experimental data yielded quantitative results that support M-VTON's practicability.

2 Related Work

2.1 Outfit Representation in Fashion Recommendation

In the field of modelling fashion compatibility, most research has attempted to learn item representations rather than outfit representations. Vasileva [4] modelled fashion compatibility by measuring item similarities with respect to item types. [12] proposed generating item embeddings by considering product context. SCE-Net [13] claimed to learn item embeddings without explicit supervision to alleviate the deficiency of rich labelling costs. A graph-based method OCM-CF [14] obtained outfit representation by employing a multi-head attention mechanism to exploit fashion item context information. A relatively small body of studies has investigated the task of fashion

cognitive learning. [1] studied the relationship between fashion outfits and human physical attributes and encoded outfits through 1-dimensional convolutional filters of different sizes. [11] used realistic try-on photos of celebrities as input but employed a clothing parser to separate each item. In contrast to representing an outfit by discrete clothes, approaches such as [10, 15] suggested the modelling of outfits through try-on images. In this paper, we argue that the try-on image is a more natural angle for encoding an outfit compared with separate item images due to its consideration of scale, spatial location, and multi-layer issues.

2.2 Virtual Try-on

Virtual try-on (VTO) is a key concern in the field of fashion synthesis and can improve user experience of fashion e-commerce platforms. Most of the existing approaches to VTO are based on Generative Adversarial Networks (GAN). [16] proposed a coarse-to-fine framework to transfer a product item onto a target person.

ACGPN [17] considered the semantic layout of reference images and then determined the areas of images that need to be changed or preserved to solve the challenge of large occlusions of human pose. [18] proposed an RT-VTON to extend application clothes of virtual try-on to non-standard items. To solve the quality limitation of try-on results due to garment textures, C-VTON [19] was designed.

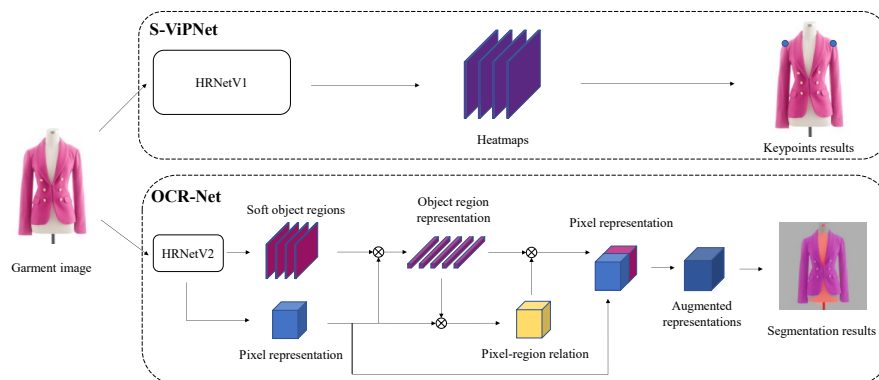


Fig. 3. Pipeline of processing a single garment. Each garment is sent to the keypoint detection model and semantic segmentation model separately. The former is achieved by using S-ViPNet [2] and the latter is realized by utilizing OCR-Net [3].

It consists of a geometric matching procedure and a powerful image generator. Morelli [20] introduced the Dress Code to bridge a serious research gap: VTO currently neglects lower-body clothes and full-body clothes.

Although there has been continuous development of VTO, the approaches continue to suffer from poor quality of try-on images and loss of garment details. However, details such as print and texture are crucial for the fashion recommendation task. So, we propose a new VTO framework which can produce try-on results quickly and reliably.

3 Approach

Our proposed M-VTON consists of two modules, as shown in Fig. 2, namely the keypoint detection model and clothing segmentation model. Both are based on deep learning methods.

3.1 Keypoint Detection

The aim of the keypoint detection task is to detect K keypoints from an image. In the context of fashion, we focus on detecting fashion-oriented keypoints for garments. Fashion keypoint detection and human pose estimation are different in a number of ways such as clothing is more challenging because of the presence of non-rigid deformations. There are two reasons why we use the method ViPNAS [2] which belongs to pose estimation: 1. Images in the mainstream fashion datasets are dominated by product images which suffer from non-rigid deformations. 2. One major drawback of fashion keypoint detection methods is their inefficiency.

We utilize the pose estimation model ViPNAS [2] which provides comparable performances at a lower computation consumption rate by using Neural Architecture Search (NAS). ViPNAS contains two sub-models which are S-ViPNet, which aims to estimate keypoints on key frames, and T-ViPNet, which aims to estimate video-based keypoints. Since our goal is to extract keypoints from images rather than video, we only use the S-ViPNet. The pipeline of S-ViPNet is illustrated in Fig. 3.

Heatmaps are firstly regressed based on the high-resolution representation extracted by HRNetV1 [21]. The k th heatmap indicates the confidence of k th keypoint's location. Following the work of ViPNAS [2], we use the NAS to search an optimal network architecture based on a pre-defined spatial search space, including depth, width, kernel size, attention, and group.

Fashion Segmentation

Table 1. Details of the segmentation dataset.

	Training	Validation	Testing
Real	1992	87	87
Sketch	4613	213	213
All	6605	300	300

A fashion segmentation model can parse out the front and back pieces of apparel. To date, there is no available dataset that can be used to train the desired segmentation model. Thus, we created a new dataset focusing on the semantic segmentation of the fashion layer. The steps for creating this dataset are as follows. Firstly, we collected 10,000 images of fashion items containing real product images and sketch images in a ratio of 3:7. Secondly, we carried out a process of data cleansing and pixel-level annotation. Finally, we split the data into training, validation, and testing sets and details are shown in **Error! Reference source not found.**

OCR [3] (Object-Contextual Representations) is a popular segmentation method which fully utilizes all representations of object regions belonging to the corresponding class to augment one pixel's representation. Due to its advantages, we employ OCR for garment segmentation based on the newly created dataset. As shown in Fig. 3 above, OCR has three steps:

Soft object region. Firstly, we employed the HRNetV2 [21] as the backbone to segment K soft object regions from the given image I . Each object region M_k is a coarse segmentation result represented as a matrix. Each entry of M_k means the degree to which the pixel belongs to the corresponding class k .

Representation of object region. Secondly, we obtained the representation of each object region f_k using the following function:

$$f_k = \sum_{i \in I} \tilde{m}_{ki} x_i \quad (1.)$$

where x_i is the representation of pixel p_i , and $\tilde{m}_{ki}$ represents the normalized degree that p_i belongs to k th object region.

Representation of pixel. Lastly, we computed the representation of pixel p_i after considering the relations between it and all object regions:

$$y_i = \rho \left(\sum_{k=1}^K \omega_{ik} \delta(f_k) \right) \quad (2.)$$

where $\rho(\cdot)$ and $\delta(\cdot)$ transformation functions. ω_{ik} indicate the relation between the pixel and object region:

$$\omega_{ik} = \frac{e^{\kappa(x_i f_k)}}{\sum_{j=1}^K e^{\kappa(x_i f_j)}} \quad (3.)$$

where function $\kappa(\cdot)$ is an unnormalized relation function.

The final representation of the pixel p_i is obtained by aggregating x_i and y_i :

$$z_i = g([x_i^T \ y_i^T]^T) \quad (4.)$$

where $g(\cdot)$ is the same transformation function as $\rho(\cdot)$. Finally, a pixel-level cross-entropy loss is applied to learn the segmentation model.

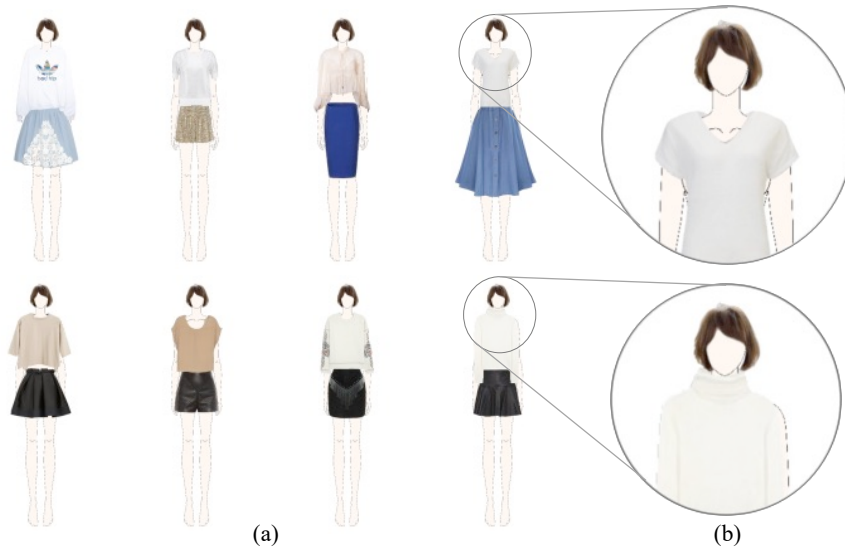


Fig. 4. Try-on results on O4Y [1] dataset.

3.3 Outfit Synthesis

Scale. We first calculated the scales of items, which are obtained by aligning the keypoints of garments with the mannequin's corresponding keypoints.

Layer. To present items in a multi-layered manner, we introduced a layering system. We use the segmentation results to divide clothes into front and back pieces, and then paste the scaled items to the target position piece by piece according to the pre-defined try-on order (in this paper the order from outside to inside is outerwear, dress, blouse, skirt, and trousers).

4 Experiments

We present below the results of try-on images found on two datasets: Outfit for You [1] (O4Y) and Type-aware Polyvore [4].

4.1 Results on O4Y Dataset

We present the qualitative results on the O4Y [1] dataset in **Error! Reference source not found.**. The O4Y dataset contains 29,352 outfits and each outfit includes one top and one bottom. From these eight examples (**Error! Reference source not found.** (a)), we can observe that all garments are scaled properly and placed in the correct position. A zoom-in view of the neckline position is shown in **Error! Reference source not found.** (b). The interaction between the mannequin's neck and the top is accurately depicted by M-VTON.



Fig. 6. Outfits containing one garment.



Fig. 5. Outfits comprised of two garments.

4.2 Results on Type-aware Polyvore Dataset

Type-aware Polyvore dataset [4] contains 32,140 outfits and 175,485 item images. Unlike the O4Y dataset, outfits in the type-aware dataset have a varied number of items and there are in total 11 fashion categories such as outerwear, all-body, and top. Therefore, in this subsection, we present the try-on images with different item combinations. Fig. 5 shows the results of trying on a dress, and Fig. 6 presents the results when outfits contain one top and one bottom item. In Fig. 7, more interesting results are shown since these dresses should be covered by outerwear. Fig. 8 shows the most complicated cases. Outfits are comprised of three garments and these try-on results show that our proposed M-VTON can accurately demonstrate multi-layers of an outfit in a predefined order.



Fig. 8. Outfits comprised of outerwear and dress.



Fig. 7. Outfits comprised of three garments.

5 Conclusion

This paper aims to develop a multi-layer try-on system named M-VTON to facilitate the task of fashion recommendation. M-VTON includes two sub-models, namely the keypoint detection model and the semantic segmentation model. Through the detection model, we can obtain the position and scale of items, and the segmentation model is utilized to separate item images into front and back pieces. We validated M-VTON on the O4Y [1] dataset and the Type-aware Polyvore [4] dataset. The effectiveness of our approach is demonstrated by the quality of the resulting try-on images.

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Fashion Sketch to Real Image System: A Designer Aids based on Generative Adversarial Network

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Abstract. Studying converting sketch images into corresponding real pictures is challenging. The rapid development of the generative adversarial network (GAN) and its excellent performance in image-to-image translation tasks make this research possible. This paper proposes a fashion sketch image to real image (FSRI) system based on the StyleGAN network. The system leverages the pSp encoder to extract the styles of the sketch image, inputs the pre-trained StyleGAN to obtain the corresponding real picture, and implements the image warping algorithm to automatically adjust the head-to-body ratio of the model in the output picture. Extensive experimentation and visualization results derived from a self-established sketch dataset show that the system has excellent capabilities to convert complex sketch images to real images.

Keywords: fashion sketch, real image, StyleGAN, pSp encoder, image warping

1 Introduction

Translating fashion sketches into real images is a crucial step for designers to visualize their design concepts and ensure the feasibility of their ideas. The enhanced display effect and emotional impact make real images more likely to attract consumers and boost sales. Developing a system that quickly translates sketches into real images is of great value for the fashion industry. Such a system can accelerate the clothing design process, reduce design errors and unnecessary revisions, and improve the overall quality and accuracy of fashion products.

In recent years, deep learning models achieved remarkable outcomes. However, only a few studies focus on generating corresponding authentic images from hand-drawn sketches in clothing design.

Various challenges are reported. Firstly, there exists a vast range of types and styles of clothing. Secondly, clothing datasets that can be used to train deep learning models are few in number and operationally limited. The emergence of the Generative Adversarial Network (GAN) [1] has greatly aided the development of image-to-image translation. In terms of the clothing matching task, Attribute-GAN [2] studied semantic attribute-based clothing matching rules based on the CGAN [3]. MS-SA-WGAN-gp [6] is an automatic generation model of clothing patterns based on WGAN-gp. In sketch image to real image translation, FashionGAN [7] can only process sketch images that contain

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simple pieces of clothing without colour and texture. It cannot handle sketch images containing entire outfits. Research in this area is almost non-existent, and so this paper sets out to remedy this situation and take the technology to a new level.

This paper introduces a designer aid named the Fashion Sketch to Real Image (FSRI) system, which translates fashion sketches into real images. Our encoder is based on the pSp encoder [8] that leverages a Feature Pyramid Network [9] to extract style vectors from different pyramid scales of sketch images. These styles are then fed into a StyleGAN pre-trained on a high-quality real fashion dataset to generate real images. Considering that the real image output directly from StyleGAN may not satisfy the head-body ratio of the model, we propose an image warping method [10] to adjust the head-body ratio. Experimental results show that our system can translate multiple styles of sketch images into corresponding real images. The main contributions of this paper are (1) an FSRI system that can directly translate sketch images into real images, and (2) a new methodology for adjusting the model's head-body ratio.

2 Related Work

2.1 Generative Adversarial Network

Generative adversarial networks (GAN) [1], proposed by Goodfellow et al. (2014), are currently the best method for generative models. Based on the GAN framework, many advanced methods have been proposed that can generate high-resolution and high-fidelity images by taking random code as input. Among these methods, StyleGAN [11, 12] has attracted the most attention due to its style-based generator network. Several studies using StyleGAN have achieved state-of-the-art results on tasks such as image inversion [13, 14], image editing [15, 16], and image-to-image translation [8], especially in the domain of face images. In this paper, we use a fixed StyleGAN pre-trained on a high-quality fashion dataset as a real image generator to obtain a fashion image corresponding to the real domain by inputting the style of the fashion sketch image into it.

2.2 Image-to-Image Translation GAN

Image-to-image translation techniques aim to learn a mapping that transforms an image from a source image domain to a target image domain. Isola et al. [17] first proposed using conditional GANs to solve various image translation problems. However, their pixel2pixel framework was limited to using image pairs corresponding to the source and target domains. To address the dependence on paired data, researchers proposed two unpaired image-to-image translation models: DiscoGAN [18] and CycleGAN [19]. To overcome the limitations of existing methods for two-domain image-to-image translation, Choi et al. [20] proposed a unified framework called StarGAN, which uses a single generator and discriminator to learn mappings among multiple domains. The pSp framework [8] proposed an encoder network that directly generates a series of style vectors, which are then fed into a pre-trained StyleGAN generator. The pSp framework has demonstrated potential in facial image-to-image translation tasks.

2.3 GAN in Fashion Design

Attribute-GAN [2] studies semantic attribute-based clothing matching rules based on CGAN [3]. FashionGAN [7] proposed a two-to-one architecture that translates fashion sketches combined with fabric images into real images based on CGAN. GD-StarGAN [4] was improved based on StarGAN, so that the model is able to generate clothing images with input image textures based on input texture pictures and clothing category labels. ClothGAN [5] proposed designing new patterns and styles of clothing with Dunhuang elements based on GAN and style transfer algorithms. MS-SA-WGAN-gp [6] is an automatic generation model of clothing patterns based on WGAN-gp. There are two major differences between the FSRI system and the above methods. Firstly, compared with the clothing matching methods (Attribute-GAN and GD-StarGAN) and the clothing pattern generation methods (ClothGAN and MS-SA-WGAN-gp), FSRI is designed for translating sketch images to real images. Secondly, unlike FashionGAN, which requires simple clothing sketches and corresponding fabric patterns as input, the FSRI system takes the sketch image as input to output relatively realistic patterns. The input and output are shown in Figure 1 below, and the architecture of the FSRI system is shown in Figure 2.

Fig. 1. Generated examples from fashion sketch image to real image.

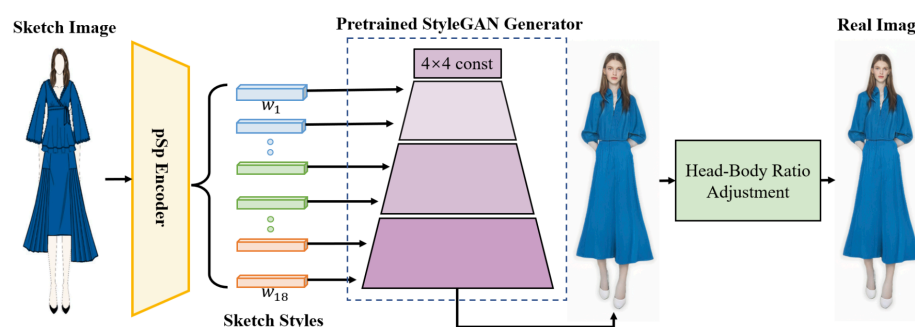


Fig. 2. The architecture of FSRI system.

3 Fashion Sketch to Real Image (FSRI) System

3.1 The overview of FSRI System

Fig. 2. illustrates the structure of our proposed FSRI system, which consists of three components: the pSp encoder for extracting fashion sketch image styles, the StyleGAN for converting sketch styles into real images, and image warping for adjusting the head size of the model.

Specifically, given a fashion sketch image x as input, the feature maps are first extracted using a standard feature pyramid over a ResNet backbone. Next, a trained map2style network extracts the 18 target styles from the corresponding feature maps, which are then used as input for the StyleGAN to generate the real fashion image. Finally, the model's head size can be adjusted using the image warping method based on a human head detection algorithm.

3.2 pSp encoder for sketch image style extraction

In this subsection, we introduce how to extract the style of the fashion sketch image by leveraging the pSp encoder. The pSp encoder is a powerful encoder that matches the input image to an accurate

encoding in the latent space. Existing methods copy the single 512-dimensional vector output from the last layer of the encoder network into 18 copies as the $W +$ space input for the StyleGAN model. In this way, they learn all 18 style vectors together. Unlike these methods, the pSp encoder considers the fact that different style inputs to StyleGAN correspond to different levels of detail, which can be roughly divided into coarse, medium, and fine. Therefore, the pSp extends the encoder backbone with a standard feature pyramid for sketch image feature extraction and leverages map2style network to map the features to the corresponding style for more accurate style expression.

The structure of the pSp encoder is shown on the left side of Figure 2 above. As described previously, it mainly contains a standard pyramid network based on the ResNet backbone to extract the sketch image features and the map2style network to map the corresponding feature maps to low, middle, and high-level styles. Take a sketch image x as input, the function of the encoder is:

$$\mathbf{s} = \mathbf{E}(\mathbf{x}) \quad (1)$$

where $\mathbf{E}$ is the pSp encoder and $\mathbf{s}$ presents the 18 style vectors output by the pSp encoder.

3.3 StyleGAN for real image generation

As noted earlier in the paper, StyleGAN is a state-of-the-art framework for generating high-quality images. A well-trained StyleGAN preserves the semantic information of the training dataset. By taking the normalized vector in W or $W +$ space as input, the pre-trained StyleGAN will output an image that satisfies the training dataset domain. In this formulation, input images are directly encoded into the desired output latents, which are then fed into StyleGAN to generate the desired output image. This allows us to utilize StyleGAN for image-to-image translation, even when the input and output images are not from the same domain. Based on this observation, the StyleGAN pre-trained on the high-quality real fashion image dataset is able to preserve the semantic information of this dataset. Furthermore, by taking the 18 target fashion sketch image styles of $W +$ latent space as input, the StyleGAN can generate a real fashion image the style of which is related to the fashion sketch image. The middle section of Figure 2 illustrates the structure of StyleGAN and the connection detail between the pSp encoder and StyleGAN. By taking the 18 style-output by the pSp encoder as input, the function of the StyleGAN is:

$$\mathbf{x}_{realistic} = \mathbf{G}(\mathbf{s}) \quad (2)$$

where $\mathbf{G}$ is the StyleGAN pre-trained on real fashion image dataset, $\mathbf{x}_{realistic}$ refers to the output real fashion image.

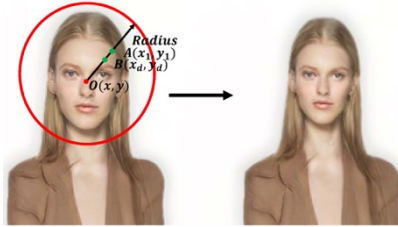
3.4 Image warping for head-body ratio adjustment

To optimize the head-to-body ratio of the model in the generated image and increase the visual aesthetics, we propose to adjust the head size of the model by using the image warping method to achieve a harmonious proportion of the head and body. This method comprises mainly two parts: landmark detection to detect the key points of the model head, and image warping for head size adjustment based on the key points detected.

Landmark detection. Landmark detection entails locating the center point of the model's head. Based on this location, the model's head size can be adjusted by image warping. As shown in Fig. 2 above, we take the real image output by StyleGAN as input, the face key point detector will detect and output key points of the model's face in the image. We can then find the center of the head by reference to the index of the key points, draw a suitable radius with the center as the center, and frame the head area of the model.

Image Warping. After detecting the head region in the image, the image warping algorithm [10] will adjust the size of the head according to the obtained circle center and radius. Specifically, with the center of the head as the center point, the effect of adjusting the size of the head is achieved by shrinking the head area inward or outward. As shown in Fig. 3 below, assuming that the center of the known head is $O(x, y)$, the radius is R , the current coordinates of point A are (x_1, y_1) , and the input scaling intensity is I . The coordinates of the reduced target position $B(x_d, y_d)$ of pixel A can then be obtained by formulas (6) and (7).

$$\text{dis}^2 = (x_1 - x)^2 + (y_1 - y)^2 \quad (3)$$



$$k_0 = \frac{I}{100} \quad (4)$$

$$k = 1.0 - \left(1.0 - \frac{\text{dis}^2}{R^2}\right) \times k_0 \quad (5)$$

$$x_d = (x_1 - x) \times k + x \quad (6)$$

$$y_d = (y_1 - y) \times k + y \quad (7)$$

Fig. 3. Image warping in progress

3.5 Loss Functions

The training loss of pSp encoder follows [8], which includes a pixel-wise L_2 loss to constrain the similarity between the generated image and the original image, a LPIPS [21] loss L_{LPIPS} for preserving image quality, a regularization loss L_{reg} for encouraging the encoder to output latent style vectors closer to the average latent vector, and a recognition loss L_{ID} to measure the cosine similarity between the output image and its source. The total loss function is defined as:

$$L(x) = \lambda_1 L_2(x) + \lambda_2 L_{LPIPS}(x) + \lambda_3 L_{ID}(x) + \lambda_4 L_{reg}(x) \quad (8)$$

where $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ are constants defining the loss weights.

4 Experiment

4.1 Experimental Setting

Implementation details. We used the pSp encoder pre-trained on StyleGAN-Human as the feature extractor. The input size of pSp is 256×128 . The backbone of the pSp encoder is ResNet50. The StyleGAN2 pre-trained on the StyleGAN-Human is used for real image generation. The output size of StyleGAN2 is 1024×512 . In addition, the face detector and key point detector integrated into the dlib library are used in conjunction to detect the face key points. The face detector is used to obtain the face bounding box, and the key point detector is used to detect 68 key face points. We chose the 29th key point as the face center and set the face radius to 100. The scaling intensity I is set to 15 for head-body ratio adjustment.

Evaluation. We conducted extensive experiments on the FSRI system using sketch images of varying degrees of complexity. The sketch image dataset used for evaluation was created by us and was divided into 3 levels according to the complexity of the sketch image. As shown in Table 1 below, the complexity of the sketch image is divided into three levels: A, B, and C.

Table 1. Three levels of sketch complexity.

	Sketch	Single Color	Multiple Colors	Print	Model
A	✓	✓			✓
B	✓		✓		✓
C	✓		✓	✓	✓

Of these levels, the sketch image at level A is the simplest and contains only a single color. This level is used to evaluate the ability of the FSRI system to translate the clothing shape and a single color in the sketch image into a real picture. The sketch image at level B contains two or more colors, and is used to evaluate the ability of the FSRI system to translate the color of the top, bottom, and shoes based on the translation of the clothing shape in the sketch image. The sketch image at level C is the most complex, including as it does multiple colors and prints. This level is used to evaluate the translation ability of the FSRI system for print. The colors of the sketch image come from Pantone color of the year 2011-2022. The specific colors and names are shown in Fig. 4 below.



Fig. 4. Pantone color of the year 2011-2022.

4.2 Experimental Results

We conducted extensive studies to determine and demonstrate the effectiveness of the proposed FSRI system in terms of: i) translation ability for a single color sketch image, ii) translation ability for a sketch image with multiple colors, and iii) translation ability for a sketch image with multiple colors and print patterns.

Translation Ability on Single-Color Sketch Image. The translation results of the FSRI system for single-color sketch images are shown in Fig. 5 below. It can be seen that, overall, the real image generated by the system is very close to the sketch image.



Fig. 5. Examples of sketch images at level A and corresponding generated results.

Specifically, for the model in the sketch, the FSRI system generates a person with a similar face shape, hairstyle, and body shape to simulate the model in the sketch. In terms of details, our system has achieved relatively accurate translation of the attributes of the clothing in the sketch, such as the length of the sleeves, the collar shape of the clothes, the length of the skirt, the width of the skirt, the width of the pants, and the shape of the pants. Finally, our system can accurately extract single colors in sketches and produce corresponding real images.

Translation Ability on Multiple-Color Sketch Image. In The sketch image selected was divided into two categories according to whether the color difference between the upper and lower parts was obvious. These two kinds of picture and the corresponding generated results are shown in the first row and second row respectively of Fig. 6 below.



Fig. 6. Examples of sketch images at level B and corresponding generated results.

It can be seen that, regardless of whether the color difference is obvious, the system can accurately translate the different colors of top and bottom clothing while retaining the ability to translate the model and clothing shape in the sketch image. The encoder of the FSRI system can successfully extract the different color features and shape features of the top and bottom, as well as the features of the model, and outputs natural and real generation results in the generator part.

Translation Ability on Multiple-Color-Print Sketch Image. In this section, we evaluate the FSRI system's translation ability on sketch images that contain prints and multiple colors by introducing different print styles such as stripes, florals, and pine prints to the top and bottom clothing. Examples of such images and their corresponding generated results are shown in Fig. 7 below. The results demonstrate that the FSRI system accurately identifies the presence of prints on the top, bottom, or entire clothing and generates prints that are similar in size and color to the original prints. However, the resulting prints lack details and appear as blurry patches. Despite this limitation, the experimental results indicate that the FSRI system can extract the attribute information and multiple color information of clothing from the sketch images while also capturing some of the print details.



Fig. 7. Examples of sketch images at level C and corresponding generated results.

5 Conclusions

This paper proposes the FSRI system for translating sketch images into real images. The system utilizes a pSp encoder to extract sketch styles and a StyleGAN pre-trained on a high-quality fashion dataset to convert the styles into real images. Additionally, a new image warping method is introduced to optimize the head-to-body ratio of the model. Experimental results on the sketch dataset demonstrate the effectiveness of FSRI. In future work, we aim to further improve the accuracy of the generated real images.

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Unorthodox Interventions – Fashion Garment Creation through Modification of FFF 3D Printing Processes

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Abstract. The aim of this research is to explore how we may negotiate the relationship between traditional craft methods and innovative technologies by integrating the programmed orderliness of digital fabrication machines with the poetry of organic human intervention. Applying interventions via modifications of G-code data allows us to trigger pauses at specific moments of the 3D printing process, allowing human agents to interact directly the printed artefacts-in-progress, imbuing them with additional properties and behaviours. This paper elaborates on the applications of these various intervention techniques (i.e. ductile insertion, substrate separation, textile reinforcement) onto a series of 3D printed garments, and aims to show how these techniques provoked the development of innovative fashion architectures that circumvents the limitations of conventional FDM 3D printing and surpasses the wearability and comfort constraints of SLS and SLA processes. From a wider perspective, the authors demonstrate the possibilities of a decentralised, democratized maker culture, wherein consumers see themselves as crafters and inventors, harnessing and hacking everyday technologies for exciting novel outcomes.

Keywords: additive manufacturing, fashion design, computation, digital fabrication, craft

1 Introduction & Background

1.1. Overview

Fashion has always been at the forefront of adopting new technologies, and this is especially the case for digital fabrication and computing technologies. As digital fabrication technologies such as 3D printing, computerized knitting and laser cutting are becoming more accessible, usable and reliable fashion designers are becoming increasingly fluent with the software and digital tools to interface with these methods of fabrication.

Opportunities to apply 3D printing in the fashion industry have long been identified (Scott et al., 2012; Sun & Parsons, 2014), and fashion designers were quick to capitalize on the potential benefits of these new technologies in their own practice (Delamore, 2004). No longer limited to the fabric-based output of sewing and embroidery machines, designers began to harness additive manufacturing to fabricate garments with three-dimensional solid forms and in materials of varying physical properties. These technologies enable designers to translate digital models into physical volumes without being encumbered by manufacturing complexity, while reducing the manual labour required (Sun & Zhao, 2017). The technologies' versatility and convenience have proved attractive to designers and makers, justifying its growing popularity.

The focus of this paper is the design processes used to develop garments in the fashion collection titled, “Mindful Intersections: Charting the Course Less Travelled”. This collection was the first runner-up in the “Singapore Stories” fashion design competition held in October 2022 at the Asian Civilisations Museum in Singapore. Designed and developed by the authors, this was the only collection making significant use of computational methods and digital fabrication techniques in its creation. Furthermore, several of these techniques used were novel in their approach, and this significance warranted the documentation of these techniques as contributions to the body of knowledge of computational fashion design.

The inspiration for this collection was the Astrolabe, one of the earliest analogue mathematical devices employed by Muslim travellers from the 8th to the 17th century. As one of the most important scientific instruments for maritime trade, it expanded trade beyond borders and greatly increased intercultural contact. By measuring the positions of sun and stars, the astrolabe can give many kinds of information, such as latitude, estimations of time and predictions of future celestial events. Furthermore, the astrolabe can be used to derive elevations of monuments and mountains, and identify the direction of the Qibla for Muslim prayer. (Britannica, 2019; Poppick, 2017)

As this design competition was based in Singapore, the collection also served as a commentary of the island nation’s heritage as a global, multicultural cosmopolitan port city. It reflects Singapore’s interconnections with the world and the constant flow of people, practices and relationships. Together with nautical elements, these features provided the inspiration for visual motifs. In the spirit of innovation and bold experimentation, the authors in developing this collection explored novel methods of fashion creation using digital fabrication. This paper will focus on the development of three of the six garments (see Images 1, 2, 3 below), as these relied heavily on innovative interventions of the Fused Filament Fabrication (FFF) 3D print process.



Images 1, 2, 3 (left to right). Three garments to be discussed from the collection, titled “20:31”, “11:42” and “18:48”. Models: Yvonne Sashirekha, Denissia Li, Mohana Prabha.
(Image credit: Singapore Fashion Council)

1.2. Additive Manufacturing for Fashion

Additive manufacturing (AM) produces tangible artefacts from intangible digital data, through a process of layered material deposition. This process dictates both the artefact form as well as its

properties, and the latter can be affected by material properties of the part as well as the settings of the equipment (Thompson et al., 2016). The process is inherently additive, with materials being added to form an artefact. This contrasts with the subtractive manufacturing process, in which cutting tools remove matter from a stock of raw material, AM is widely regarded as efficient, more versatile, and less complex than traditional fabrication processes reliant on machining.

Amongst existing examples of 3D printed, computationally designed garments, there are many that stand out due to their initial impact and resultant influence in the 3D printed fashion field. The first notable example was classically trained fashion designer Iris van Herpen, who brought the concept of additive manufacturing into high fashion consciousness with the debut of her 3D printed Crystallization dress in 2010, designed in collaboration with architect Daniel Widrig (Pallister, 2014; van Herpen, n.d.). Since then, most of her collections from 2011 to 2021 incorporated 3D printing as part of their fabrication toolkit, either directly using printed pieces as parts of the garments, or as parts of the fabrication processes themselves (i.e. using 3D printed moulds to cast garment components). Additionally, many of these collections were outcomes of cross-disciplinary collaborations between a classically trained designer such as van Herpen, and Computational Design specialists, such as architects Isaïe Bloch, Julia Koerner, Neri Oxman and Philip Beesley. Other creative partnerships were formed in that period, for instance between designer Anouk Wipprecht and Niccolo Casas (Boorman, 2014), as well as fashion collective threeASFOUR and architects Bradley Rothenberg (Thimmesch, 2015) and Travis Fitch (McKnight, 2016).

Designers such as Danit Peleg and Maria Alejandra Mora-Sanchez were able to develop fully printed garments using FFF technology (Kim et al., 2019). Additionally, Italian designer Chiara Giusti used the same technology to print plastic filaments on stretched fabric for creative visual effect (Chaudhari, 2020).

Even so, there are many barriers to the adoption of additive manufacturing processes in garment making. Of these barriers this paper will highlight two that directly impacted the development of our 3D printed collection. We will propose solutions to address these challenges in this paper.

3D printed materials and wearability

Among the various additive manufacturing technologies available, the authors focused on using Fused Filament Fabrication (FFF) to develop the three garments.

In this process, raw thermoplastic feedstock filament is melted and extruded through a nozzle, which deposits layers of solidified material to form the printed shape within the printer's build envelope. The rigidity of printed form depends on both the physical characteristics of the feedstock, as well as the design of the printed piece. For example, using thermoplastic Polylactic Acid (PLA) or Acrylonitrile Butadiene Styrene (ABS) filament on FFF printers will result in rigid prints, while Thermoplastic Polyurethane (TPU) filaments of low shore hardness can be used to create pliable, flexible results. Designing objects composed of thin walls or branches means they will have reduced stiffness, and so have a greater capability to bend and deform.

To improve a garment's wearability, it should be designed to be lightweight and accommodate the wearer. In the context of AM fashion, this means the garments should have the capability to flex and conform to the wearer's body and to achieve these outcomes means either using a pliable

material (i.e. TPU) as feedstock or ensuring that the structure of the garment incorporates hinges or interlocking units for movement. For this collection, the authors chose to use TPU as the main feedstock for the 3D printed portions of the garments.

Long completion times for additive manufacturing

There are many factors contributing to the length of time taken to complete a 3D print job. Due to these, there is a common impression that additive manufacturing is a relatively slow endeavour unsuited to the demands of industry.

One major contributor to long print times in this exploration was the decision to use TPU as feedstock. Due to the relatively low Shore hardness of TPU, its softness constrains the speed at which the printer nozzle can move. Setting the movement speed of the extrusion nozzle too fast risks deformation of the print and clogging of the extrusion mechanisms. Furthermore, the time required for extruded materials to cool and solidify in an FFF process dictates a minimum speed at which a print can be successfully executed; any faster than that and the material will warp, or layers of print will fail to adhere to each other satisfactorily.

In the context of AM garment design, printing of shapes with organic silhouettes that conform to the wearer's body is a common design convention, as can be seen in examples such as the 3D printed nylon garments created in the collaboration between designer Iris van Herpen and architect Daniel Widrig for the Crystallization collection in 2010 (Pallister, 2014; van Herpen, n.d.).

Using technologies such as Selective Laser Sintering to render these forms exemplifies the benefits of the SLS process, with its minimal feedstock wastage and negligible impact on print times. However, it is not as efficient to print such organic forms on FFF machines, as these forms tend to have large areas requiring support structures and occupy more layers within the print envelope. This means more material being used as support structures and then being discarded, and longer print times to render both support structures as well as taller printed parts.

Unorthodox innovation for FFF processes

Concerted cooperation and effort are required of the companies in the industry and of end-users and adopters to nurture and maximise the impact of these technologies in the field. These companies are responsible for the development of printing technologies to increase their reliability and capabilities, along with formulating feedstock with a wide enough variety of physical characteristics to suit the end-users' requirements. End-users, especially designers and practitioners, play the important role of encouraging adoption of additive manufacturing through showcasing creative applications of such technologies through their own work, as well as devising novel methods of using 3D printing unanticipated by manufacturers.

It is this notion of unorthodox innovation that will be highlighted in this paper, as the authors sought to address the abovementioned challenges of FFF 3D printing for fashion garments.

2 Process Interventions

Besides the use of TPU as the main material, another goal of the authors was efficiency; to minimise print time and material use as much as possible. Thus, instead of printing the entirety of the garments as three-dimensional renditions, the patterns were printed on individually.

Furthermore, this collection provided the means for exploration of ideas in 3D printing, on how we may intervene with the FFF printing process to achieve novel outcomes beyond the intended parameters of the technology. This section will elaborate three such interventions: Ductile Insertion, Substrate Separation and Textile Reinforcement. These interventions were devised to work in tandem with the printing of flat TPU patterns, to enable them to successfully deform and be assembled into the three-dimensional configuration as a wearable garment.

To successfully carry out the following interventions, it was crucial the printing system used allowed print operations to be paused at specific heights. For this collection, once the G-code files for each flat pattern print were generated by the slicing software, the authors modified the files to include pause instructions at appropriate junctures to carry out the interventions.

2.1. Ductile Insertion

The natural elasticity of the TPU will cause our flat patterns to spring back when deformed. Normally when the patterns are attached together, the tension of the seams ensures the patterns do not spring back. However, on some areas of the garments, the designers sought to incorporate an element of moldability so that the shape of the garment can be customised. To achieve this, canal-like cavities were computationally generated along some of the pattern edges (see Image 4 below). The authors intervened by pausing the operation at specific layer heights to allow the installation of steel wire within these cavities. In continuing the print, TPU material is extruded on top of the wires, effectively hiding them from sight and creating a seamless appearance (see Image 5).



Image 4. Channel for wire insertion as seen in slicing software. (Source: author)



Image 5. Steel wires hidden within these sewn prints help support the sculptural form of the garment.
(Source: author)

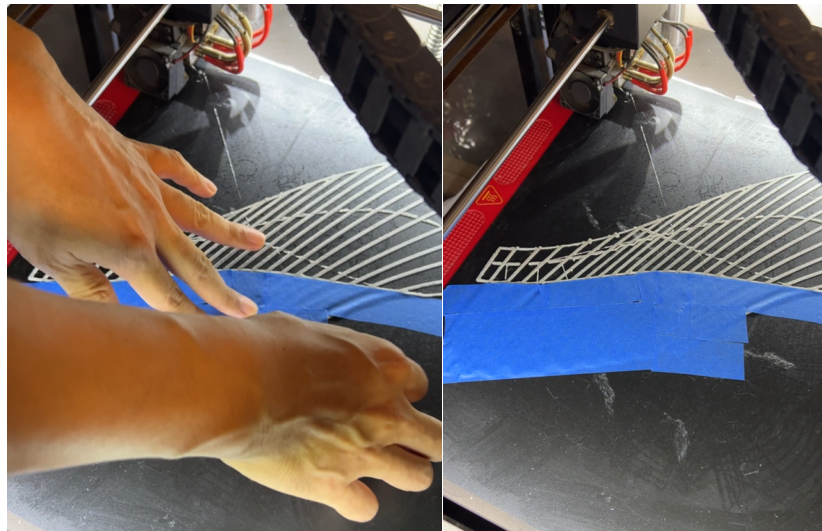
2.2. Substrate separation

Molten TPU extruded from a printer nozzle adheres very well to parts made of TPU on the printed plate. This reliable adhesive quality is a benefit of the medium, but the authors sought to negate that to form structures that cannot be easily rendered otherwise. To achieve soaring, spike-like structural elements (see Images 6, 7, 8 below) through conventional printing strategies would expend a significant amount of material on support structures, and yet would not achieve a satisfactory, smooth finish due to the non-isotropic nature of the process (Thompson et al., 2016). It is necessary to intervene and introduce a separation barrier between the structures to be bent upwards to form spikes, and the base layers underneath. To do so, the prints were paused before the spike structures began to print, and blue painter's tape applied over the areas of separation. (see Images 9,10) This tape is suitable since extruded filaments adhere easily to its surface (TapeManBlue, n.d.).

Once the flat patterns were stitched together, spikes from neighbouring segments were fused together by hand using a 3D printing pen.



Images 6, 7, 8 (clockwise from left). Spike-like structures achieved through substrate separation technique.
Models: Yvonne Sashirekha, Denissia Li, Mohana Prabha.
(Source: author, Singapore Fashion Council)



Images 9, 10. Substrate separation using adhesive tape. (Source: author)

2.3. Textile Reinforcement

For the third intervention, the authors took the lead from existing practices and experimented with 3D printing on fabric. Similar to the previous interventions, by strategically pausing the print, designers were able to insert mesh fabric for these garments between the second and third layers of a 0.25mm layer height print, and two to four more layers were printed subsequently above it. Additionally, the G-code was set to skip printing the layer where the mesh fabric would reside, providing spatial allowance for the fabric and minimizing compressive stresses on the print, which might cause the synthetic fabric to melt.

In this way, the resultant flat pattern print remains thin and flexible, but gains the sturdiness and strength of the mesh. Moreover, these meshes allowed the flat patterns to be stitched and sewn together akin to traditional garment making methods (see Images 11, 12).



Image 11 (left). Flat patterns printed with inserted mesh fabric. **Image 12 (right).** Pattern pieces being sewn together. (Source: author)

3 Discussion and Future Work

In describing the applications of the above intervention techniques (i.e. ductile insertion, substrate separation, textile reinforcement) onto a series of 3D printed garments, the authors have demonstrated the creation of innovative fashion architectures that circumvent the limitations of conventional FDM 3D printing by drastically reducing the print time required to render similar three-dimensional structures through unwrapping and reassembly processes. The processes described minimized the consumption of material by doing away with the need to build wasteful, one-off support structures.

Additively manufactured garments used to be uncomfortable and restrictive to wear due to the rigidity of materials commonly used in large scale STL printers. However, the series of intervention strategies proposed above resulted in improved garment flexibility that surpassed the wearability and comfort constraints associated with SLS and SLA processes, and thereby demonstrated the viability of FFF print processes in fashion garment creation. The models wearing dresses from this collection provided anecdotal feedback to the authors, reporting that the garments felt comfortable to wear, and allowed considerable freedom of movement, especially at the shoulders and elbows. The models were able to raise their arms at least 90 degrees, pose and walk up the stage stairs. Our approach permits the manufacture of viable 3D printed garments, and we recommend that future investigation should focus on rigorously quantifying reported improvements in comfort levels and wearability.



Bending of 3D printed sleeves.

Image 13 (left). *"18:48"* worn by Mohana Prabha. **Image 14 (right).** *"20:31"* worn by Yvonne Sashirekha.
(Source: Singapore Fashion Council, author)

In demonstrating this potential for innovative outcomes in using FFF technology with unorthodox interventions, the authors propose that affordable, widely available digital fabrication processes can produce feasible outcomes on par with more expensive, inaccessible alternatives, and everyday technologies can be creatively applied for exciting novel outcomes.

Media Link

<https://www.dropbox.com/sh/e77ph9ya0iv0kms/AADQGIXe7vGoe1cLJp9ThoDua?dl=0>

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Creating an environment to fight the fashion system: Fashion Tech Farm

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Abstract. We describe here the design and implementation of the Fashion Tech Farm (FTF), which aims to drive sustainable innovation in garments and fashion [1]. We describe our goals, design principles, and the implementation. The design principles are rooted in an understanding of the fashion system, open networks, and entrepreneurial thinking. After four years of work on the FTF, we review three projects to evaluate how far the work has achieved the main goals and how our design principles are developing.

Keywords: Fashion design, enterprise design, innovation, e-textiles.

1 Introduction

Spaces like FabLabs and MakerSpaces [2, 3] have become centers for design research into textiles, often collaboratively with academic, societal, and commercial partners. Most of these are supported by public or private funding; yet many spaces close once the external funding has ceased [4].

We present a case from the perspectives of design researchers and designers where the design goal is to re-inject innovation into the fashion system by setting up a new kind of enterprise. We do this from a first-person perspective in that our reflections upon the process as design researchers bring insight from an action research perspective, a process recently shown to be important in design research [5]. This aim is expressed by Todeschini et al. when they write "*the technological innovation in garment materials and manufacturing processes enable a new way to think about business models that go beyond scale economies and scope advantages generated by fast fashion.*" [6]. Fashion and technology have been intertwined since ancient times [7-9]. Yet, in the landscape of innovative spaces, it is hard to find examples that are at once commercially viable, collaborative, and sustainable.

Despite the rise of fast fashion in the past decades, innovation in the field is somehow lost. The fashion clothing and textiles industries are complex and multi-stakeholder [10, 11]. Yet recent design research has shown that design often emerges from everyday practice [12]. The process itself is as important as the outcome [13]. The fashion industry expands with harmful side effects because of globalization. McKinsey [14]: "Globally, the fashion industry is responsible for around 40 million tonnes of textile waste a year, most of which are either sent to landfill or incinerated." In practice, many companies refuse to share their process in the name commercial protection, yet design research has shown the value of sharing samples and the design process [15]. In a framing of designing a financially viable, collaboratively innovative, and sustainable-minded space, we describe the context, design goals, design principles, implementation, and example projects of FTF. We reflect upon the projects to understand how the implementation works, and whether the principles are feasible and effective.

2 Situated Context (Context of Design)

Recent research has highlighted the importance of the context and situation of design [16]. Designers often look at an artifact, how people use it, and for what purpose [17]. Auto-ethnographic research [18] is important when reflecting on an artifact like a dress, but as this is an institute the authors take a poly-ethnographic approach as situated designers and design researchers in the institute. The way we describe and evaluate the projects borrows from the duo and trio-ethnography argued by Dejardin et al. to produce valuable meaning in dialogic reflection [19]. Our situation and context are the actual FTF in Eindhoven. We look at three project examples as artifacts in order to reflect on the situation of the FTF as a designed environment.

3 Our Design Goals and Design Principles (FTF framework)

The design goals of FTF are 1) to establish a stable profitable business, 2) develop an ecosystem of designers around it, and 3) plant seeds for a truly innovative fashion tech system. Here “profitable business” means generating enough income to sustain a family, grow the business, and involve others. The design principles are rooted in a modern understanding of the fashion system, open networks, and entrepreneurial thinking.

The fashion system. The Fashion system is under pressure and out of control [14]. Therefore, our first design principle is: Not to play by the rules of this fashion system and that means no attractive launch of another label. Our second design principle is: To introduce innovative technologies in projects and products (that means no projects which are just more of the same). We value tactility, hands-on prototyping, and user focus to make desirable functional products from our first-person experience [20] in the team.

Open Networks. Open source arose in software engineering [21]. Its principle is that knowledge, code, and design patterns are shared as much as possible. The next principle is therefore to connect people and establish and grow networks based on mutual respect and trust.

Entrepreneurial principles. First: Real paying customers. Next: Avoid too large upfront investments, which come with financial risks and may thus lead to loss of control. It is preferred to grow slowly, reinvesting profits into the business and into the network. With that comes the last entrepreneurial principle: to share profit amongst all the individuals in the collective.

4 Implementing FTF

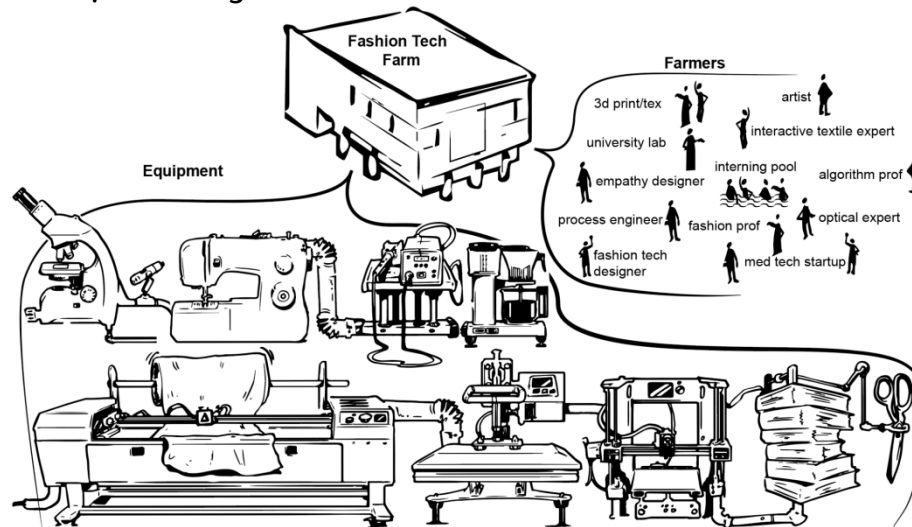


Fig. 1. FTF, its 'Farmers', and its tools. Illustration by Ruud van Reijmersdal.

Fashion Tech Farm is located in the Brainport region, Eindhoven, The Netherlands. The annual Dutch Design Week provides a platform for exhibiting to an international design public. FTF is more than a single company. It is home to a number of small companies, researchers, artists, engineers, interns, and residents, ranging from established to start-ups and young talents founding their first companies [1]. We call all these persons and entities "Farmers". The FTF workspace is a physical structure, not virtual, based on our experience that trust grows when people meet physically. Acts of making together, eating together, meeting visitors, etc. cannot be done virtually. Shared tools are chosen to stimulate digital ways of physical prototyping and construction, including a large 3D printer, sublimation printer, and laser cutter [22].

5 Example projects of FTF and Experiences

Three large and multifaceted projects initiated and executed at FTF were selected to report here as exemplars. We used them as carriers for collecting experiences and reflecting on the operation of FTF.

5.1 Sustainable Medical Gown (SMG)

The Sustainable Medical Gown [23] assignment was set by the national government and aims to reduce medical waste. At FTF a social scientist, an LCA expert, a business developer, a textile circularity expert, an emphatic designer, a pattern maker, and a UV-C disinfection expert (former intern) developed with by-wire.net [24] an isolation gown + system of use that can lower the environmental impact by 92% compared to the current practice of using disposable gowns.

History. When the Covid pandemic started, the emphatic designer and by-wire.net redesigned an earlier prototype of a facemask, achieving first sales five days after the first prototype. Selling thousands of facemasks, the team learned about user preferences and design acceptance. A national call to reduce medical waste occurred as medical waste piled up. We responded to the call, based on the facemask project and the innovation capacities of the larger FTF team.

Learnings. FTF was required to produce rapidly 150 gowns for user testing. The available FTF team was notably over-skilled to run the (small-scale) production. It was only because of solidarity and the mutual trust in the FTF community that the production part of the project was successfully completed. We became conscious of the lack of persons excelling in real production in the FTF.

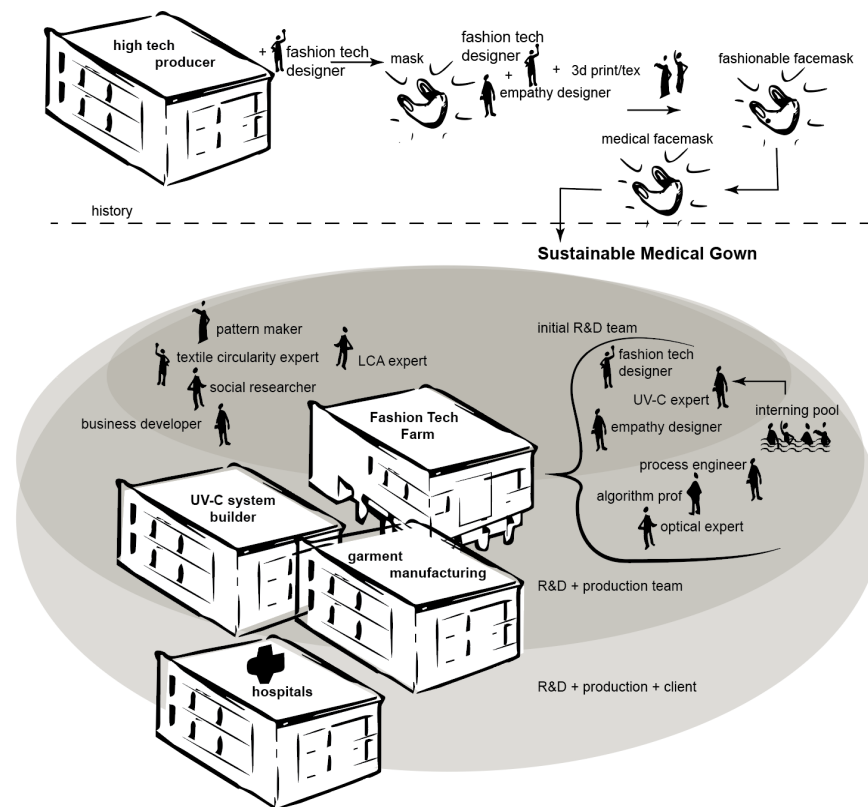


Fig. 2. Visualization of FTF stakeholder involvement for the SMG project, showing how the network of Farmers was formed, expanded, and was leveraged. The shading of the three areas corresponds to the expanding network during a project. In many cases, selected parties from the expanded network are invited to become farmers later.

5.2 Wearable Phototherapy for Jaundice (WP)

WP is a project by the FTF Med Tech startup Bilihome [25] developing a solution to support parents and newborns with jaundice in the first weeks of life. The wearable device can be worn by the baby during breastfeeding, with skin-to-skin contact, while providing blue light therapy. The garments are both aesthetic and technological, appearing to be much like an ordinary baby jumper.

History. The employees of Bilihome used to work in the field of high-tech medical products. By-wire.net [24] worked on blue light applications and advanced baby goods for high-tech partners. At the beginning of this development (2019) the team was 3 people. Along the way more partners within and outside of the FTF connected to this development: Hospitals as clients and researchers for the testing.

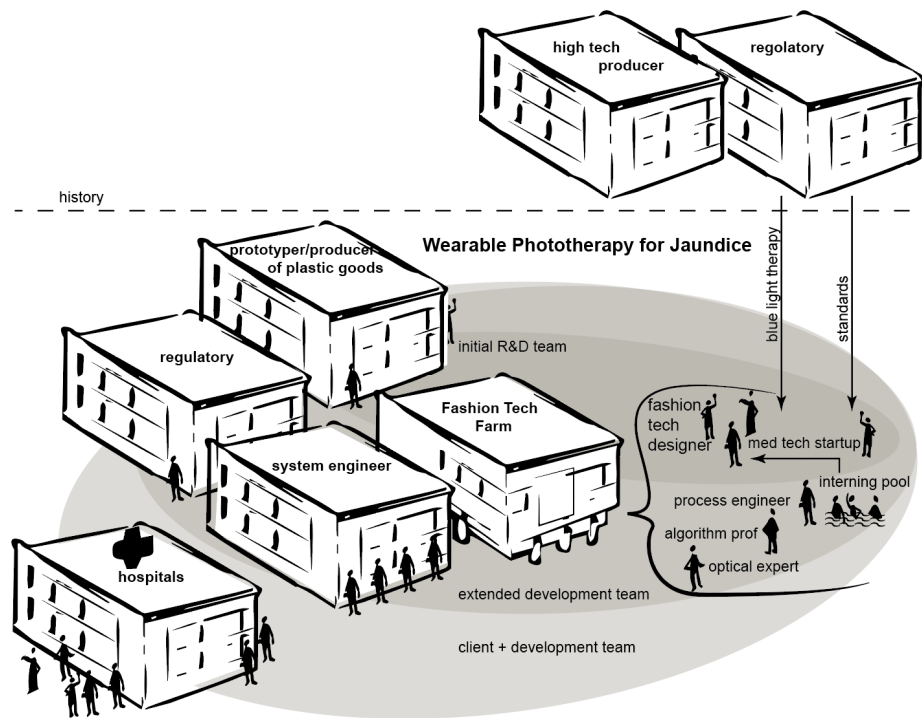


Fig. 3. Network visualization of stakeholder involvement during the WP project.

Lessons. The project began as a concept with a small and agile team (receiving a Red Dot Design award in 2020). The collaborative and sustainable practices of the FTF continued, but Med Tech developments require investments, Investors ask for patents, turning some parts of the project into a closed development (the Farmers seemed to understand). We learned about navigating through regulatory aspects as this product is defined as a medical device, and the expertise of the Farmers helped in that process. It was disappointing to find that sustainable challenges are more complicated than we thought because of the medical regulations.

5.3 Visual Identity By Experience (VIBE) [26]

By-wire.net was asked by a European consortium to research how wearables can motivate young people (genZ) to visit musea. 18 interactive vests and bodywarmers with integrated speakers and vibrators are developed and used for 9 days in a museum in Barcelona.

History. We co-developed the national ecosystem for printed electronics production (PE) since 2016. We decided to apply this printed electronics technology in this project and get a societally relevant and real test case for the robustness of this system.

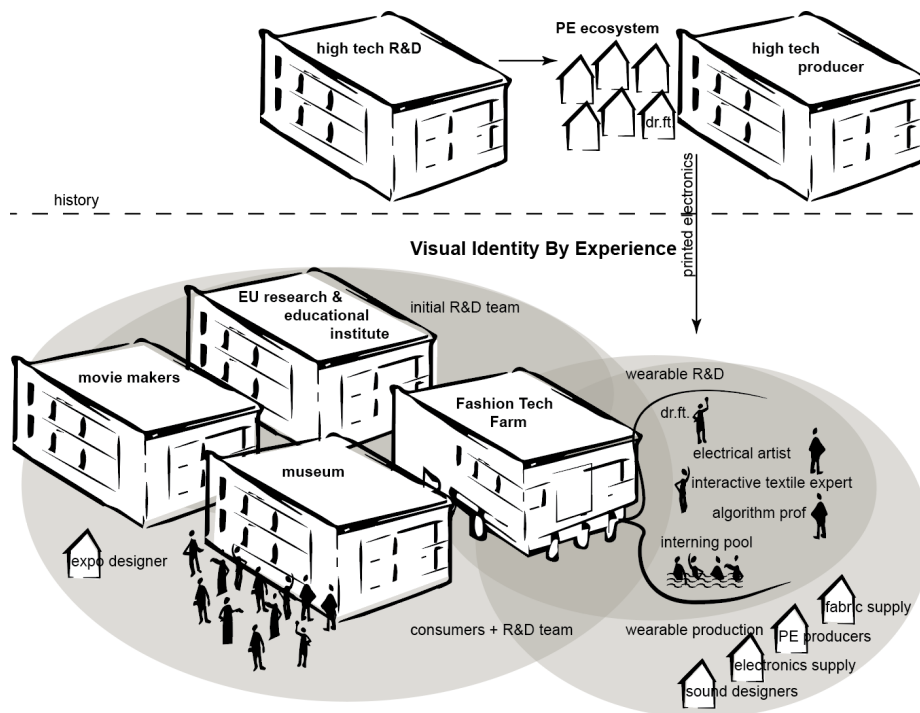


Fig. 4. Network visualization of stakeholder involvement during Visual Identity for Experience

Lessons. Looking back, we are critical as the wearable was mainly developed inside FTF, but there were problems in connecting to the music composers, the space designers, and the external communication team abroad. We were overly ambitious in using printed electronics sourced locally; the technology was immature and soldering backstage in the museum was needed to fix broken tracks. Owing to lack of time, the electronic effects were not in sync with the specially composed music. The public did not notice any of these problems, yet we look back on it as a stressful experience full of lost opportunities.

6 Evaluation and Reflection

As Farmers at the FTF, we offer a critical reflection on the FTF framework in action. Our analysis borrows from the duo- and trio-ethnographic methods as a poly-ethnographic discussion. The design principles of Section 3 can be seen as an idealistic way of working, aimed at contributing to long-term design goals. We make a distinction between general design principles and “our” design principles. The FTF of Section 4 is based on practical decisions, seized opportunities, and serious investments. Section 5 describes exemplar projects, how we experienced them. Looking back, we ask if and how:

1. the implementation facilitates the intended ways of working;
2. the design principles and implementation are effective for acquiring innovative interactive electronic textile projects; and
3. the projects reinforce the design principles and viability of FTF.

Our design principle, fashion system: *To not play by the rules of this out-of-control fashion system* has been respected. In SMG (1) the gowns are now being commercially offered to hospitals (still under negotiation). Similarly for WP (2) we created a business model where the device is bought by

hospitals and loaned to patients with insurance companies paying the hospital for the treatment. A national investors foundation supports the project: FTF and by-wire.net are negotiating for a scale-up project. The VIBE project (3) is an EU-funded project where by-wire.net was hired for the wearable. Museum visitors have free access to the use of the wearables. None of these three (or other FTF) projects originally had a goal to put profitable products on the market, yet the experience of the Farmers made this easier to achieve.

Our design principle, fashion system: The principle *to introduce innovative technologies* has been applied as follows. SMG (1) introduces UV-C cleaning as an intermediate local cleaning method to extend the lifetime of a gown. WP (2) combines blue light and wearables (romper). VIBE (3) integrated printed electronics of actuators in the museum setting. Although some of the technologies were known and validated, the combinations in these contexts are all new applications.

Our Design principle, fashion system. *To value tactility, hands-on prototyping, and user focus to make desirable and functional products:* All three development processes depended on hands-on textile prototyping, which goes beyond typical fashion system practice. SMG (1) included an extensive textile selection process and multiple cycles of user testing in six hospitals where nurses tested the gowns. WP (2) included an extensive textile selection process with chemical tests, multiple cycles of user testing, and user validation processes with 45 subjects divided from different target groups. VIBE (3) included extensive user testing with GenZ on the identity design process.

Design principle, open-source: *To share as much as possible.* SMG (1) is *almost* 100% open-source. We made a booklet, a video and put the full report and construction-related documents on an open website. This worked out positively as caregivers submitted voluntarily to participate in user tests. The “almost” refers to the design patent filed on the thumbhole, which we did because the funding-body wants projects to generate intellectual property (IP) rights – so we compromised. Fortunately, 99% of the projects’ achievements do not depend on the use of the specially developed thumbhole of the gown. WP (2) is half open as it is partially investor driven; the investors tend to favour IP approaches. Still, we tried to be open as much as possible, also to facilitate feedback gathering. VIBE (3) is open-source: the report is published on vibe-experience.com and the code on github. VIBE was presented to the public in the Dutch Design Week.

To connect people, establish and grow networks. The SMG (1) team grew during the development process. Interns became fully paid team members. Business developers became members of the core team. Well-established connections became stronger while the user test production had to be done. The WP (2) team grew slowly but surely from 3 to a team of about 20 persons and 50 supporters in the wider network. VIBE (3) was a loose international network, transformed into a formal consortium for the duration of the project. But the collaboration with the international community did not become stronger. We have learned a lot:

Entrepreneurial actings

Have real, paying customers. SMG (1) was an assignment for a national government based on a fixed amount of money and an accepted offer from the team’s side. WP (2) is an assignment for Bilihome based on an investor model with the hope of reaching a break-even point 4 years from now. VIBE (3) is EU-funded, so not really matching our definition of real, paying customers.

Avoid overly large upfront investments. The pre-investment for SMG (1) was to develop a project proposal based on the government’s aim to reduce medical waste plus an offer. For WP (2) there

was no pre-investment from FTF's perspective; on the contrary, the med tech startup pays rent for office/lab space in FTF, contributing to its economic feasibility. For VIBE (3) the pre-investment was needed to develop a project proposal based on the funding call.

Share profit amongst the individuals in the collective. The total SMG (1) budget is spread within the Farmer collective and community. WP (2) assignments are used to pay Farmers and enlarge the community. The VIBE (3) budget gave the opportunity to hire Farmers to execute jobs and strengthen the connections with suppliers. However, we also felt the tensions between the demands of funding bodies and investors and the Open Network design principles, as was to be expected.

7 Conclusions and Future

To assess our work to date, first recall our design goals: 1) to establish a stable profitable business, 2) develop an ecosystem of designers around it, and 3) plant seeds for a truly innovative fashion tech system. Regarding 1), the FTF has been operational for almost four years now, is economically stable and manages to support itself. However, return on investment is not yet comparable to industry standards. The building is expensive and keeping up with the sustainability goals to upgrade the FTF to be energy-efficient is difficult. The ecosystem of designers is strong, contributing demonstrably to the design communities in the Eindhoven region. Regarding 3), it is sure that FTF is planting seeds for innovation.

Does FTF address all problems of the fashion system? Todeschini et al. [5] present 15 drivers of sustainable innovation, five of which have significant overlap with the design goals and major activities in FTF: sweatshop free, (all our production is local), collaboration (the core of the FTF concept), zero-waste (for example the Sustainable Medical Gown), wearables (the VIBE project), and Slow Fashion (projects on innovative aesthetics). Being critical: it is only 5 out of 15.

The most important lesson is that the collaborative atmosphere and the open nature of the FTF are the main enablers of projects. This confirms the “emergence” argument of Gaver et al. [12]. We facilitate and encourage the ad-hoc improvised processes of the FTF. A second lesson is that we have to be realistic: we cannot directly address the totality of problems and troubles of today's fashion system, nor the problem of consumer waste. Economically, FTF is stable, but cannot handle independent big investments yet; there is a tension between the open-source design principle and the IP policy of some of the investors. Yet that tension is vital for innovation.

What is the academic contribution of this work? We refer to Mukendi et al. [27], who classify 465 articles on Sustainable Fashion, and find two main categories of research, viz. pragmatic and radical, but at the same time identify several important gaps for current and future research directions. FTF is radical in the sense of [27]. Mukendi et al. [27] write: “In lieu of being able to change the education system, the provision of places and spaces for development in these areas may fall on the third-sector of civil society, but studies investigating the role that could be played by third-sector organizations is presently lacking.” Mukendi et al. [27] also argue that: “Much SF research is undertaken in silos, however, by

crossing disciplinary lines, exciting new ideas may be introduced into the field.” In this paper we have shown that it is possible to create a non-school space for innovation, operating across disciplines. Moreover, we described and critically analyzed the working of FTF from a first person perspective.

Learning about our characteristics and our sustained belief in the strength of diversified creativeness and entrepreneurship, we remain confident in being able to improve the human context in future fashion production.

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03/

Innovation in Product and Service Design

Disappearing Stitch: Exploring e-textile design for disassembly

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Abstract. E-textiles combine electronics and textiles, making it difficult to recycle them due to the inherent difficulties already associated with their constituent parts and the tight integration of electronic components and textiles. In order to enable circularity in e-textiles, components need to be easily removable from the textiles. This paper addresses the disassembly of textiles integrated e-textiles, by exploring stitching techniques that permit e-textiles to be designed with efficient disassembly in mind. This paper presents the inquiry into designing e-textiles for disassembly. The disappearing stitch project demonstrates how the e-textile design can leverage existing textile technologies to achieve circularity and optimisation of material recovery, allowing conductive threads and electronic components to be re-used.

Keywords: e-textiles, embroidery, sustainability, disassembly

1 Introduction

Sustainability is a concern within e-textiles (electronic textiles), as it is in many areas of everyday life. The fashion and textiles industry has a significant negative environmental impact, which is being tackled by industry and research organisations (Mistra Future Fashion, 2019; WRAP, 2019). The integration of electronics into textiles compounds these problems, adding issues associated with electronics, such as the consumption of scarce resources e.g., metals, and contributing to increased waste through progressive technological obsolescence. E-textiles can be difficult to recycle due to the tight integration of electronics and textiles (Hardy et al., 2020; Köhler, 2013). Applying a Design for Environment approach to e-textile design is one means of addressing these issues. This is a multi-faceted approach that aims to address environmental issues caused by the production and/or disposal of a product, by tackling different aspects of design, such as Design for Product Recovery, Design for Product Disassembly, and Design for Recyclability (Fiksel, 2009). This design ethos has been seen in product design (Framework, 2022), as well as within research (Forst, 2020; Rahman & Gong, 2016).

The disappearing stitch project explores the use of removable stitch techniques to produce circular textiles-integrated e-textiles; that is, e-textiles designed with disassembly in mind. This work explored chain stitch, a sewing stitch that consists of intra-looping threads, typically used in decorative embroidery, to enable disassembly and sustainable reuse of materials.

2 Literature Review

2.1 Disassembly in fashion and textiles

Fashion and textiles are typically not designed for recycling and remanufacturing, therefore creating a circular economy in which waste can be reused in production is a challenge; a challenge that can be effectively tackled if the issue is considered in the product development process (Vignali et al., 2019). Clothing is largely non-modular in construction. It needs to be hardwearing, therefore attachment techniques i.e., stitching, are designed to be permanent. As such, the process of disassembling and recycling existing garments is time-consuming and inefficient (Pal et al., 2021). This contrasts with the situation for electronics. Electronics legislation, such as WEEE (waste electrical and electronic equipment) (UK Gov, 2021), provides motivation for designing electronics that can be disassembled and recycled since they must comply with standards. Modular garment design for sustainability has been explored (Rahman & Gong, 2016). While the modularity of the garment could increase product lifespan, the modular pieces suffer from the same issues of disassembly as conventional garments. It potentially adds a further burden to the recycling process due to increased fastenings in modular pieces. As such, although modularity can contribute to the Designing for Environment ethos, design for disassembly still would need to be considered.

Designing for disassembly in fashion and textiles can be tackled from different angles. From a materials perspective, dissolvable threads offer a solution that can integrate easily into existing production practices. These threads weaken under microwave radiation (Durham et al., 2014) or high heat (Resortecs, 2022), simplifying the disassembly process. However, the requirement for industrial microwave units could prove to be a financial barrier to adoption. From the perspective of e-textiles, high heat and radiation may not be a suitable disassembly method for textiles with electronics integrated into them.

Design for disassembly can be approached through innovative design. Designer Lee Mattocks (2022) uses an interlocking technique to join the pieces of leather bags without stitching or fastenings. Forst (2020) also used the principle of interlocking to tackle the challenge of recycling textile blends (mixed material textiles). The techniques combine textiles semi-permanently to achieve different material properties. While techniques based on interlocking materials are promising, they require hand assembly and material-specific properties such as a certain level of rigidity.

2.2 Designing for disassembly in e-textiles

Exploration into sustainable practice in e-textile design has been investigated from a system design approach, as well as product design. Closed Loop Smart Athleisure Fashion (Veske et al., 2019) is a collection of garments that monitor heart rate and respiration, and that approach sustainability through the design of the system. The garments are part of a lease and recycle system, with delamination as the means of disassembling the electronics from the fabric.

It is worth focusing on disassembly in the context of e-textile prototyping. Delamination as a means of disassembling e-textiles is utilised in the Rapid Iron-on User interface (Klamka et al., 2020), a system for easily prototyping e-textiles through iron-on components. The system consists of a specially designed rolling iron and components in tape form to allow the maker to draw on the conductive circuitry. While the iron-on system works well for the disassembly of the circuitry, the

rigid electronics may still need to be attached by stitches or snap buttons, which are difficult to remove from fabric.

The affordances of textiles techniques have been leveraged in e-textiles prototyping. Punch needling, a method in which yarn is pushed through the fabric with a punch needle has been used by Jones et al. (Jones et al., 2021) as a means of creating easily removable e-textiles circuitry. Mistakes in the circuitry can be easily rectified since the yarn can be easily pulled out. However, there are situations in which the technique does not lend itself to sustainable practice, and it is necessary to overcome its limitations. Wu and Devendorf (2020) developed a technique that allows woven e-textiles to be readily disassembled. In woven fabrics, namely fabrics woven on shuttle-less looms, weft threads (horizontal threads) are cut at the edges of the fabric, which means that it is difficult to recover a usable quantity of material. This limitation was overcome using continuous weft and doubled supplemental continuous warp (vertical threads), although production is limited to a hand-operated loom.

Common in the existing research on e-textiles disassembly is the use of what can be considered more manual textile craft techniques. The affordances of manual craft techniques have proven valuable in e-textiles development (Chen et al., 2021), as they allow for direct intervention with the material, which is especially necessary when developing textiles outside the realms of conventional design.

3 Exploring removable stitching

Stitching is prominent in e-textile research. Hand embroidery is often used in e-textiles for STEM teaching to create textile circuitry and attach electronic components (Peppler, 2013), while machine stitching allows for complex designs to be produced easily and reliably (Hamdan et al., 2018; Jo & Kao, 2021; Lenninger et al., 2013; Nabil et al., 2021; Rocha et al., 2022) using digital embroidery machines. Machine stitching and its role in the end-of-life of the e-textile product is an under-explored subject.

3.1 Chainstitch

Chainstitch (see Fig. 1 (Left)) is a technique that can be produced both by hand and machine, under the formal name BS 3870-1:1991, ISO 4915:1991 stitch 101 (British Standards Institute, 1991). It consists of intra-looping thread, whereby a loop of thread is held in place by the succeeding loop (British Standards Institute, 1991). It can be created using a sewing needle or using a fine hooked needle. This is called tambour embroidery and an advantage of tambour chainstitch embroidery is that it can be quicker to produce compared to forming chainstitch using a sewing needle since it uses a continuous length of thread, and the hooked needle doesn't have to pass completely through the fabric.

While the first sewing machines used chainstitch, chainstitch machines became less popular after 1900 and today chainstitch machines are primarily used for embroidery (Risley, 1973). Lockstitch, a stitch formed by 2 interlinking threads superseded chainstitch since it has the advantage of being strong and difficult to unravel. In contrast, a simple chainstitch unravels very easily if the end of the

stitch is not secured. It is this feature that this project takes advantage of. This project explored hand-produced chainstitch through tambour embroidery and machine chainstitch using a Cornely embroidery machine; a machine design dating back to 1865 (Risley, 1973).



Fig. 1. Chainstitch (Left), Moss stitch (Middle), Lockstitch (Right)

3.2 Other stitch options

Before chainstitch became the focus of this project, other stitches were examined in relation to their ease of removal. Chainstitch has considerable advantages not only due to its ease of removal but also because the thread can be removed intact, which is an important consideration since the aim of this project is to design for revalorization, i.e. recovery of materials for reuse (Fiksel, 2009, p. 70). A criterion was that the stitches could be produced on a machine as well as by hand, in the interest of scalable production. Punch needling and lockstitch were examined in addition to chainstitch, through a hands-on approach. Stitch samples were produced and disassembled, and the process was recorded and examined.

Punch needling can be produced by hand using a punch needle, a hollow needle with an eye. The same stitch can be produced on the Cornely embroidery machine; a Moss stitch (Risley, 1973) (Figure 1(Middle)). Punch needling is an easily unravellable stitch, but it is much less secure compared to chainstitch since it is essentially an unsecured chainstitch. Punch needling/Moss stitch would be impractical for an e-textile garment. As there is no intra-looping in punch needling, pulling a single loop anywhere along the stitch with enough force can unravel the stitches.

Lockstitch samples were stitched using a Bernina domestic sewing machine. Although lockstitch is difficult to unravel, it is not impossible to remove. Using the longest stitch setting, in this case no.5, made removal significantly easier. It is possible to pull one of the threads out, though the tension typically used to create a strong stitch makes this difficult. Forcefully pulling the thread can snap it. The removability is further hampered when the stitch follows tight bends and corners, as the fabric then ruches rather than allowing the thread to be removed (Figure 1 (Right)).

Chainstitch strikes a balance between the removability of punch needling and the security of the lockstitch. It can be unravelled with ease even when stitched into shapes with tight bends and corners, while only being unravellable if the final stitch is not secured. The stitch can be secured by threading the end of the thread through the last loop.

3.3 Resistance and thread usage comparison

It was necessary to check whether there were any disadvantages in using chainstitch from an electronics perspective. The resistance of the stitch and thread usage was examined for chainstitch and lockstitch. The conductive thread used was HC12 from Madeira. The thread weight is 235x2 dtex, with an advertised < 100 ohm per metre (Madeira, 2019). For this test, the lockstitch was stitched using a Bernina domestic sewing machine, with the conductive thread fed through the lower bobbin and a polyester thread used for the top thread. Stitch length 5 was used in these samples. For the chainstitch, the conductive thread was not used with another thread. It was not possible to vary the stitch length for the Cornely machine. For each condition, three 30cm stitch samples were produced and a mean average was calculated. The thread usage was calculated by unravelling the stitched sample after the resistance was measured. For the lockstitch, the thread usage measurement relates to the conductive thread only. The results are shown in Table 1 below.

Table 1. Resistance and thread use for chain stitch & lockstitch for HC12 (30cm of stitching)

Sample	Chainstitch		Lockstitch	
	Ohm	Thread usage	Ohm	Thread usage
A	10.7	124	20.8	31.5
B	13.2	137.7	19.4	31
C	10.8	140.3	18.6	32

The results were in line with expectations, with the chainstitch having a lower resistance over a 30cm length of stitching, compared to the lockstitch. However, the resistance of the lockstitch can be decreased by using a conductive thread for the top thread. The thread usage for chainstitch is higher compared to lockstitch, using approximately 4 times more conductive thread. However, this is not a negative point as the lower resistance is due to the higher thread use. The thread supplier recommends using more thread to lower the electrical resistance (Madeira, 2019).

4 Design inquiry: chainstitch for e-textiles

After determining that chainstitch was the most appropriate option for a removable stitch, the production process for circular e-textiles had to be developed. The assembly process for circular e-textiles was refined through a series of sensitising activities, which involved creating and disassembling several e-textile samples using chainstitch to identify areas of opportunity and concern. The repeated processes of construction and deconstruction allowed for the construction process to be refined and the effects of multiple cycles of material reuse to be observed. Three key elements of the circular e-textile construction process had to be considered: attaching rigid electronics, designing for disassembly, and designing for maximum material recovery.

4.1 Attaching rigid electronics

E-textiles often incorporate rigid electronics into the fabric, however it is difficult to use the Cornely machine to stitch electronic components since it cannot accommodate the components underneath the machine foot. Some solutions were considered, such as mounting the electronics to a fabric with conductive fabric tabs, in a similar manner to Buechley's construction kit for electronic textiles

(Buechley, 2006) prior to machine stitching. However, this would add additional steps to construction and extra bulk to the e-textile product. Therefore, combining hand-stitched chainstitch with machine chainstitch is a more appropriate option. The Cornely machine is used to quickly stitch the bulk of the circuitry. The ends of the machine stitch can be temporarily secured using a safety pin (see Fig. 2 (Left)), with excess conductive thread left to continue the stitch. At a later stage, the chainstitch can be continued through tambour embroidery (Fig. 2 (Right)), allowing the components to be stitched to the circuit.



Fig. 2. Left: Transferring chainstitch to tambour hook. Right: Chainstitching the component

However, there are some circuit designs in which using the chainstitch to attach the components is less convenient, such as the parallel circuit in Fig. 3 (Left). Since the distance between the positive and negative stitching lines is the width of the LED, it is easier to use standard stitching to join the LED to the circuit and the fabric. This stitching can be removed relatively easily using a stitch unpicker.

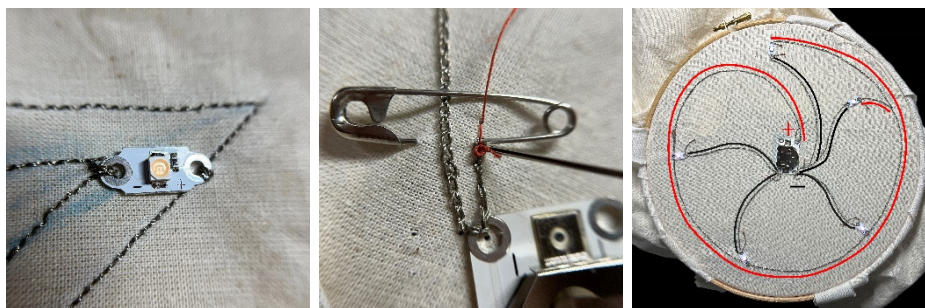


Fig. 3. LED stitched onto the circuitry (Left), Contrasting stitching (Middle), Parallel e-textiles circuit (Right)

4.2 Designing for disassembly

During the sensitising activities, the deconstruction process took place a few weeks after the samples were created to allow the author to forget the construction process and separate 'the assembler' from the 'disassembler'. The main issue found in the disassembly process was the difficulty in finding the end of the chainstitch to start the unravelling process. To address this issue, a contrasting stitch is used to indicate the end of a chainstitch. The tail of the chainstitch is pulled through the loop to prevent it from unravelling, while an additional stitch is used to both secure the loop and as a marker (Figure 4 (Middle)). The marker can be removed with a stitch unpicker, and the tail of the chainstitch pulled out of the loop.

4.3 Designing for maximum material recovery

To ensure that the recovered conductive thread from an old e-textiles piece can be reused effectively, the stitching of the circuit needs to be designed to minimise the number of short conductive stitching sections. Short lengths of conductive stitching are less useful for later reuse. In the context of simple illuminating e-textiles, using a parallel circuit design helps to this end, as there can be a long positive and negative main line from which the circuitry can branch out towards the components, as seen in Figure 4 (Left). It is difficult to avoid wastage entirely. While small segments of conductive thread are less useful for machine stitching, they may still be reused for tambour embroidery. However, the conductive thread becomes more frayed with repeated handling, making it more difficult to work with.

5 Proof of concept: Embellished Jacket

The e-textile design principles for disassembly developed through the design enquiry were applied to the embellishment of a denim jacket. The jacket (Figure 5) was embellished twice, with the previous chainstitch e-textile circuit disassembled, and a new circuit stitched in the same position. Electronic components, such as the battery holder and LEDs, and conductive thread were reused from the first design.



Fig. 5. Embellished Jacket, undergoing 2 design cycles

6 Conclusion

This paper has demonstrated how an existing textile technique can be used to address the urgent problem of e-textile sustainability. What has been considered a negative characteristic of chainstitch is leveraged in this study to help to make e-textiles an important part of the circular economy. The hands-on approach to design inquiry was important in developing an understanding of the affordances of chainstitch and how to integrate it into e-textile design for disassembly. This project has highlighted the value of employing handcraft to address design problems associated with the current limits of technology. There is potential to further explore chainstitch in e-textile design, particularly the aesthetic possibilities of tambour embroidery. As a technique that is typically used with beading and embellishments, it has the potential to create highly decorative circular e-textiles pieces.

Existing technology has been used successfully in this project though it is hoped that new technology can be developed that can encourage the adoption of the techniques outlined in this paper. For instance, combining chainstitch with digital embroidery technology could aid in its adoption in larger-scale e-textile production. This project focused on one aspect of circularity in e-textiles, disassembly. The e-textile assembly and disassembly processes demonstrated in this paper need to be integrated into a closed-loop e-textiles system to ensure that e-textile products are recycled.

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A Priori: Design Knowledge in AI

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Abstract. With the developments of AI and its introduction into the design processes, designers must question the ways in which to engage with this new technology. Contemporary discussions concerning the ways design knowledge engages with AI have taken an *a posteriori* perspective, where designers engage with pre-established models. This approach is limited by its expectation that a model is capable of performing in a designerly way. In this paper we conduct a research through design study in which we develop a novel AI that can annotate online user reviews for user need finding. From our study we show that design knowledge is instantiated at the outset in the development of AI. This means that an AI is developed with a perceived context. We conclude that *a posteriori* engagement with AI will be limited if designers do not also instantiate their design knowledge *a priori* in an AI.

Keywords: Research through Design, Artificial Intelligence, Design Knowledge, Natural Language Processing, Design Theory

1 Introduction

Since the 1960's computational support systems have been used by designers to aid the design process [1]. In current uses of artificial intelligence (AI), designers are confronted with algorithmic models that can generate innovative opportunities and ease the intense manual demands that come with a traditional design process [2-4]. The integration of an AI in the design process can take on many forms, from proposing novel design concepts through to obtaining unique data to expand the scope of design opportunities [5]. As innovations in AI continue to progress, designers will be at the forefront in questioning the role of AI in the design process and the tasks it will be involved with [6-11].

However, contemporary design discussions in this vein have primarily approached the integration of AI in the design process from a top-down perspective, superimposing design knowledge onto AI. In this respect, [6] for example, studied the effects of a design team collaborating with a pre-established deep learning AI by evaluating the performance, behavior and perceived workload when working through a design problem. Others [9], developed a shared shape grammar that allowed for both the designer and AI to communicate in order to produce human-level proposals. Though valuable in understanding how the designer can affect the ways AI will be utilized in the design process, the design knowledge only has an effect *a posteriori*¹ on the AI. In this sense the AI will be an intelligent collaborator, curtailing its output according to the design knowledge that incentivizes it, but, as [6] concluded in their study, the AI they used was limited in its capacities and ended up damaging the

¹ After the fact.

overall performance of the design team. It begs the question then, that without being instantiated from the beginning with design knowledge *a priori*², whether an AI can truly become a design-intelligent collaborator.

This paper will take a bottom-up approach to investigate where design knowledge is instantiated in an AI *a priori*. The importance of such an approach is its reformulation of the AI design relationship. Rather than an AI being an inevitable adoption to be optimized within the design process, we show that its algorithmic make-up is a design process in and of itself, demanding the adoption of designers. To achieve this, we conduct a research through design (RtD) study wherein we develop an AI model to perform user research that takes the design perspective into account. Specifically, we showcase the development of a natural language processing (NLP) model that is able to annotate online user reviews from products to identify users' needs. The model is able to analyze the users' sentiment levels and opinions about a product and its attributes, and is unique from previous models in that it captures this for both the explicit and implicit levels of the users opinion. This is important as users are not always explicit about what they need from a product and oftentimes leave feeling implicit.

The significance of using an RtD methodology is its allowance for the design of an artifact to become a research tool for the generation of knowledge [12]. The enactment of design activities plays a formative role in the generation of knowledge, depending on the professional skills of designers, such as gaining actionable understanding of a complex situation. The goal of this research is to expose where design knowledge is relevant in the creation of AI and how designers and researchers can navigate their questions and actions when assessing the collaboration with AI. In this paper we will first introduce the design scenario for which we are developing the NLP model. Secondly, we will describe the design process necessary to develop the model. Third, we will discuss our findings from the RtD study and propose theoretical considerations to inform the methodological design approaches to AI. We will conclude the paper with propositions for future work.

2 Design Scenario

The identification of user needs enhances the ability to innovate, enabling early product development phases that identify requirements for features [13, 14]. Online product reviews are becoming a critical step in enabling this phase, as they have accumulated an immense amount of user-generated information on many products and services. Recent market surveys show that more than 93% of customers' purchase decisions are influenced only by reviews [15], 77% of customers 'always' or 'frequently' read online reviews, and 89% of them are 'highly' likely to use a business that responds to all of its online reviews [16].

When dealing with a pure text-based database like online user reviews, the noisy and unstructured nature of the review data often hinders the ability of NLP models to extract valuable insights about user needs. Sentiment analysis has emerged as a key enabler for automated need finding as it allows for the extraction of opinions from a myriad of online reviews [15]. Sentiment analysis is the process of identifying the subjective opinion of an opinion holder (e.g., user) for a target (e.g., product attribute) from an unstructured text (e.g., product review) [17].

There has been an increasing demand for sentiment analysis as a unified method of analysis because of its ability to extract information from user reviews using meaningful annotations. Aspect-based sentiment analysis (ABSA) has the potential to provide the most fine-grained information from the

² Before the fact.

raw text of the user. Traditionally, ABSA employs a triplet extraction of the user reviews: *aspect*, *opinion*, and *sentiment* (AOS). Some researchers are expanding this task to include *category*, making the task become a quadruple extraction problem (ACOS) [18]. However, the AOS triplet and ACOS quadruple are limited by their ability to elicit implicit opinions and aspects of the user.

Among both extraction methods, the implicit opinion has been ignored or simply denoted as a “Null” label. User needs have the potential when fulfilled to create satisfaction, delight, or avoid user dissatisfaction. Users themselves though are often unconscious of these needs as they are difficult to discern, or omit them because they are viewed as prerequisite [19]. The neglect of the implicit expressions of the user omits a possibility for innovation and potential success of a product or a service in the first stages of its development [20]. The neglect of the implicit level in user reviews will additionally prevent the model from extracting necessary information that could lead to product innovation by anticipating the users’ needs.

The design scenario is as follows. We designed a novel annotation methodology that allows for the extraction of the implicit dimension of the user's review. We then collected annotation data where students annotate user reviews of shoes using our methodology. We then created a NLP model that is able to perform these annotations on a test set of shoe user reviews.

3 Designing the NLP Model

3.1 Designing the Annotation Methodology

[19] found that existing studies only extracted explicit aspects and opinion terms, while 44% of the time user reviews contained an implicit aspect term or opinion term. The proposal of the ACOS was meant to account for this lack of comprehension by previous extraction methods. For example, an annotation of the review, “I like the look and the velvet is great, but the velvet quality doesn’t hold up,” where *cushion* is the aspect term, *Material* is its category, *great* is the opinion on this aspect, and + is its corresponding sentiment, which gives [velvet, Material, great, +] as an ACOS label. Additionally, [NULL, Appearance, like, +] can be extracted, where the aspect term is implicit when talking about the look; and [velvet, Material, NULL, –], where the opinion term was implicit in the second part. The quadruple extraction allows for implicit levels in the review because, for example, if the aspect term is NULL, it can still be related back to the larger categorical ontology. The same is the case for the opinion term, where sentiment represents the higher level. The quadruple extraction though still does not effectively model the four subtasks together as the implicit aspects and implicit opinion still contain useful information. In our example review, the opinion is labeled NULL because no word is represented that is part of the models sentiment lexicon dataset, but as we have seen, the velvet’s durability was brought into question.

To augment the performance of the ACOS, we introduced the implicit *i* subtask. The ACOS_i quintet remains the same systematically as ACOS previously, where aspect, category, opinion and sentiment retain their previous function. Additionally, the implicit aspect (NULL) remains, as it indicates what is not said, but still retains meaning as it is connected back to the ontological categories. Now for the opinion text span, the annotation identifies whether it was a *direct* or *indirect* opinion. From the above example, “the velvet quality doesn’t hold up”, we now annotate [velvet, Material, quality doesn’t hold up (Indirect), –]. This allows us to retain the information from the opinion text span, while still tagging it as being implicit. This is advantageous as users' subjective opinions, if implicit,

still retain a wealth of subjective preference that can inform design decisions. Rather than neglecting 44% of subjective feedback as noted above, we can now retain 100% of what the users said.

3.2 Collecting the Annotation Dataset

To shift the annotation methodology into the footwear domain, a categorical ontology has been established. Previous work by a team of engineers and students created the first ontology lexicon [21]. The lexicon is a collection of shoe-related words and phrases that recurred most frequently in the reviews, and was later used to train a model for an ABSA AOS extraction. Because we were going to perform an annotation data collection task with ACOSi on user reviews, a team of designers first coded and categorized the previous lexicon from a new set of user reviews, according to a grounded theory methodology [22]. The goal of this open coding was to establish the categorical ontology of the shoe, to which the aspect terms would be fitted. This involved an iterative process that went back and forth between reviews and literature [1], [23] to derive a saturated sample of categories and subcategories representing the ontology of shoes based on user review data (see Table 1 below).

The combination is category#subcategory. Not included in the table because they are categories themselves are #Cost_Value, #General, and #Misc. The categories represent form (appearance), function (performance), and behavior (context_of_use). #General is for when the user review is too broad to be talking about anything specific, #Cost_Value is monetary relations to the shoe, and #Misc is for categories that we may have missed because they were not revealed during the coding.

Table 1. The categorical ontology of shoes and their respective subcategories.

Performance#	Appearance#	Context_of_Use#
General	General	Usage_frequency
Fit	Form	Use_Case
Comfort	Color	Place
Durability	Material	Review_Temporality
Stability	Shoe_Component	Purchase_Context
Functional_Applicability	Misc	
Misc		

The next step was to have students annotate the user reviews using ACOSi and our established ontology. There were 16 graduate students who performed the annotation task, 8 of whom were drawn from engineering disciplines, and the other 8 from design disciplines. In total there were 2,000 user reviews that were annotated twice by two different annotators, respectively. The 4,000 annotated reviews were then aligned by the team of designers for data consistency, making a new dataset of 2,000 annotated reviews. At the sentence level, the annotators would first annotate the aspect term in the sentence which is either a noun or a verb. This represents the objective target of the review sentence. The opinion span is the subjective portion of the review sentence and can be a word or phrase that directly or indirectly refers to the user's feelings about the aspect. These two categories are then connected together by their associated category and sentiment (see Figure 1 below). It is important to note that a review sentence can contain multiple aspects and opinions, and so multiple meanings can exist. In such cases, the annotators annotated the sentence more than once to capture the full content of the review sentence.

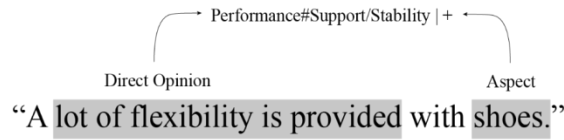


Fig. 1. Example of an annotated sentence.

3.3 Building the Annotation Model

Language models transfer words into matrices based on the probability-inner relationships in natural language expression. With the rapid growth of deep learning, researchers have begun to pre-training language models on large corpora. *T5*, short for *Text-To-Text Transfer Transformer* [24], is one of the strongest pre-trained language models, developed by Google AI Language, which uses transformers as a benchmark model structure training on massive datasets. Users of the model are required to ‘fine-tune’ these capable deep language models for their particular NLP task (e.g., by adding a single layer atop to deal with various tasks like classification and generation).

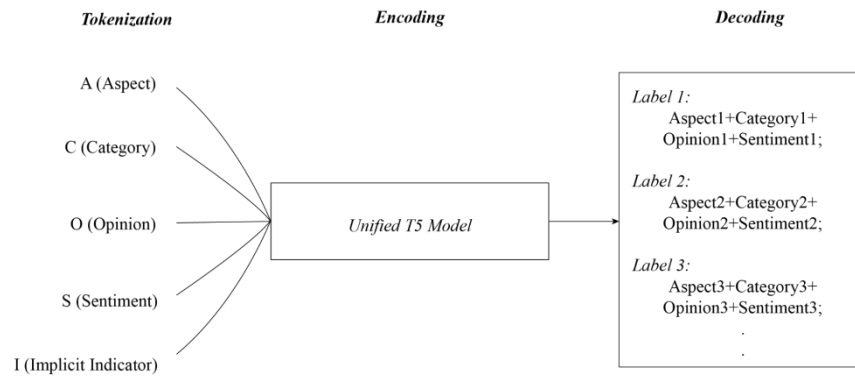


Fig. 2. T5 models three stage annotation flow.

The ACOSi extraction was performed with a T5 unified model in a generative manner. This model learns a joint probability of inputs and labels and uses the Bayes rule to predict the most likely label. This is preferred over language models such as BERT that perform extraction using discrimination by learning a direct map between input and labels. This is because we expect our model to learn how to annotate from the annotators directly and not just mimic them. The T5 model treats all text-related tasks in a sequence-to-sequence manner, that is, classification tasks such as sentiment analysis will output strings such as ‘positive,’ and ‘negative.’ The model even treats the regression task in this format by predicting the number of strings like ‘five’. The flow of the model includes three stages based on a standard encoder-decoder structure [25] (Fig. 2).

Tokenization. To feed the text input to the model, all the text needs to be transferred to input IDs; in the experiment, we use the T5 tokenizer which contains a 32128-sized vocabulary. As a multitask, multilabel problem, we add five special tokens to the vocabulary, ‘<label>,’ ‘<A>,’ ‘<C>,’ ‘<O>,’ ‘<S>,’ ‘<I>’ indicates the beginning of a label and different types of labels, respectively.

Encoding. To encode the input data, the T5 model encoder is a standard transformer encoder with 8 attention heads and 6 layers, and the hidden feature size inside the model was 768.

Decoding. The decoder's output is a generative format decoder, using a 6-layer and 8 head attention structure like the encoder, the decoder generates an autoregressive prediction, and every next prediction will be based on the encoder output and previous outputs.

Performance. The hyperparameter settings that produced the best results for the models generative process is as follows: Dropout rate: 0.2; Training epochs: 30000; learning rate scheduler: cosine learning rate scheduler; initial learning rate: 1e-4; Batch size: 16 reviews per batch; maximum input length: 128; maximum target length: 64; Beam search for candidates labels: 2; repeat n-gram size: 5. We provide three examples of generated annotation results.

(1) *"Bought them out of nostalgia. They almost look the same but the leather is not soft as before."*

Label1: (NULL, ContextOfUse#PurchaseContext, Positive, "Bought them out of nostalgia," Direct)

Label2: (NULL, Appearance#Form, Positive, "almost look the same," Indirect)

Label3: ("leather," Appearance#Material, Negative, "not soft as before," Direct)

(2) *"It is narrow and fits pretty well. However, the tread design traps mud and other debris which I then track into the house. After I started wearing this shoe, I notice bit of dirt and debris on the floor in places where I walk or sit consistently. This has never happen before so I quickly tracked the problem down to the small pockets in this shoes tread design."*

Label1: (NULL, Performance#Sizing/Fit, Positive, "narrow and fits pretty well", Indirect)

Label2: ("tread design", Appearance#ShoeComponent, Negative, "traps mud", Indirect)

Label3: (NULL, ContextOfUse#UseCase, Negative, "notice bit of dirt and debris on the floor in places", Direct)

Label4: ("small pockets", Appearance#ShoeComponent, Negative, "the problem down to the small", Direct)

(1) *"The Crocs I purchased for my grandson had to be returned. Unfortunately, they were defective because the back strap that fits, normally, around the back of the ankle was ridiculously short and did not fit around. Measuring them against another pair of the same Crocs he had that I wanted to replace, they were at least one inch shorter! So, regretfully, the pair was returned."*

Label1: ("Crocs", ContextOfUse#PurchaseContext, Negative, "I purchased for my grandson had to be returned," Indirect)

Label2: ("back", Appearance#ShoeComponent, Negative, "they were defective because the back," Indirect)

Label3: ("Crocs," Performance#Sizing/Fit, Negative, "Measuring them against another pair of the same Crocs," Indirect)

Label4: ("pair", ContextOfUse#PurchaseContext, Negative, "was returned," Direct)

4 Discussion

The design of the T5 annotation model identified the necessity for design knowledge at three stages. First, automated methods for sentiment analysis lacked the ability to go beyond the explicit levels of text. Work had been done to adopt the implicit levels of the users' language, but it neglected the wealth of information that was contained in the opinion text span. When reframed as a design task

to identify user needs, it became essential to identify as much information within the text as possible. User needs are relegated through reviews both explicitly and implicitly. This meant redesigning the ACOS quadruple extraction to include a fifth subtask to extract the implicit levels, but also retain the subjective language that contained a wealth of information. The designers had to determine the best way to capture and associate the aspect terms to opinion terms in order to determine the ideal relationship for extracting needs.

Second, it was necessary in the data collection phase to move away from the previous strategy of grouping categories with a high occurrence rate in reviews, and towards ontological categories that are representative of design knowledge of the artifact — its form and function, and also the context in which it is associated. The subcategories are partial and relegated to domain specificity, but are enabled by the larger ontological relationship that the user has with their product. Not all products are meant to adhere to comfort, but they do all maintain a performative dimension.

Third, the design of the T5 model requires the adjustments of its parameters to deliver meaningful annotations. Closely related to [26]'s *seeing-moving-seeing*, this involves the designers' ability to identify what they want to see. What may be optimal for a model may not be so for the designer.

From this RtD study of developing a novel annotation model we see design knowledge instantiated a priori throughout the development of an AI. To arrive at a more holistic sentiment analysis model for user needs than what came before, design knowledge dictated the decisions in each stage of the models development. The design knowledge of user needs broached the underlying framework of the NLP model, from the implicit ACOSi dimension to capture users' implicit language, to the ontological categories and fine-tuning of the model. Rather than rely solely on an a posteriori approach to incentivize a pre-established AI for design purposes, this highlights the necessity for designers to engage a priori in the development of models for design problems, e.g. user need finding. AI is very impressionable, but if not instilled with the knowledge necessary to augment its performance, it is limited to less than desirable design performance by not being able to fully capture the context in which it is to perform, e.g. the limitations of ACOS.

Design, therefore, needs to consider the integration of both perspectives when engaging AI. As discussed earlier, AI is limited in its performance for designers when engaged only a posteriori [6]. By developing the methodology and ontology in an AI, we see design knowledge present a priori. Top-down design knowledge is serial, incentivizing attentive modes for an AI, whereas bottom-up design knowledge instills perceptions and perceived contexts within the AI. Therefore, the effect that top-down communication can have with an AI is only as effective as the knowledge that it embodies a priori.

5 Conclusion

In this paper we conducted a RtD study of AI by developing a novel annotation model for user need finding. The creation of the model took place in three stages and within these three stages involved the discernment of design knowledge to augment the process. Rather than AI instantiating itself on the design process after the fact, this showed the presence of design knowledge a priori in the development of an AI. This calls for a broader and deeper role of designers in the development of AI if it is to be applied within a design process.

Constraints to the current research stem from the fact that design knowledge is present a priori in this particular model, resulting in a case-based theoretical claim. Future research is needed to develop a more systematic framework of how design knowledge is involved a priori in models more generally. This would enable the ability to address how different types of design knowledge (e.g. domain expert vs. generalist) shape the outcome of the AI.

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Towards a Data-Informed-Design (D-I-D) Framework for Autonomous Vehicle Design

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Abstract. Autonomous Vehicles (AV) have the potential to positively contribute towards a safer, greener, and more sustainable mobility. Yet, amongst the public, there is a general sense of distrust and apprehension with regards to autonomous technology that compromises AV acceptance and uptake. This paper introduces first steps towards the development of a Data-Informed-Design (D-I-D) framework for AV design with the aim of providing design practitioners with tangible, relatable anchors to direct activities towards critical AV design features that help ensure prospective passengers' needs and motivations, such as the need for safety and security, are met. A series of interviews were conducted with senior designers to identify key design features. The interviews revealed themes rather than individual design features, such as the need for 'comfort', which hint at the complex interactions between people's needs and motivations and how design can and should respond to this complexity. The results are discussed in the context of the further development of the D-I-D framework and future research.

Keywords: Autonomous Vehicles, Design process, Vehicle Design, Safety Perception, Public Acceptance

1 Introduction

In this paper we present the results of a study into the development of a Data-Informed-Design (D-I-D) framework to support the design of future Autonomous Vehicles (AVs). The ultimate aim is to i) provide design practitioners with tangible, relatable anchors to direct activities towards critical design features, and ii) enable design management to introduce a greater degree of objectivity in their decision making.

The D-I-D approach is in part motivated by current design practice which heavily depends on designers' tacit knowledge. While this of course can lead to successful design, here we explore the potential to enhance the design process by incorporating data that informs the designer if and to what extent certain design features have the intended effect on customer perceptions and experiences.

Data-Informed-Design can be distinguished from Data-Driven-Design in which data is paramount, a primary input and at the centre of design decisions and suitable for engineering design where requirements can be defined explicitly. By contrast, the D-I-D approach assumes that the design team uses data to inform their decisions and that data are used as one of many references, including design intuition, creative expression and qualitative feedback. The aim of D-I-D is to enhance design practices by helping designers to make mindful design decisions and empower their creativity instead of confronting it. The intention here is to enhance design efficiency and effectiveness by sizing or shaping the design space [1, 2, 3].

Both approaches have their advantages and disadvantages. A data-driven approach can provide valuable insights and inform decision-making, but it can also have limitations such as incomplete or inaccurate data, inability to capture everything, and the need for human judgment. A data-informed approach, on the other hand, combines the power of data with human judgment and expertise, and this permits researchers to make better decisions, optimize processes, and improve the customer experience. Such an approach accounts for the limitations of data and the need for human judgment while still using data to inform decision-making.

We focus here on a particular application area in which the D-I-D approach is expected to provide considerable value, i.e., the design of future AVs and their perceived safety, arguably the most critical aspect for their public acceptance [4] and the subsequent socio-economic and environmental benefits they may bring [5].

Highly automated (SAE level 4) vehicles no longer require people to be in control of the vehicle and allow them to watch movies, socialise, or simply relax during their travels. This scenario calls for a radically different design strategy whereby the focus of attention shifts away from the currently dominant driver-centric design approach to an entirely passenger-centric focus [6]. A key consideration for this passenger focussed design era is the general sense of distrust and apprehension with regards to autonomous vehicle technology amongst prospective customers [4], which is of particular concern in the initial phases of exposure to AVs. This subsequently led us to ask the question what design features are of particular importance in instilling a sense of safety in prospective customers?¹.

Whilst safety may be relatively well understood for conventional vehicles (e.g. elevated seating position, high belt line etc.), AVs introduce a new set of challenges, with people's concerns only partially understood [6, 7]. Furthermore, given that AVs are an emerging technology and only experienced by the public at a demonstrator or concept vehicle level, designers lack feedback with regards to real-world interactions with such vehicles, and this limits designers opportunities to explore alternative design directions. Subsequently, this creates an *informational asymmetry* between designers and prospective AV customers (see Figure 1 below).

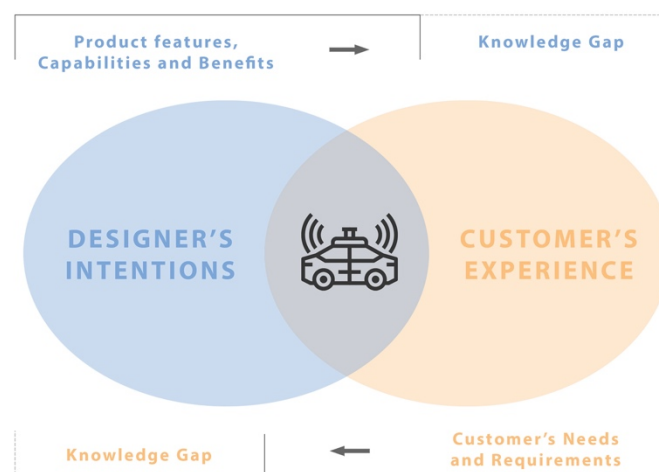


Fig. 1. Knowledge gap and information asymmetry in the design of future autonomous vehicles (after [1]).

Based on the idea of the design process as a communication model [8, 9], the designer is assumed to play the role of a communicator creating a range of forms (e.g., design features) and develop a

¹ Note that the public here refers to both prospective AV passengers as well as bystanders, i.e. (vulnerable) road users interacting with such vehicles.

relationship with the customer as part of the communication process, as shown in Figure 1. However, designers may have an incomplete understanding of prospective AV customers' needs and requirements, while AV features and characteristics designed to fulfil assumed needs and requirements may not be perceived or appreciated by prospective AV passengers. In turn, this *information asymmetry* comprises a *knowledge gap* both for the designer and prospective passenger. In turn, this may lead to a potential breakdown in communications [8,9] which, in the current context, may result in low acceptance and uptake of AVs. The D-I-D approach attempts to bridge this gap by creating data and knowledge to assist designers in (explicitly or implicitly) making informed creative decisions that positively address, in this case, concerns around safety of AVs.

To this end, we had previously conducted a study in which we interviewed senior automotive and transport designers about their understanding of the role of exterior vehicle design and in particular specific vehicle design features that may instil a sense of safety in both passengers and bystanders, i.e. pedestrians and cyclists [2]. The study revealed a common understanding of key features but also an apparent dichotomy or incompatibility in terms of design directions when considering passengers versus bystanders. Figure 2 below provides one such example: whilst a higher belt line (left image) was considered to enhance a passenger's sense of safety, a pedestrian may feel safer when confronted with a less robust looking AV featuring a lower belt line (right image). Furthermore, the designers indicated that their understanding was largely based on their experience of conventional vehicles leading to uncertainty as to the validity in the context of future AVs, reflecting the knowledge gap identified earlier in this paper.

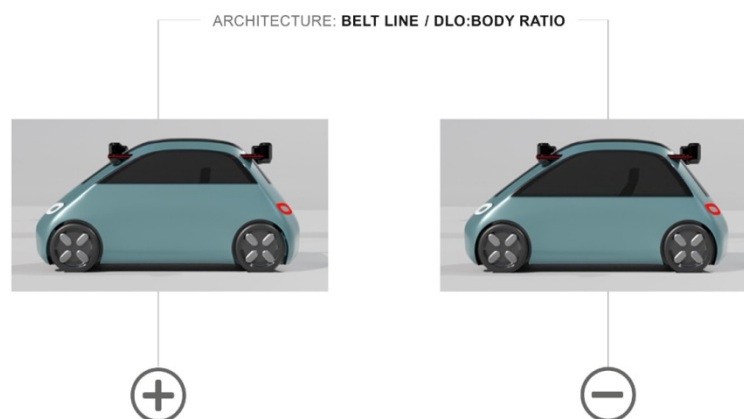


Fig. 2. Illustration of design features (belt line) considered by designers to affect people's sense of safety (illustrations by Yichen Shu)

The aim of the current study was to build on the previous study and expand beyond the exterior design features by focusing on interior and User Interaction (UI) design features instead. We conducted a series of semi-structured interviews with senior automotive and transport designers and educators to develop an initial list of interior and UI design features deemed to be relevant in the context of future AV passengers.

2 Methods

2.1 Recruitment

Invitation letters were sent to five senior automotive and transport designers with 10 plus years of experience in industry. They were asked to participate in a 30-minute interview and informed that the interview would be audio-recorded and that personal data would be treated anonymously with consent requested on the day of the interview. Interviewees were not offered financial compensation for participating in the study.

2.2 Interviewing procedure and analysis

The interviews were semi-structured and based on a predefined protocol that consisted of open-ended questions to explore what design features were considered to be important in the perception of safety of AV interiors. Acknowledging the wide variety in AVs including automation level, vehicle size, seating arrangement, and context of use, for the purposes of this study the interviewees were first provided with a short description of the type of AV to consider. The type of AV referred to in this study constituted a shared vehicle managed by a mobility service provider; SAE level 4 automation; no vehicle controls; small footprint 2-seater; forward-facing seating arrangement; urban use in mixed traffic conditions; geofenced area of operation and driving at a maximum speed of 30mph.

Table 1 below shows an adapted and expanded version of the hierarchy of vehicle design framework which sets out fundamental levels of design features of exterior vehicle design [10]. We used this to assist interviewees in considering a range of design features, they were shown.

Table 1. Hierarchy of interior vehicle design

Level	Design features
<i>Architecture</i>	Cabin Windows, Roof, Transparency, Height, Width
<i>Form</i>	Furniture Seating- form/proximity/height/position, seating direction, privacy features, Controls, interior layout, storage space
<i>Detail</i>	Colour, Materials, Finish, Seatbelts, Lighting, Sound, Design Language, Biometric Monitoring
<i>Communication</i>	Info display, Commands, Override/ Changing course, Entertainment, Visible tech vs. Hidden tech, Haptic touchpoints, Passive vs. Active, Security measures

While the original framework was intended to refer to vehicle exteriors, we applied it here to the vehicle interior and included a fourth level, i.e. communication. The *Architecture* level refers to the cabin (size, structure, transparency), and the *Form* refers to the furniture (seating, direction of travel, interior layout, privacy features). *Detail* refers to colour, materials and finish as well as lighting,

restraints and design language. (Note that in the original framework [10] Architecture, Form and Detail are referred to as Bones, Muscles and Graphics, respectively). Finally, *Communication* encompasses the method and display of information delivery, override/commands, proximity and type of controls, entertainment, and the visibility and passivity of technology.

Following the presentation of the framework, interviewees were asked to discuss and expand on which design features they deemed most important in instilling the perception of safety from the perspective of the AV passenger.

All interviews took place over a conference call facility (Zoom) with associated capabilities to share screens and show the hierarchy of vehicle design for reference. The interviews were recorded and transcribed using an automatic transcription software (Panopto). Transcripts were subsequently reviewed and corrected where needed. The data was analysed using the hierarchy of vehicle design framework. For brevity, in the next section, the results are summarised and discussed together.

3 Results and Discussion

3.1 General comments

The interior design interviews often began with a higher level discussion of what safety in interiors consists of. Discussions raised more nuanced and multi-system issues than the hierarchy of design features suggests. There was a discussion about whether the perception of safety needs to be consciously designed and constructed in an obvious and visible manner, or whether safety ought to be designed in a more nuanced and intelligent way. There was also conversation on whether the interaction within an autonomous interior ought to be more passive as it is during an elevator ride, or more active in the way gamification of a vehicle interior might offer. The importance of the need for connection with the outside environment was highlighted, both visually through glazing, and digitally through the recognition and engagement with passing structures or services. Lastly, a distinction was made between the concepts of feeling safe *in* the car, versus feeling safe *from* the car as an approach to thinking about interior safety in autonomous vehicles (see Figure 3 below).

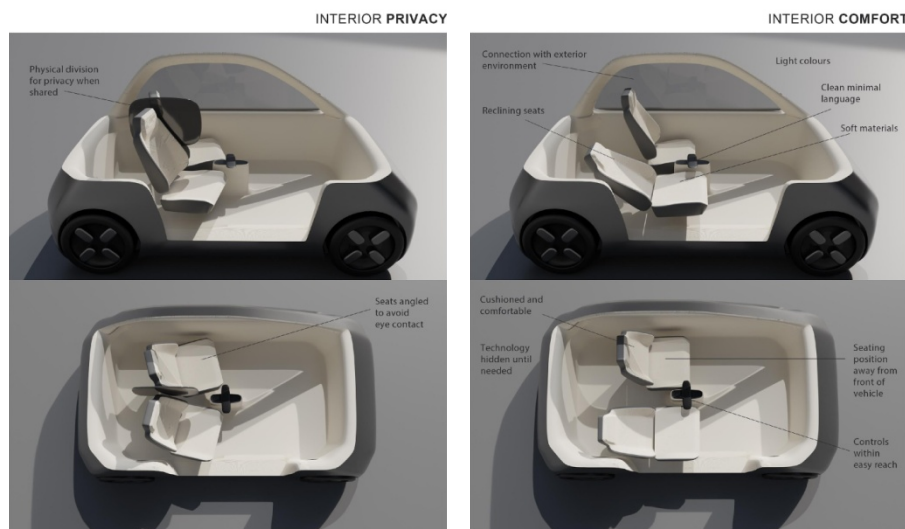


Fig. 3. Illustrations of a selection of interior design features considered to be of importance in instilling a sense of safety in AV passengers (illustrations by Yichen Shu).

3.2 Architecture

With regards to the design features at the architecture level, the following features were considered. Respondents were equally split as to the preference of more or less *glazing*, half stating that more glass equals more visibility and connection with the outside environment, thus putting the passenger at ease, with the other half stating that less glass was preferable so that passengers feel less exposed. One respondent also suggested a *panoramic roof* aids visibility and provides a premium feel. No comments were made as to the *height* or *width* of the interior cabin.

3.3 Form

At the form level, most respondents agreed that forward *direction of travel* was preferred in an autonomous vehicle given that this is the preferred choice in environments like trains or buses where both are available, with one respondent suggesting non-forward travel to be considered only in short journeys, and the consideration of flexible/rotating seating directions to avoid passengers being committed to one direction of travel only.

With regards to *seating*, it was considered that a higher *seating position* within the vehicle would help passengers feel safer and less looked down upon by other drivers on the road, as well as the seating being situated away from the front of the vehicle since it the first point of contact in a potential collision. Within the vehicle, respondents also mentioned angling seats away from each other so passengers could avoid eye contact in a car sharing scenario, thus maintaining a desired personal space that grants a degree of privacy. In order to increase comfort, reclining seats were suggested by interviewees as preferable, with one mention of bench seating to allow passengers to sit closer together, for instance in the case of parents and young children. It was also mentioned that considering the growing size of adults across the globe, it is necessary to offer more inclusive seating and to consider standing or perch options for shorter journeys or when passengers wish to remain at a distance from others.

With regards to *interior layout*, physical barriers for *privacy* in a shared environment with strangers was recommended by respondents to help make passengers feel safe, and curating the interior layout to feel as spaced apart as possible was an important consideration in a small footprint vehicle, especially with regards to having free space in front of the seating area.

3.4 Detail

With respect to details, there was a clear consensus on using lighter *colourways* to create a calm environment that appears more spacious, and help to reduce anxiety or panic associated with a lack of control in an autonomous driving situation. However, it was suggested that darker colours would be a better choice in a shared environment to better mask any accumulation of wear associated with heavy-duty use.

In terms of *materials*, the consensus from respondents was to use materials to create a warm and comforting environment, with materials that are both durable and easy to clean seen as of particular importance.

With regards to *lighting*, the majority of respondents felt that mood lighting that was changeable would help passengers feel more relaxed and hence safer. On the subject of *sound*, it was felt that soundproofing the vehicle would help to eliminate unexpected noises that are a normal part of a journey when in control of driving and witnessing the contributing factors. Having a soundtrack of the passenger's choice would also contribute to the careful creation of a *personalised environment* even before entering the vehicle; a recommendation made by most interviewees.

Providing *restraints* was supported by the majority of interviewees, with support for seat belts stemming from the fact that they are a psychologically ingrained part of the experience of being in a vehicle, and so contribute to passengers feeling safe. Belts were noted as being of particular importance when travelling with younger children.

Respondents were in favour of *biometric monitoring* for the purpose of the vehicle being able to respond to the passengers changing physiological parameters by consequently changing the speed of the vehicle, or introducing changes in lighting, smell, or sound to reduce anxiety for the passenger. Related to this, it was suggested that *motion sickness* would need to be addressed to improve the journey experience and feelings of safety in a small footprint vehicle.

In terms of *design language*, no clear consensus was presented, however respondents felt that a clean and minimal language would be preferred, avoiding harsh or utilitarian themes, with one respondent viewing a premium offering to be essential to improving uptake and use of a small footprint autonomous service. There was consensus however on the theme of 'comfort' being a clear suggested direction in creating a sanctuary feel for the interior.

3.5 Communication

The communication section of the framework dominated the discussions, with a consensus amongst interviewees that the information system was the most important parameter in assisting the feeling of safety for passengers. With regards to the overall communication of *information*, all respondents suggested a 'status update' method of communication where information is constantly displayed with relation to the health of the vehicle and the status of the journey. This was suggested as important in keeping the passenger up to date and reassured, with the method of delivery suggested as a continuous passively running but subtle visual update that could be turned off if desired, as well as concurrent but intermittent audio updates. It was noted that updates should be inclusive of passengers with disabilities.

With respect to *commands*, it was universally agreed that the presence of a clearly visible emergency button is needed to assure passengers that in the event of needing to immediately curtail the journey due to health or emergency reasons that they would have the control to do so. It was also agreed that all controls the passenger may have access to for configuring the interior environment should be within easy reach of any seated and restrained passenger.

The topic of *technology* generated discussion on what would be most appropriate for the autonomous experience as a whole, with the majority of respondents deeming a lighter touch, with more intuitive technology that remained hidden until needed, to be the best way forward. A few respondents also felt that in the absence of customising the interior environment for comfort there is no need for extra technology to be added to the interior; indeed, they imagined a future where

passengers bring their own technology with them to plug into the vehicle. With respect to screens, some interviewees felt that the absence of screens altogether was best, with technology embedded into surfaces instead, whilst the remainder agreed that screens should be kept to a minimum and of a smaller size where possible. The importance of haptic controls for important operations like stop/start or the opening of doors was highlighted, but digital controls were recommended for everything else, and a suggestion for movable controls was also put forward to aid ergonomic efficiency whilst seated.

With regards to *security*, camera monitoring was suggested by multiple respondents as a necessity to improve feeling of safety in a shared vehicle as well as to aid in the ability to relax, which is no different from current transport modalities like taxis, buses or trains. The desire to create a system where the passenger has access to a human being at the touch of a button to assist with emergencies or queries was suggested, as well as humanising audio voices to create a less machine oriented and more personal environment of safety. It was also felt that rides should be able to be shared with a friend remotely to aid in feeling safe when travelling in a shared scenario.

Lastly, the topic of *entertainment* was an important one amongst interviewees with ideas such as a digital concierge and a personally curated environment suggested to aid in distraction and hence relaxation and a subsequent feeling of safety. It was suggested that time well spent is a currency in the world of automation, and enabling the passenger to choose activities that are rewarding or pleasurable helps to overcome the hesitation of use of such a service. The importance of creating a new level of experience with incentives not available when a passenger is in control of a car was also suggested, possibly with the earning and redeeming of points that could be exchanged in a retail setting for example as a reward for supporting a more sustainable mode of transport.

4 Conclusions and Future Research

In this paper we have attempted to identify interior vehicle and UI design features that may instil a sense of safety in future AV passengers as part of a wider Data-Informed-Design (D-I-D) framework for AV design. To this end, senior automotive and transport designers and educators were interviewed. Consensus was arrived at within the realms of technology and security as a means to increasing the perception of safety for passengers in a small footprint vehicle.

Themes, rather than individual design features, emerged such as the need for 'comfort' as a design direction for the interior, the concept of creating added value and experience through entertainment, added luxuries not possible whilst driving, and the curation and customisation of the interior. The importance of linking the vehicle to its outside environment physically as well as digitally was also an outcome and an area to be further explored.

Interesting areas for future development as a consequence of this research include the opportunity to develop a subtle visual language for safety that extends beyond the more expected use of text, audio or icons, and exploring the narrative and experience-related philosophy of an autonomous interior with gamification and enhanced or unexpected levels of interaction not previously possible.

Together with the previous study into exterior design features [2], our work provides a starting point for the development of the D-I-D framework for the design of future AVs. The current findings also hint at potentially complex interactions between people's needs and motivations and how design

can and should respond to this complexity (see also [6]). Previous research into the role of human needs and motivations in the context of the acceptance of AVs have identified the need for safety and security, competence, autonomy, stimulation, and the need for meaning as key factors [7,11]. Whilst the prioritisation and focus on safety and security in our work to date seems justifiable and has been informative, the suggested impact of the wider passenger experience (e.g. comfort, entertainment) on people's perceptions of safety point towards the importance considering other factors at first instance not considered to be associated with safety. This approach is supported by the theory of constructed emotion [13] which suggests that the way feelings and emotions are constructed is highly context-bound. For example, whether an AV is perceived as safe may depend on the level of comfort or stimulation experienced. The intention of our upcoming research is to explore these complex interrelations between design features and passenger perceptions.

Returning to the communication model, thus far, we have explored the designers' perspective. Next in the development of the D-I-D approach, the visualisation of these designers' perspectives, akin to the example provided in Figure 2, allows us to evaluate the knowledge gap on behalf of the customer (AV passenger). We will ask the question whether the safety relevant design features identified by the designers are actually appreciated by prospective passengers. In addition to qualitative methods including interviews and focus groups, our research will adopt the Best Worst Scaling (BWS) method, a quantitative choice-based technique used for understanding respondents' relative valuation of different design features at scale [12]. Using an online platform with hundreds of respondents visually evaluating different designs, the resulting data is expected to allow us to better understand and validate which AV design features play the most significant role in customers' perception of safety and beyond. Note that the current findings pertain to small footprint AVs and may or may not be generalisable to other vehicle types, a topic that will be explored in future studies.

Finally, the research aims to understand the value, barriers and enablers for the integration and acceptance of research and Data-Informed-Design in both commercial design practice and design education. Within the automotive and mobility industry, communication between departments (e.g. design, research and engineering) is often limited for practical and cultural reasons leading to sub-optimal strategic and fundamental design decisions. To date, the understanding of the role of data in examining future design solutions is at a rudimentary stage with few theories and even fewer frameworks. Interpreting data into design strategies for human benefit demands data-literate designers and, conversely, design literate researchers.

Acknowledgement

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Therapy, Play and Movement Awareness with Intraoral Interfaces

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Abstract. Adequate and high-quality sleep is essential for mental and physical health. However, the sleep of around 2 billion people worldwide is negatively affected by snoring and over 900 million people suffer from sleep apnea. The health and broader societal impact of these conditions are massive. Myofunctional therapy, which strengthens the muscles around the tongue, mouth and face has proven benefits for breathing-related sleep disorders and snoring. However, long-term adherence to this therapy is a great challenge to patients. This paper presents the design of a game-based interaction facilitated by a bespoke intraoral interface that improves snoring through play, offering potentially greater motivation for patients to engage in therapy over several months. We pay particular attention to the nature of sensory-motor function and movement awareness in the mouth and to the application of motivational and behaviour change strategies. We conclude by discussing the challenges of long-term motivation and the specific challenges associated with the design of mouth interfaces.

Keywords: Wearables, Intraoral Machine Interface, Interaction Design, HCI, Motivational and Behaviour Change

1 Introduction

Snoring might seem like a mild annoyance at first glance, but it can have a deep impact on personal health, resulting in serious problems on a societal level. The condition can be diagnosed on a continuum between simple snoring, through to the more serious conditions of upper airway resistance syndrome and varying degrees of obstructive sleep apnoea [1, 2]. More severe forms have been linked to depression, cardiovascular disease, hypertension, stroke and mortality [3]. The point at which a condition becomes a serious health threat is not easily discernible, but at any stage snoring can seriously impact both the sufferer and their partner's sleep, and treating the condition early will likely prevent the development of more serious respiratory problems [4]. Snoring and sleep apnoea have a massive impact on sleep quality and quantity. The resulting deprivation of quality sleep has a profound effect on mental and physical health, work productivity and the risk of vehicle and workplace accidents. One study in Italy on the national economic impact of sleep apnea has estimated a cost as high as 32 billion euros based on negative health outcomes and rates of accidents [5].

Fortunately, the lack of muscle control which leads to snoring and/or mild sleep apnea can be treated through myofunctional therapy. This involves exercises that strengthen the upper airway and tongue

muscles. One study showed that performing specific exercises for eight minutes per day over a 3 month period decreases snoring volume by 60% and improves measures of sleep quality [6]. Additional studies have shown improvements for several markers of sleep apnea such as reduced arousal index, decreased apnea-hypopnea index, daytime sleepiness and sleep quality [7]. While these treatments are non-invasive and highly effective, they do require adherence to a therapy plan of 3 months or more to improve and maintain results.

These issues led to the conception of Tongue Fitness (TOFI), a bespoke intraoral tongue interface that allows patients to undertake myofunctional therapy while playing games on a smartphone or computer, with the goal of building long-term therapy adherence, which we defined as at least 3 months, in accordance with the findings of the study of Ieto et al. [6]. The development of the TOFI device and the supporting theories provide transferable knowledge to therapy in speech-language pathology, myofunctional treatment for malocclusion and mouth-breathing as well as other diverse use cases for Intraoral Computer Interfaces (ICI) such as control modalities for accessibility devices and hands-free scenarios.

2 Related Work

2.1 Intraoral Computer Interfaces

Despite the apparent novelty of interacting through the mouth and tongue with digital systems, there are numerous existing examples demonstrating both control and display modalities for accessibility aids and therapeutic tools together with hand-free control and other niche applications. The earliest demonstration was in an electropalatography device developed in the late 1930s [8]. Although not strictly a digital device, the apparatus allowed the tongue position on the palate during speech to be measured electrically, as an aid in speech-language pathology. The “sip and puff” interfaces originated in the 1960s [9], and these allow tetraplegic users to control various systems with their mouth and is still used extensively today. The “Brainport” enables sight and other sensory modalities via an electrotactile display on the tongue, based on theories of sensory substitution proposed by Bach-y-Rita [10] and technology developed by Kaczmarek [11]. Perhaps inspired by the work of Bach-y-Rita, there have been numerous experimental intraoral computer interfaces demonstrations in the two decades since Brainport, with several control modalities [12, 13, 14], digitally controlled taste [15, 16, 17] and novel haptics for the mouth [18]. From the field of design, the most well-known work is likely in the speculative *Audio Tooth* by Auger and Loizeau [19], but there have also been notable explorations of tongue interfaces by Aisen Caro Chacin [20], Dorothee Clasen [21] and in the highly playful work of Emilie Baltz [22]. There is also one existing example of a tongue-controlled joystick, developed to improve tongue strength through gamified therapy for young people with speech impairments [23]. Patients who trained with the device over several sessions gained improvements, but the device is currently bulky and limited to use in a laboratory setting.

2.2 Motivation strategies and Behavior Change Theory

To better understand which factors of a persuasive design lead to behaviour change, Fogg et al. proposed the Fogg Behavior Model (FBM) for persuasive design [24]. According to the model, three factors must come together: A person must be sufficiently motivated, they must have the ability to

perform a certain behaviour and there must be a certain trigger to start the behaviour. In our design study and further development of the TOFI interface, we have taken the FBM model as a key reference. The Fogg model also provides a useful tool for analysing shortcomings and success in the results of our study to identify helpful, problematic or missing simplicity factors.

Oinas Kukkonen et al. describe five strategies for Persuasive Technology: self-monitoring, social role, praise, reminder and suggestion [25]. The five strategies provided us with an additional basis for analysis in this study. We structured survey questions and diaries provided to participants of our user study to evaluate these strategies in our design. The paper by Geuens et al. [26] provide us with an additional taxonomy of motivational design strategies specifically for mobile health apps, with 7 categories: Ability, Information, Awareness, Gratification, Social Interaction, Autonomy and Credibility.

2.3 Movement awareness

Flow states, as described by Csikszentmihalyi [27] are periods of skill performance associated with feelings of fulfilment, loss of time perception, and other characteristics conducive to a pleasurable experience and high levels of intrinsic motivation. However, periods of skill acquisition are not necessarily conducive to flow states, yet they can provide gratification and feelings of accomplishment, and are a key component for mastery goals [28]. By shifting from External Focus of Attention (EFA) to Internal Focus of Attention (IFA), we may lose aspects of performance and flow, but we gain support for mastery goals and movement awareness.

In recent years a growing body of literature has suggested that motor skill performance is aided by EFA and inhibited by IFA. However, the picture is likely far more complex than many studies have indicated, with IFA playing a key role in skill acquisition and EFA benefits being limited to skill performance [29]. Furthermore, the process of IFA has considerable parallels with mindfulness practices and could be constructed as a form of movement meditation. While not necessarily conducive to high levels of performance while in use, IFA may lead to greater quality of movement, and when used habitually, could lead to long-term improvements in motor skills. In our design, we implement both games that are supportive of flow states, but also one game that supports IFA in a movement meditation.

2.4 Multisensory and Cross-modal interactions

We argue that the sensory-motor systems of the mouth must be considered holistically for the design of ICIs. For example, through the sensory-motor based perception of dynamic touch, we can explore and understand spatially, which can be framed within the enactivist concept of “bringing forth the world” [30]. It is through similar multimodal sense-making processes that we might interpret the basic affordances of a system, interpret feed-forward signals (the purpose of an action) and perceive inherent feedback (tight coupling between action and feedback). Even though the ICI device described in this paper is focused on input modalities at the mouth, given embodied and enactivist understandings of interaction, we should not only consider the motor abilities that allow us to “input” into a system but also the multi-sensory and cross-modal sensory mechanisms that allow us to perceive and make sense of that system. Some contemporary neuroscience suggests an entanglement of motor-sensory pairings that might provide some scientific basis for enactivism [31],

and should push us towards heightened consideration of sensory perception in input modalities, and vice versa, for motor activities in output modalities in all forms of Human Computer Interaction.

3 The TOFI System

The TOFI trainer device consists of a bespoke splint fitting the hard palate and teeth of the upper jaw connected via bridge to a capsule which houses the electronics in front of the lips (Fig. 1). Four force sensors are positioned on the hard palate and one sensor outside the mouth on the bridge. Activating the sensors requires the user to coordinate the movement of the tongue to find the sensors, and then apply isometric force. Tactile bumps provide basic tactile affordances. This external sensor provides a more challenging exercise of pushing upward with the tongue outside the lips. The level of force required and speed requirements for coordination are defined by the individual games played in our application, which connects to the device wireless over BLE.

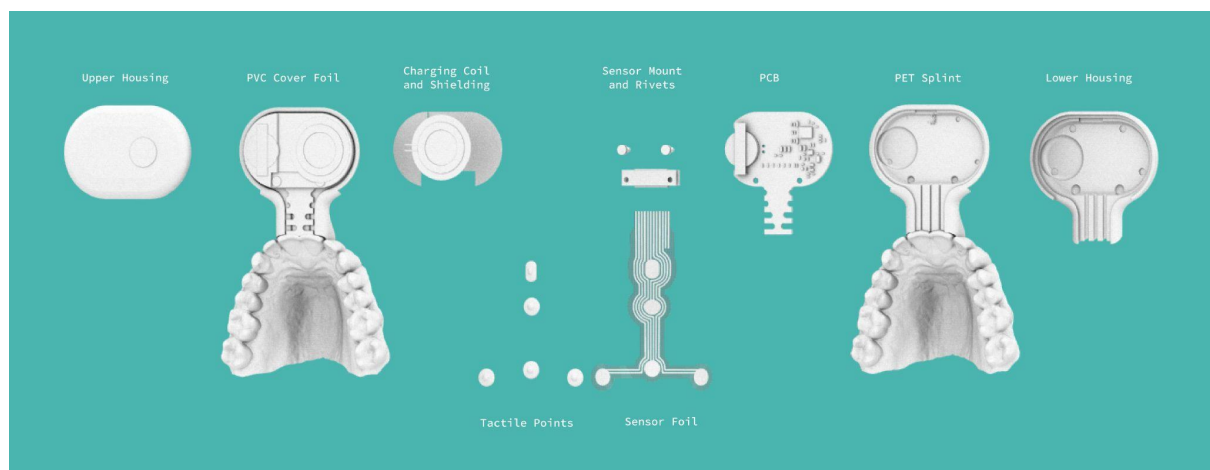


Fig. 1. Rendering of prototype, showing an exploded view of the device.

The device can be charged through wireless induction to allow for complete hermetic sealing. We developed custom thin film dielectric force sensors for the design, allowing us to maintain a 1-millimetre thin splint construction on the in-mouth portion of the design. This increases comfort and allows for unobstructed tongue movement. Further details of our fabrication process and the device construction are beyond the scope of this paper, but they are covered extensively in “TOFI: Designing Intraoral Computer Interfaces for Gamified Myofunctional Therapy” [32].

The design underwent numerous iterations, to refine the comfort and wearability, as well as resolving challenges of hermetic sealing, sensor construction and distribution (Fig. 2). The final design appropriates contemporary fabrication techniques used in orthodontic appliances, using 3D oral scans, 3D printed moulds and vacuum forming. These developments were iterated based on feedback from self-testing with users selected from our team before the final prototypes were provided for the study participants.



Fig. 2. Hardware, fabrication materials and various prototypes.

3.1 Software Prototype

Once users put on their bespoke device, they can connect it to our web application running on their computer or Android device. The app provides guidance for the initial calibration process, access to games for therapy and usage statistics. The rationale for providing therapy that is gamified comes from evidence of gamification increasing adherence to rehabilitative exercises [33]. However, one systematic review pointed out that most existing studies of gamification for health goals take place over relatively short durations [34], so it is still difficult to draw conclusions for truly long-term outcomes. Another survey of the relevant literature highlighted the effectiveness of gamification but also pointed out a number of caveats, namely the qualities of the users [35]. By developing a number of game types suited to different personas, we address the most serious caveat, which was raised by Hamari et al. The four simple games we developed were as follows:

1. Simon: Based on the classic electronic game, challenging short-term memory and dexterity. Each sensor is mapped to a distinct tone and players must repeat a sequence of activations to match a given melody.
2. Meditation: A non-goal-oriented visual and sonic exploration, with a focus on movement awareness.
3. Tilt Maze: A 3D maze game, requiring spatial problem-solving and dexterity. The four in-mouth sensors control the tilt of a maze in order to roll a ball to the target. (Fig. 3.)
4. Speed Test: A simple benchmark exercise, checking the progress of speed and dexterity. Users must activate specified sensors with a nominal force as fast as possible.

All games provide visual and auditory feedback to sensor activations made with the user's tongue. This, together with the passive tactile feedback provided by points on the device provide redundancy

and coordination of sensory modalities, in line with the synesthetic design principles of Haverkamp [36]. All games provide a direct visual map showing the sensors and the force applied to assist spatial orientation. The “Meditation” activity is the most unique offering, in that there is no set goal for the activity. Activations of the sensors with varying levels of force stimulate visualisation and auditory feedback. The activity was designed explicitly to elicit movement awareness through IFA.

The current iteration of the device requires daily calibration. Inserting the device into the mouth introduces forces into the splint which are registered by sensors. The application provides a prompt at the start of each session to calibrate the device, which requires a number of forceful activations with the tongue on each sensor.

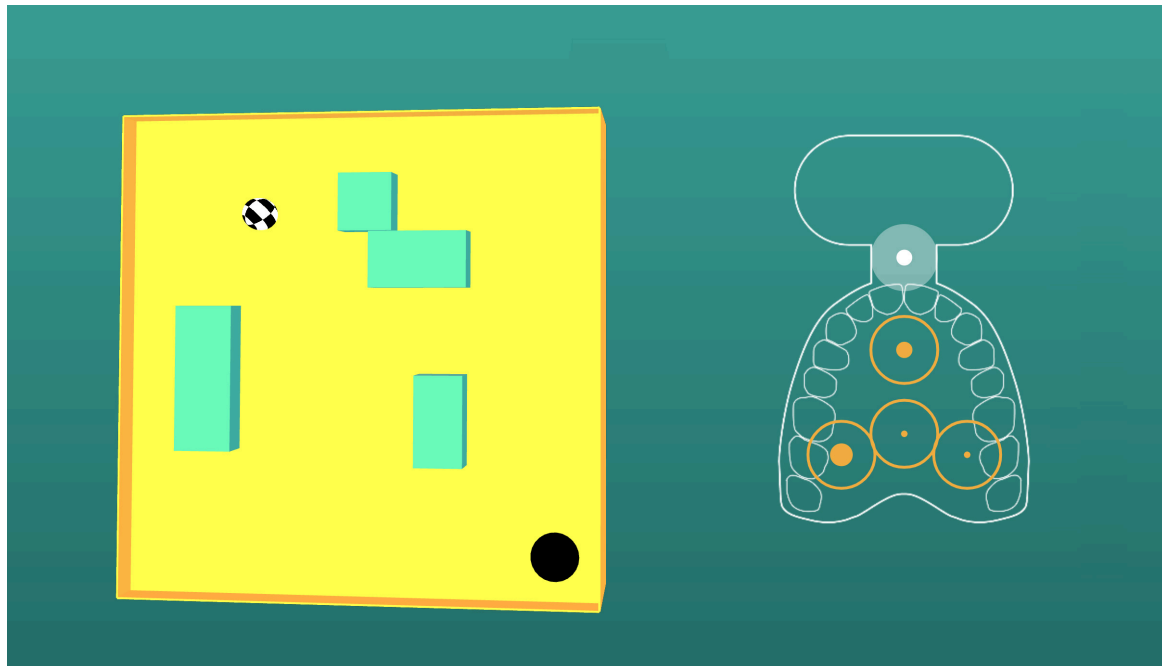


Fig 3. Screenshots of Tilt Maze game

3.2 Motivation Cards

We provided Motivation Cards as an analogue supplement to the function of the software prototype (Fig. 4). For the development of the Motivation Cards we used the strategies discussed in Oinas Kukkonen et al. [25]. For the conceptual design, we used the inspiration of an open-source project attempting to change behaviour for more sustainable living [37].



Fig. 4. Example Motivation Cards

Each card provided a single strategy to increase motivation and disrupt the typical drop in enthusiasm after the initial “honeymoon phase” of a new product or app. Ultimately such strategies would be incorporated into the software prototype through notifications.

4 Process and Methodology

The participant took part voluntarily and did not get paid for their participation. The participants ranged from 19 to 44 years old with an equal gender ratio. All of the participants were working or studying in medicine, with some drawn from dentistry. The user testing started with a group of 10 candidates, who underwent a 3D oral scan. The majority of the participants took part in the testing out of curiosity and only two people referred to snoring as a motivation.

The participants first filled out a questionnaire based on FBM (Core Motivation, Simplicity Factors and Behaviour Triggers) and addressed basic questions about initial motivation, daily routines and issues around snoring. It asked how the participants built routines and habits and called for them to identify the typical obstacles they confronted when trying to maintain routines. Seven participants were selected based on the questionnaire and bespoke devices were fabricated for them using 3D scan data.



Fig 5. Package for Participants with TOFI Device and Charging Station.

The participants then received a package with the TOFI Device (Fig. 5), a charger, a diary, the motivation cards and the end questionnaire. The introduction for participants was done in a video-call interview. The participants received a brief explanation of basic usage, before being instructed to explore the interface and attempt the four available games. We shadowed their progress and provided assistance only when necessary.

After the interview, the participants were asked to exercise at least 5 minutes a day and answer some brief questions in a diary. The diary contained structured fields targeting trends in motivation, daily hurdles and how the training was initiated (the routine formation). The use of the motivation cards was voluntary.

5 Results

From Questionnaire 1 it emerged that the main motivation to participate in the study was curiosity. In the interviews, we got feedback that the interface is clearly understandable and easy to use. All users reported that the device was comfortable to wear and they could still talk clearly with little difficulty. Almost all could locate and feel the tactile pumps, and they could correctly correlate those points with the locations indicated on the screen visualisation. Ergonomics and basic affordances offered by the interface did not appear to present any barriers.

Two users aborted the study at the outset, one because of a dental operation and the other because of difficulty using the device due to severe limitations in spatial acuity and dexterity with the tongue.

From the user data, we saw a significant drop off in the time spent playing daily by many of the participants. Two users experienced technical issues with the initial prototypes, but others could not articulate a strong reason for the drop-off in interest. The game that was most often played was “Tilt Maze”, which has a clear goal, mission and thus purpose. However, the candidate with the most consistent usage played “Meditation” the most, which focused on movement awareness.

6 Discussion

The fact that most participants did not follow the training consistently, according to FBM, suggests that either the core motivation was not strong enough, simplicity factors were difficult to overcome, or there was a lack of triggers. As the most stated reason to participate in the study at the beginning was curiosity, we concluded that this was the main driver for the non-adherence. In the user data, we also saw that at the start of their training phase, there was a peak that thereafter decreased, which is consistent with their motivation of curiosity.

For simplicity factors, we concluded that the ergonomics of the TOFI is not an issue, but the wearing of the device conflicts with social norms. Some users reported a wish for more discreteness so that they could use it in public spaces (Table 1). In the diaries, we also saw that the training was perceived as physically exhausting, another conflicting simplicity factor. The daily calibration of the device is also a considerable barrier. The task is inherently repetitive, and if done incorrectly, can cause performance issues. At the time of the study, the interface was not accessible on iPhones, limiting usage to a computer or Android device.

Another consideration is missing triggers. In most of the questionnaires, we also noticed that a self-made calendar entry was the main reminder function the participants used. This could likely be overcome with trivial solutions like conventional notifications or integration with calendar apps.

Table 1. Aspects of the prototype under Kukkonen et al. strategies

Self Monitoring	Reminder	Suggestion	Social Role	Praise
Infographics	Questions in study diary	Context screens by first view	Inherent social structure of study participation	Speed Test
Motivation Card "Checkliste"	Notifications	In app pop-ups and informations/ suggestions	Training tandem	Free Flow
Motivation Card "Über Zeit"		Notifications with suggestions	Network to doctors/ specialists	Sonic Simon
Motivation Card "Highscore"			Virtual coach	Tilt Maze
Entries in study diary			Community	Motivation Card "Belohnung"
				Infographics (improvements over time)
				Congratulation screen
				Praising notification for streaks

Implemented in interface
 Implemented in study
 Not implemented

7 Limitations and Future Work

Two of the candidates, out of the total 10 study and pre-study users, mentioned difficulty locating and activating closer-spaced sensors with the tongue. Both candidates also specified strong snoring in the questionnaires. There is likely a correlation between limited spatial acuity/tongue dexterity with snoring intensity, suggesting the need for basic research and the development of robust guidelines for designing such interfaces.

The aspects of sensory-motor integration, cross-modal and multisensory perception in relation to intraoral devices have not been extensively investigated in the past. The study here indicates some success in this area, but there is no thorough analysis of the individual components. This is an exciting area for future research.

The most consistent user in the study played the IFA-oriented game the most. However, the study is too small in scale to draw any major conclusions about the nature of IFA in relation to motivation. Ultimately, providing different types of game play to accommodate different personality types may be a winning strategy.

Technical issues in the prototype were mostly concerned with the calibration and related sensitivity issues with the force sensors, which can be resolved with future iterations. However, there is an underlying problem in evaluating long-term motivation for use of a prototypical device, which will inherently have technological shortcomings. For this reason, such studies might better be considered as walkthroughs aiming to identify barriers to motivation, rather than actually aiming to achieve long-term motivation.

Social deviance was a serious barrier to the use of this device. A prototype that integrated all electronics into the mouth, and thus be invisible from the outside, would be a clear advantage in this regard.

8 Conclusion

In this paper we have presented a novel intraoral interface for gamified therapy to reduce snoring, together with qualitative results from a user trial based on interviews, questionnaires and diary entries. We presented a new and unconventional form of interaction using the tongue, together with the experimental application of Internal Focus of Awareness for skill acquisition and increased motivation for therapy. The user testing showed success in basic affordances, visual, sound and passive tactile for tongue interaction. The evaluation also showed positive results for the usability of our web application. However, despite positive results in the interface evaluation, we saw a relatively poor adherence to therapy. Using the five strategies for persuasive design from Kukkonen et al. we could identify shortcomings as well as key areas for improving adherence through future iterations of our design.

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04/

Wearables and Alternative Skins

Doctor Kiwi: A persuasive game concept to treat skin sores among children in New Zealand

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Abstract. In Aotearoa, New Zealand, skin infections are a serious health concern for children, especially among preschool-aged children, Māori and Pacific children, and those living in northern regions. Treatment of such conditions often includes antibiotics and external skin treatment that should be followed for multiple consecutive days. However, anecdotal reports indicate that children often lack the motivation to complete the treatment, especially once the skin sores have started to improve. In this qualitative study, we report on a design project conducted in collaboration with iMOKO™ in New Zealand that explored the development of a persuasive game to increase adherence to the treatment of skin-related infections. We conducted an initial context exploration involving young children and their caregivers to determine barriers and facilitators in the context. Two design phases focused on creating initial concepts and developing prototypes, which were evaluated by participants. As part of the game, children receive reminders, information about the treatment and relevant treatment instructions. The focus was put on making them become active partners rather than passive recipients of the treatment.

Keywords: persuasive strategies, children's healthcare, game design, simulation, education, engagement, stigma

1 Introduction

The increase of skin infections among children is on the rise worldwide and especially in New Zealand this trend can be clearly observed [1]. This increase is also inequitable, with Māori and Pacific children, and those living in the low socio-economic areas or northern parts of the country facing an increased likelihood to experience serious skin infections [1]. Skin conditions are commonly treated in a primary care setting but can also lead to hospitalization [2]. Parents are often surprised by the fast deterioration of skin-related health conditions and lack access to information about skin infections despite expressing the wish to know more about causes and treatment options [3].

One existing project that aims to address these issues is the iMOKO™ project led by Dr Lance O'Sullivan and his company Navilluso Medical, which focuses on rural communities in New Zealand. Laypeople get trained by the Navilluso Medical Technology team to use smart tablets with custom software to document common health problems among children such as dental and skin infections, strep throat infections, head lice and other medical conditions [4]. The information collected with the software is then shared with the doctor to confirm the initial diagnosis. Schoolchildren have the opportunity to interact with the iMOKO™ medical team, who conduct free, regular visits at Kohanga Reo, daycare or school. Parents are informed about the assessment results and receive information about the treatment protocol and prescriptions

if needed. However, the iMOKO™ team thought it would be beneficial if there was a way to get the children engaged beyond the initial diagnosis and into the following treatment process, for example, by using a game environment to provide treatment information. Accordingly, our research builds on this established project to create a more meaningful approach to engagement with children during the treatment phase.

The purposeful attempt to influence one's behavior through design without forcing or deceiving users is referred to as persuasive design [5]. Technological applications that use game-based components and mechanisms as part of their design are referred to as *Persuasive Games* [6]. In the context of health-related games a distinction can be made between games for (1) health promotion and prevention; (2) and disease management. In the context of this study, we focus on persuasive games for disease management which aims to provide health-related education and self-management skills [6]

2 Methods and Material

This research was carried out as part of a 12-week summer scholarship program at the School of Design Innovation at Victoria University of Wellington (New Zealand) in collaboration with the iMOKO™ medical team in Kaitaia, New Zealand. The aim of this project is the development of a persuasive game for young children living in rural New Zealand that facilitates engagement to follow the treatment protocol for skin sores. The study consisted of different phases that we report on using Fogg's eight steps framework to create persuasive technology [7]. The HREC committee of Victoria University of Wellington approved the study. Participants and/or their caregivers provided informed consent.

3 The Eight Step Design Process

3.1 Step 1: Choose a simple behavior to target

The iMOKO™ app focuses on various skin conditions. We discussed the prevalence of the different conditions with the medical team in Kaitaia and chose the following: (1) Impetigo; (2) MRSA (superbug); (3) Eczema; (4) Boils; (5) Cellulitis; (6) Insect bites. Ringworm and chickenpox were reported to rarely occur in the region and, therefore, were excluded. The different treatment protocols varied for various skin infections (see Table 1 below). It was decided to focus on impetigo for the game during the discussion with the project leader Dr Lance O'Sullivan who pointed out that the condition is the most common one. The game focuses on the "Clean, Cut, Cover" advice for impetigo treatment but also takes account of antibiotics that are prescribed for moderate to severe impetigo [8].

Table 1. The different conditions require different treatment steps.

Condition	Length of treatment	Antibiotics	Baths	Environment	Skin treatment	Nails	Avoid products
Impetigo	5 days	Yes, 5 days	Regular bath with bleach to disinfect		Cover sore with dressing	Cut nails to reduce contamination and	

						infection	
MRSA		Yes, 5-7 days	See above	Clean all surface, wash all sheets to disinfect	Cover sore with dressing	See above	
Eczema	Returning chronic condition		See above		Keep skin clean	See above	Avoid soap
Boils and abscess	1-3 weeks	Yes			Cover sore with dressing		
Cellulitis	7-10 days	Yes, 5-7 days					
Insect bites	1-2 weeks			Treat pets for fleas	Keep skin clean	See above	

3.2 Step 2: Choose a receptive audience

The New Zealand school system requires children to enter primary school at the age of five years. They usually transfer to a secondary school when they are twelve years old and stay until seventeen [9]. In consultation with the team, it was decided to focus on the age group of 5–7-year-old children. It was further noted that since the parents would primarily receive instructions on how to treat the child, the game should include them to ensure that the treatment is carried out correctly.

3.3 Step 3: Find what prevents the target behavior

We conducted group interviews with families including children that had experienced the impetigo skin infection previously. We interviewed three families with children aged 5–7 living in Kaitia as part of this phase. Families were recruited by the iMOKO™ team. As part of the interviews, barriers and facilitators to the treatment process were explored using a semi-structured interview. It became evident in the interviews that skin infections were often a condition associated with a great degree of stigma. For example, when children were asked how they felt when they had the skin infection, the younger children especially refused to talk about it. However, some of the older siblings mentioned that they tried to hide the condition whenever possible. Skin conditions such as the contagious MRSA were seen as giving rise to stigma as the sores require the child to stay away from school and the house to be thoroughly cleaned. In addition, some of the medications the children need to take were mentioned as being rather unpleasant or tasting “funny”, and just seeing the bottle could cause an adverse reaction among the children. One family member mentioned that she believed girls were more likely to see the iMOKO™ team for treatment advice than boys. It was also mentioned that older siblings treated by the team create a feeling of acceptance and normalization of the condition, which would reduce the feeling of stigma, so the younger siblings were more likely to seek consultation and follow the treatment protocol. A further barrier to effective treatment is the requirement to take antibiotics for the recommended length (e.g., five days). The children tend to stop taking medicine once the symptoms stop rather than for the recommended length. The iMOKO™ team pointed out that this could cause antibiotic resistance in the long term. It was also mentioned that well-timed triggers were sometimes lacking, primarily when the parents or grandparents were not engaged in the treatment process. Some of the families interviewed had 5–7 children, and one of the participants mentioned that even though she wanted to follow the treatment recommendations and remind her child to take the medications, there is the risk of simply forgetting to do so.

3.4 Step 4: Choose a familiar technology channel

It was mentioned during the interviews that most children have regular access to a parent's mobile device to play games. Children regularly used their parents' phones to play games such as "Subway Surfer" or "Cooking Fever" or "Colour Switch" (see Figure 1 below). We decided to focus on Android smartphones for the game, which were identified as being the most common smartphone platform in Kaitiaia.

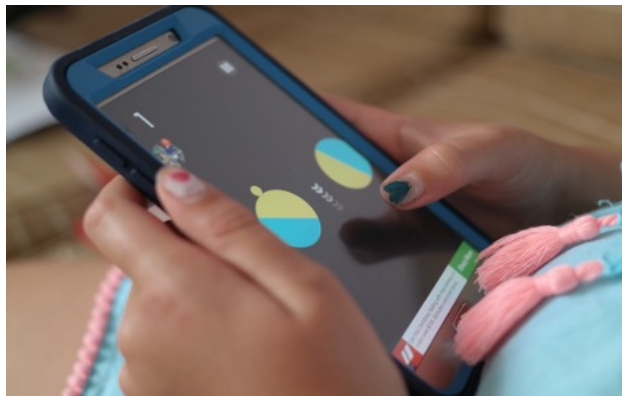


Fig. 1. Color switch app played by one of the interviewed children.

3.5 Step 5: Find relevant examples of persuasive technology

Health management games are games for people with illnesses who can benefit from the education and self-management skills that the games try to provide. We reviewed different games that addressed various medical conditions such as cancer or asthma (e.g., [10–13]) but found these games lacking aspects that take account of the stigmatizing effect that impetigo can have on a child.

3.6 Step 6: Imitate successful examples

After reviewing the games, we also investigated the opportunity to include an augmented reality (AR) function. Skin sores often need to be closely supervised to ensure that antibiotics are working and that symptoms are decreasing. The AR function was seen as an opportunity to encourage the child to take a photo of the sore while playing the game and sending it back to the iMOKO™ team for a check-up. This fitted with iMOKO™'s existing use of tablets to document photos of children's medical conditions. The AR marker was conceptualized to be provided as a temporary tattoo that the child could attach close to the infected area as a reference point [14].

3.7 Step 7: Test and iterate quickly

We could not find a successful game concept suitable to be transferred to the context of our study, which includes children in a rural area experiencing a stigmatizing health condition. Therefore, we chose to use a set of persuasive technology strategies [15] as a starting point for the design explorations. The strategies aimed to motivate the majority of gamer personalities and avoided demotivating players. We developed six initial design concepts and refined two of them further. Design concept one named *AR pet* uses few medical references and pieces of advice. The game instead offers the child an individualizable pet in the form of a small monster flying above an AR marker attached next to the skin infection. The child has the opportunity to dress and add accessories to the monster and feed it. More accessories and assets become available the longer the child follows the treatment protocol and sends regular photos of the skin infection to the iMOKO™ team. The second design concept named *Germinate* shows the germs as enemies that need to be eradicated. The game provides pieces of clear medical and educational advice. For example, the children can select from a set of tools such as soap, to attack the germs. A countdown adds some fun urgency while the child experiments with various tools to find out which is the best for the job.

3.7.1 First testing session

We tested the two game concepts during the initial interviews described in section 3.3. The children found both game aesthetics pleasant and recommended adding more interactions for the *Germinate* game. For the *AR pet*, they recommended more mini-games and interacting with the pet as well. The children enjoyed dressing up the monster and found that it made the game more personal. The parents viewed the temporary tattoo component of the design critically. It was pointed out that tattoos can be an indicator of gang membership in some regions in New Zealand, and can also hold special cultural meaning, so they did not want to encourage children to get permanent tattoos. Participants also suggested making the game a "Doctor in your pocket" so children could attend to AR wounds, such as stitching cuts on hands.

3.7.2 Second testing session

We further developed the *AR pet* and created paper markers, rather than a temporary tattoo for its interactions (see Figure 2 below). The child could access the game's menu by clicking on the book icon, pat the monster, and feed it with an apple by clicking on the apple icon to keep the health bar at a good level and fight germs that surround the monster. The concept for the game was to use a physical coloring book that contained a story to explain the treatment protocol and the digital component that would complement the story and offer AR functionality. The marker to access the digital part of the AR game (e.g., the monster) was situated on the bottom right of each coloring book page.



Fig. 2. Paper marker for the AR pet developed as part of the initial design concept. Patting the monster on the screen makes it laugh.

We tested the game with eight children between 7-12 years during a second visit to Kaitia. The germ component of the game worked with all children, but only one child could find the marker on the page of the coloring book with the aid of prompting from the interview instructor. None of the children tried to pat the creature, and once prompted, they often thought it was crying. Only one child said he thought the creature liked the patting. The interaction with the game elements proved challenging (e.g., elements had to be dragged instead of clicked on). The iMOKO™ team also pointed out that a printed coloring book as part of a treatment protocol may be inefficient since parents would already receive a lot of printed material.

3.7.3 Step 8: Expand on success

We developed another iteration of the *AR pet* game concept and included additional mini-game components to explain the treatment steps to children. This brought us closer to our aim of engaging the children in their medical treatment protocol and addressing associated stigma. As part of the game, we created a *Kiwi doctor* character who asks the child for help to take medical care of a friend. This was done to assign the child the role of an expert advising others rather than a passive recipient of treatment recommendations. As part of different mini-games, the child then learns and discovers how to treat the friend. For example, in one of the mini-games the child needs to add a small amount of chlorine to the bath water to treat the skin infection. Each day one game is unlocked to support motivation and adherence to the treatment protocol.

The game consists of six mini-games played on six consecutive days. Once diagnosed with the condition, the child receives a code to download and unlock the game. Day one entails an introduction by the Kiwi doctor and an explanation of how the game works. The first mini-game on day one focuses on picking up the antibiotics. On the second day, the child learns to change the dressing. On day three, how the nails need to be cut. On the fourth day, the game reminds them to take the antibiotics until the end of the treatment protocol. Day five explains how to add the right amount of bleach to a bath to treat the skin sores and the sixth and final day focuses on taking a picture of the skin sore and sending it to the iMOKO™ team to confirm that the treatment was successful.

Each day a new scene allows the child to have a *challenge* (treating a friend who also experiences a skin condition), develop *solutions* (find out in the mini-game what works) and receive a *benefit* after successful completion (new asset for the AR component of the game). We built upon the AR function developed during the first two phases and used it as an element that allowed the user to personalize an avatar that they received at the start (see Figure 3 below). For example, a stethoscope could be collected in one of the mini-games as a reward to dress up the avatar in the AR part. The game is also connected to the parent's phone, from which reminders could be sent to the child to take the daily antibiotics and compliment them when they completed the daily mini-games.

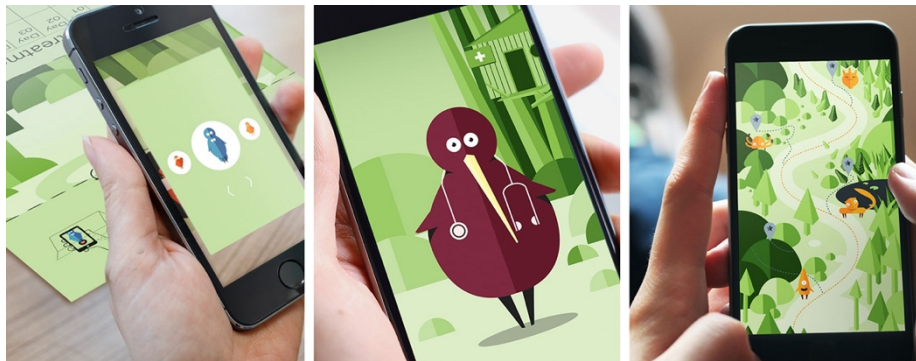


Fig. 3. The AR function of the app allows the child to personalize a character and is shown on the left. The center shows the Kiwi doctor who leads the child through the main story. The right image shows an overview of the menu that allows the child to unlock a daily challenge and meet a new friend (orange creatures).

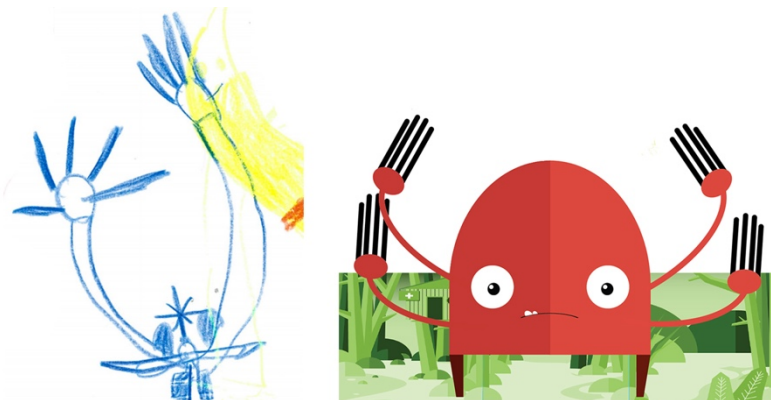


Fig. 4. The different friends that the doctor encounters and that need help from the child playing the game are based on drawings from the children interviewed.

Our game uses role-playing elements, which is the most common genre of persuasive games for disease management [16]. Furthermore, the game includes different persuasive strategies [17], including *reward* and *personalization* of the AR avatar and the strategy named *liking*. *Liking* means that a visually attractive strategy is likely to be more persuasive [17]. For this purpose, we developed different graphical elements and used wording for the voice-over parts of the game that we deemed suitable for children in Kaitaia. For example, the Kiwi doctor and different characters are situated in a forest-like environment and for the main character, we used New Zealand's national bird (the kiwi). We used drawings children had made during the interviews as a source of inspiration for the friend characters (Figure 4). We also embedded *praise* and *reminders* by letting parents send push notifications from their devices to the game. We also included *rehearsal of the correct behavior* and *simulation* to allow users to observe the link between cause and effect (e.g., cleaning bandages and feeling better) [17]. We purposefully avoided strategies such as *social learning* due to the stigma surrounding impetigo. This approach challenges arguments stating that such strategies could be effective in disease management [16].

3.8 Discussion

Skin infections are a serious health concern in New Zealand [1]. To develop a persuasive game that facilitates engagement to follow the treatment protocol for skin sores among young children, we followed Fogg's eight steps framework to create persuasive technology [7].

We note that the research described here reports on the contextual inquiry and design development process, and not a fully functional prototype. We were able to make significant progress in this 12-week period, and develop our collaboration with families and medical staff. As researchers, we also continue to engage with New Zealand's unique cultural space. To honor the Treaty of Waitangi, we continue to evolve our understanding of how to build effective partnerships with indigenous Māori people, and to address health inequities.

In this project, we learned crucial pieces of information from our Māori participants and collaborators, such as the cultural relevance of tattoos, and that the Te Reo word children knew skin sores by was "hakihihi". These types of findings that the interviews and the prototypes revealed allowed us to better interact with participants, and to ensure any final product developed would be culturally appropriate. For example, the stigma surrounding the impetigo condition was revealed in the initial interviews and not explicitly mentioned in the literature we reviewed at the start of the project. This aspect became a crucial design aspect in the project, and the interviews revealed that parents can simply forget to remind their children to follow the treatment steps. Suitable reminders should, therefore, ideally be provided as part of the game. Another crucial insight we gained was that a removable tattoo to allow the AR function of the *AR pet* concept was deemed inappropriate by parents. This was due to the associated meaning of tattoos being commonly used by gang members. This aspect has not been previously mentioned in the literature but helped us in the design process to develop alternative solutions.

Fogg's eight step framework [7] facilitated a structured process to understand user requirements and to iteratively develop and evaluate different design concepts. However, we also noticed that we had to conduct some of the steps in parallel due to participants' availability as part of the project. For example, we developed initial design concepts in parallel to recruiting participants and used the first

interviews to gain insights into the treatment process and to identify barriers, as well as asking participants for their feedback on concepts. Using a participatory approach to allow children to co-create game concepts could help develop alternative game strategies. Such an approach could also help younger children talk more freely as we observed that they often refused to talk about their experience during the interviews.

Since completing this phase of the research, we have worked with a master student to develop and refine the game and this has been presented to the iMOKO™ team [18]. We have also implemented insights from the AR aspect of the game into a project facilitating sit to stand exercises for adults who have experienced a stroke [19].

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“I had pee sneezes”: Factors influencing the health-seeking process and use of wearable devices among women with pelvic floor disorder

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Abstract. A disorder of the pelvic floor can cause several physical symptoms and have a significant impact on the social participation and self-image of the affected women. Exercises facilitated by wearable technology, such as Kegel devices, can help strengthen the relevant muscle group, but it is unclear which factors influence the use of such devices. In this qualitative study, an online survey with open-ended questions was used to determine facilitators and barriers in addressing the symptoms that typify an affected pelvic floor. The results were analysed using deductive thematic analysis. Seventy women with various symptoms of pelvic floor disorder participated in our study. Factors contributing to the help-seeking process include a changed body sensation, access to relevant and reliable information, the possibility of concealing symptoms and addressing the disorder by performing exercises. The rehabilitation process can be challenging and to produce significant requires ongoing patient commitment to producing significant results. Future studies can benefit from the results to create suitable technological solutions.

Keywords: Women’s health, women’s experiences, pelvic floor muscles, pelvic floor disorder, user experience

1 Introduction

The term pelvic floor refers to the muscle group that is situated at the bottom of the pelvic container [1]. This group of muscles works clinically as a unit [2] and is not just involved in sexual response but plays a vital part in human bladder and bowel functioning. A disorder of this muscle group can cause various symptoms, such as urinary incontinence (UI), anal incontinence, and even pelvic floor prolapse [3–5]. The term pelvic-floor disorder (PFD) has been used to refer to weakened pelvic floor muscles (PFM) and non-relaxing ones, which are often receive less attention in the literature. PFD is one of the most common gynaecological conditions among women worldwide and can significantly impact the individual’s lifestyle, such as problems with defecation, urination, and sexual function [6, 7]. Several factors seem to contribute to the development of PFD, including pregnancy [4], childbirth, injury during delivery, neurological disorders [8] or other kinds of trauma, age-related changes, hormone imbalances, and diseases [9]. The influence of those factors on the individual’s life can be profound. However, it is not entirely understood which factors most significantly contribute to the development of PFD symptoms [1] and how these factors influence the help-seeking process.

Disorder of the PFM is a significant healthcare concern for the affected women. Pelvic floor muscle training (PFMT) for weakened muscles can help to decrease symptoms such as UI [10]. The training includes repetitive and voluntary contraction of specific PFM following a protocol outlining intensity, frequency and progression of the exercises [11]. Wearable devices such as internally worn Kegel

devices [12, 13] can provide biofeedback to women who struggle to perform muscle contraction and exercises correctly. Nonetheless, if such devices are used incorrectly, there is also an increased risk of worsening symptoms [12]. It has been documented that current devices lack certain qualities such as user-friendliness and convenience, which affect user experience negatively [13]. Designs specifically for the female body have historically been a taboo topic [14] and designing for women's healthcare remains an underexplored area in research areas such as human-computer interaction (HCI) [15]. This study set out to explore the help-seeking process of women with PFD, including identification of both facilitators and barriers, to facilitate the development of suitable wearable technology solutions.

2 Method

2.1 Data Collection

A qualitative approach was chosen in the form of a survey with open-ended questions to explore women's experiences and attitudes towards their condition. We chose a survey due to the associated stigma of PFD symptoms which make it a sensitive topic for women, which may in turn inhibit them from sharing their personal experience. The survey contained 25 open-ended questions and 19 additional prompts covering demographic details, symptoms and diagnosis. Additional questions focused on factors that appear to worsen the symptoms and the kind of emotions that arose due to the condition. In a third part, the participants were asked what kind of help they had sought to treat the condition, in case they previously had used a device to treat PFD. Follow-up questions concerned the attributes that had appealed and had been helpful to them (see <https://doi.org/10.17605/OSF.IO/8HBNQ> for an overview).

2.2 Sample

We recruited participants using a convenience sample by posting the survey link on PFD discussion boards on the website reddit.com after seeking permission from the administrators. Participants were eligible to take part in the study if they were female and experienced symptoms of PFD. A formal condition assessment was not included as part of this study. The study was approved by the human research ethics committee of Victoria University of Wellington, approval number: 0000022545, and participants provided informed consent before participating.

2.3 Data Analysis

Results of the survey were analysed using thematic analysis in a deductive form [16] according to the process of change outlined as part of the transtheoretical model (TTM) of behaviour change [17]. Thematic analysis is a method that identifies, reports and analyses *themes* within the data. The analysis of the data started with familiarising ourselves with the data, followed by the generation of themes according to the ten processes of change of the TTM [18]. The ten processes include: consciousness raising, dramatic relief, self-evaluation, environmental re-evaluation, self-liberation, social liberation, counterconditioning, stimulus control, reinforcement management and helping relationships [18]. We chose the TTM because of its comprehensive theoretical components that also take account of the different stages of change that participants are in (e.g., contemplating the change of a specific behaviour). The initial data was exported into Microsoft EXCEL and reviewed in full,

followed by assigning codes to the quotes. In a consequential step, the codes were clustered according to the themes, refined and summarised in a narrative report. Codes and themes were not quantified (e.g., stating how many participants agreed/disagreed with a specific code or theme).

3 Results

The survey was online for four weeks, and seventy women participated in our study. The majority of participants came from New Zealand (n = 24), followed by the USA (n = 22), UK (n = 13), Australia (n = 5), Canada (n = 4), Taiwan (n = 1), France (n = 1). The mean age was 35 years (range 20 to 69 years). Most participants were unsure about the nature of their condition (n = 25). Of the 54 participants reporting having a child, most had one (n = 25). In the following section, we will outline the results for the ten different themes.

3.1 Theme 1: Consciousness Raising

Consciousness raising factors increase awareness about a condition in terms of its cause, consequence and possible cures [17]. A changed internal and external bodily sensation and symptoms caused by PFD, such as UI, helped raise awareness among participants. Pregnancy appears to be a significant life event during which women noticed PFD signs for the first time. Participants also noted the increased attention to bodily changes in connection with surgeries, the start of menstruation, and traumatic events such as car accidents. One barrier impacting the process of seeking help was that symptoms were also associated with different conditions, such as urinary tract infections, being sick, or simply having a weak bladder. Some participants also mentioned the condition to be a lifelong one, starting from an early age, which interfered with narrowing down the causes and factors contributing to PFD.

3.2 Theme 2: Dramatic Relief

Dramatic relief causes some initial emotional experiences followed by increased motivation to take appropriate action [17]. Participants mentioned positive results of the PFMT to lead to a feeling of relief and facilitate the process of addressing PFD symptoms. However, slow progress seems to have a negative impact on the process. Some women mentioned that they performed the exercises in the bath or the shower as recommended by a therapist. This might potentially contribute to the feeling of relief since symptoms of UI could remain unnoticed during the training. Negative emotions that contributed to the feeling of loss of control were anger, frustration, feeling dirty, depressed and feeling upset, all of which seemed to affect self-esteem significantly. Other emotions, such as shame and anxiety, were reported to be strongly connected with symptoms of PFD and the products used to conceal them. Anxiety was mentioned concerning the constant urge to check clothes -especially pants - for signs of urinary leakage and to ensure immediate access to a bathroom.

It caused major anxiety when I was working (you can't always just drop everything to go for a bathroom break). Now that I'm a stay at home mum, it's just an inconvenience that rears its ugly head when we are away from home.

Participant 63, 31 years, one child

Dramatic relief is impacted by participants starting to dislike their bodies, becoming apathetic and seeing themselves as worthless. All of these emotions seem to contribute to the feeling of a loss of identity and negatively impact the help-seeking process.

3.3 Theme 3: Environmental Re-Evaluation

Environmental re-evaluation combines the affective and cognitive assessment of how a personal habit affects the immediate environment [17]. This theme was little mentioned in the survey results. Participants reported partnership and work in this connection, and how these factors affected their environmental re-evaluation.

3.4 Theme 4: Self Re-Evaluation

Self re-evaluation is based on the cognitive and affective assessment of one's image in regards to how the behaviour in question affects self-image [17]. This theme focuses on the realisation that healthy behaviour is integral to who the person wants to be. While professional help was mainly associated with the possible relief of symptoms, some participants mentioned that they regretted seeking help and that their symptoms worsened, especially after surgery. They further mentioned that they simply hoped that symptoms would disappear after a while.

3.5 Theme 5: Counterconditioning

Counterconditioning focuses on replacing unhealthy behaviours with healthy ones [17]. Participants appreciated using devices as the only non-surgical solution to treat symptoms of faecal incontinence and UI. About a quarter of the participants used a device, and approximately half of these women had acquired the device through a recommendation of a health professional (doctor or physician). Some participants found it on the internet. Most participants preferred a device applied just externally, followed by internally, and some wanted an internal and external combination. Participants appreciated Kegel devices as effective instruments for strengthening the muscles. However, a barrier to conducting the exercises seems to be based on the fact that women are not regularly provided with such devices.

They are not available from the government for free, but should be! It's not an item I want. It's an item I NEED!

Participant 13, 27 years, no children; asked about how they accessed devices for PFMT

The use of devices to train the muscles seemed to be incorporated into appropriate situations, for example, when sleeping, while being in the shower, watching TV or using the phone. Due to a lack of muscle awareness and the hidden muscle structure, it can be difficult to assess if the prescribed movement has been performed correctly. Another obstacle to non-adherence to the exercise protocol was reported to be simply forgetting to do the exercises. Barriers in this context were the increased physical and emotional stress caused by a lack of sleep, certain kinds of food and drink, caffeine, gluten, sugar and alcohol. Extended periods of standing, sitting, and intercourse further contributed to symptoms of PFD and pain among some women and affected the process of counter conditioning.

3.6 Theme 6: Self-Liberation

Self-liberation is one's belief in being able to change and making a commitment to act on those beliefs [17]. The hope for improvements contributes to the belief that symptoms can eventually resolve, facilitating willingness to seek help and treatment. Self-therapy and professional services contribute to establishing and strengthening this hope. However, the feeling of stagnation seems connected to the slow and draining progress in addressing PFD symptoms. Devices seem beneficial in the treatment process, and some participants mentioned an easy-to-clean plastic material and discrete appearance as positive factors. However, using devices can also be uncomfortable and was even described as painful by some participants. Another barrier is the impact of the different symptoms on the individual's lifestyle: unbearable pain due to the condition, decreased libido, and stigmatising symptoms such as UI, all of which affect the women's life satisfaction. The attempt at self-therapy can become a significant life focus but it is often an extremely draining experience, and failed attempts to treat PFD can even contribute to feelings of helplessness.

3.7 Theme 7: Social Liberation

Social liberation is based on the realisation that the social environment supports certain healthy behaviour [17]. Some participants mentioned that they felt a high level of stress and stigma due to visible symptoms of PFD caused by UI that can be visible on one's clothes. Furthermore, there seems to be a lack of conversation around the topic, which causes a feeling of isolation. Access to online support was mentioned as offering the opportunity to reach out to others with similar symptoms. Current solutions, such as apps, were further criticised as being quite obvious and revealing the condition to others.

3.8 Theme 8: Stimulus Control

Stimulus control focuses on removing cues for unhealthy habits and providing reminders for a healthy alternative [17]. One way participants controlled the stimulus was by drinking less when outside their home environment.

If I drink say a cup of water, I'll be rushing for the toilet within 30 minutes. Also, when I do go, it often isn't even that much volume of urine. Needless to say, I avoid too much liquid and caffeinated drinks when I am away from the house.

Participant 63, 31 years, one child

The barriers mentioned as part of this theme were based on bodily responses that were outside the women's control. Examples included coughing, sneezing or simply having a cold, which would facilitate the sneezing and coughing even more and increase the risk of urinary stress incontinence. Other factors were weak control over the urge to go to the toilet, increased stress on the muscles while lifting heavy objects, doing exercises, a lack of rectal control and a lack of control over the PFM, which would cause additional pain such as lower back pain. Participants pointed out that pregnancy seemed to increase the risk of experiencing PFD. Complications during the delivery, such as tearing tissue during vaginal birth and delivering large babies, were associated with deterioration of the condition. Multiple participants described that the first symptoms appeared after giving birth to their second child.

3.9 Theme 9: Reinforcement Management

Reinforcement management uses increasing rewards that come from positive behaviour while decreasing those from negative ones [17]. None of the participants mentioned using rewards as a positive form of reinforcement. A mediated form of reinforcement is access to information in the form of online information and contact with health professionals. Online information and contact with health professionals contributed to the process through group recognition and positive self-statements that the intended change is possible. Barriers in the process included negative emotions in the form of mood swings and pain and a lack of support due to the condition being undiagnosed or misdiagnosed. In addition, a lack of peer and social support, little or no access to health professionals, or being told that PFD is a natural part of becoming a mother was perceived as unfavourable in the process. A slow process was reinforced by forgetting to do the exercises, slow improvements of the muscles, a lack of knowledge about the condition, and a long wait for the correct diagnosis.

3.10 Theme 10: Helping Relationships

Helping relationships happen with people who are supportive during the process of change. They provide a caring atmosphere, trust, openness, and acceptance [17]. The relief of symptoms seemed to be reinforced through learning the correct exercises, breathing techniques and additional trigger point release. Health professionals such as doctors, therapists, gynaecologists and pharmacists were seen as the last resort for help. They could provide clarification about the correct movement and explain why symptoms were not improving despite the training. However, negative encounters with health professionals also gave rise to a lack of trust in the abilities of individual health professionals.

[I am] angry that women still get treated as second class citizens in a country where they work and contribute to the tax system but yet our voices are not heard on basic matters such as childbirth when our bodies know best.

Participant 14, 38 years, three children

This lack of trust increased due to feelings of not being taken seriously, that exercises were showing no effect or being misdiagnosed. Limited access due to geographical isolation, access to funding, and extended periods to get referred to an expert further complicated access to helping relationships. Participants also mentioned that they were embarrassed to talk about their symptoms, even with a health professional.

4 Discussion

PFD and its associated symptoms can significantly influence the affected woman's life. To treat symptoms, PFMT aims to restore deep core muscle tissue and the function and fitness level of the affected tissue [13]. Wearable technology in the form of (interactive) Kegel devices can contribute to the process but should be designed appropriately to consider the level of stigma surrounding the condition [19–21]. To develop such solutions that help women, we explored the current experience and factors that influence the help-seeking process.

Devices were mentioned to be used as part of the exercises and seem to contribute to a feeling of relief, especially once positive results start to show. However, participants were often unsure if they had performed PFMT correctly and pointed out that the limited access to funding significantly impacted access to devices. Furthermore, the devices can be subject to product-related stigma and their use can even evoke a feeling of helplessness when the expected improvement fails to materialise. Even when progress is being made, women can experience a sense of failure if the progress appears to happen at a slower rate than expected [22, 23]. It also needs to be considered that the placement of the devices plays a role in the user experience, and positioning a device inside the vagina can pose a significant barrier [24]. PFMT is included into a daily routine [15] and motivational aids provided as part of exercise regime should aim to evoke realistic goals and support when the outcomes are not meeting the individual's expectations.

In the context of creating suitable solutions, it also needs to be considered that negative emotions due to PFD can contribute to a sense of worthlessness and stagnation. An awareness of such negative factors needs to be taken into account to establish realistic and personal goals that increase engagement and help manage symptoms [25]. Strategies should aim to advance a positive self-image to increase the belief that change is possible. Effective strategies can help to include the exercises into a daily routine and address barriers such as forgetting to do the exercises [26]. Women could further use tools such as weekly and monthly exercise diaries, self-administered questionnaires and self-evaluation scores to assess the progress. Inspiration in this context can be sought from research on self-experimentation [27].

A factor that was not apparent in our study but was mentioned during our initial conversations with health professionals treating PFD is that women can show a significant lack of knowledge regarding their anatomy [28]. Women can feel unreceptive to looking at and touching their own genitals. This lack of information seems to correlate with age, posing a greater need to educate older women [24]. Wearable technology could potentially offer an effective way to decrease perceived stigma while providing personalised and meaningful information [29, 30].

The results of this study indicate that symptoms of PFD are associated with several strong emotions and can influence the help-seeking process significantly. Participants described their journey as being impacted by embarrassment and confusion about symptoms and how to address them. Some participants described themselves as desperate when they tried to manage symptoms and sought help but felt that symptoms were not improving. On the other hand, women also felt relieved once interventions started to improve their situation. The different factors (See <https://doi.org/10.17605/OSF.IO/8HBNQ> for an overview) complement earlier findings [15]. They can be used to develop personas and patient pathways to guide the design process when creating design solutions to facilitate PFMT and treat PFD symptoms. The findings of this study were incorporated over two years into the development of a prototype for a biofeedback device with an accompanying mobile app to facilitate women's rehabilitation of PFD [28], which was later iteratively refined [20, 21] and evaluated by women experiencing PFD.

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FeedBreath: Designing Complementary Treatment Wearable Biofeedback System for Teenagers with anxiety disorder

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Abstract. Mental health disorders have increased in recent years, particularly anxiety disorders. This trend is especially problematic because it affects adolescents, causing emotional and physical problems. However, treatments available today tend not to focus on this specific demographic and its developmental challenges. In this context, exploring complementary therapies such as biofeedback training has recently increased and is considered a powerful tool. The most common biofeedback signal for anxiety disorder is breathing. However, today's classic breathing training methods have a limited target group and low retention rates, making them unattractive to teenage users. This project proposes the design of a wearable-based complementary biofeedback system for teenagers to promote breathing training, treatment engagement, and behavior change. The design concept uses breathing as input to control a game displayed in augmented reality. Different game modalities are investigated through user testing. In this way, the project explores how biofeedback and gamification can improve user experience, promote active participation, and improve engagement in the treatment.

Keywords: Wearable, Biofeedback, Augmented Reality, Anxiety Disorder, Gamification, Teenagers

1 Introduction

Mental health disorders have become a central concern worldwide in the recent years. Within the spectrum of disorders, anxiety disorders constitute the dominant category of psychopathology in children and adolescents [1]. Unfortunately, the number of adolescents with anxiety disorder is increasing and it is estimated that nearly 1 in 3 adolescents aged 13 to 18 will experience an anxiety disorder [2]. Since most adult disorders are an extension of juvenile disorders, adolescents have become a priority prevention target for reducing psychiatric disorders in the adult population. An anxiety disorder may lead to severe physical, emotional, and mental impairment and disability. The physical symptoms can cause teenagers to avoid public situations because of the concern of triggering these reactions leading to further social withdrawal. The treatment options for anxiety in teenagers are currently psychotherapy, medication, and a combination of the two [3]. However, these treatments can encounter challenges in dealing with teenagers as they were trialed mostly with adults.

To increase access and support for mental health problems, digital tools are being increasingly used and, in several studies, have been shown to provide benefits for young people [4]. Moreover, the increased use of mobile technologies has created new interaction opportunities for adolescents, and emerging technologies such as Augmented Reality have enormous potential to improve patient motivation and promote active participation during medical treatments [5]. Complementary therapies (CAM) to treat anxiety in teenagers are non-invasive and engaging and give teenagers a degree of

agency in managing their own health. Biofeedback-based systems have attracted considerable interest in providing sensory information to help teenagers self-regulate their physical symptoms [6-7]. The system described here is FeedBreath, and it aims to provide a complementary system to help teenagers cope with and control anxiety-related physical symptoms following the integrated behavior change model [8] to promote behavior change. FeedBreath can create motivation and engagement during treatment using an AR scenario together with the teenager's biophysical feedback to control the experience. The system supports traditional treatment methods attending to the target group's specific needs.

The project investigates:

- *To what extent does **biofeedback** help teenagers with anxiety disorder **self-regulate and cope with their physical symptoms**?*
- *What are the **benefits of multi-sensorial stimulus** in a biofeedback system compared with a single stimulus, and **how does it influence the experience of the user**?*
- *Does **gamification** in an augmented reality environment and **biofeedback** increase **motivation and engagement** in treating anxiety in teenagers?*

2 Breathing training

In the long term, regular slow breathing practice can help people to acquire a good breathing habit that sustains their autonomic balance and strengthens their resilience against anxiety [9]. Several systems have been developed for facilitating slow breathing training in the last few years [10]. The most found signals to aid novice users in slow breathing practice are feedforward guidance and biofeedback. Today's breathing guides are straightforward, simply guiding the user in a fixed six-pace routine [11]. However, despite the use of mobile apps and sensors, this classic breathing training has a limited target group, and retention rates are low. The exercises are repetitive and boring and not attractive to the younger population. So, another approach that has been gaining attention is the biofeedback-based system, which can provide sensory information during breathing training [12]. The biofeedback breathing training game Breeze [13] uses biofeedback visualization to foster long-term engagement and increase experiential value to expand the target audience and enhance adherence by motivating individuals. The study found that participants enjoyed game-based breathing training more than the traditional approach.

With the emergence of new and alternative technologies (e.g., virtual reality and the Internet of Things (IoT) devices such as smart watches, sporting sensors, and more), the approach used to train breathing has changed. AR applications are already available in education [5-14] and medicine [15] and have emerged as a helpful treatment in several areas in the field of health. However, in clinical psychology, the use of AR is still in the early stage, with just a few studies demonstrating the utility of AR for treating animal phobias [16]. This concept in which an AR scenario utilizes the patient biophysical feedback to control the experience could further improve patient motivation and active participation. Providing real-time feedback on the procedure instead of using pre-recorded sequences during the sessions can increase trust and understanding. In the last few years, some attempts to create more engagement in health treatments have been made using the gamification approach [17-18]. Unlike in conventional games, advancement to different levels in serious games is not based on the player's cognitive skills but on achieving therapeutic goals. Serious games deepen digital interventions and engagement as they provide an alternative world where exploration, learning, and agency are encouraged. Further methods for mental disorders' digital interventions already exist and

have been explored more broadly. One of these is computerized cognitive behavior therapy (CBT), which has shown evidence of success in treating anxiety and depression among teenagers [19].

3 FEEDBREATH

The FeedBreath system is based on the integrated behavior change model [8] and behavioral change theories [20]. Here FeedBreath's main features are described, including how the system supports active participation in treatment and self-regulation of physical symptoms and reflects the increase in engagement through biofeedback and the gamification narrative. An iterative, user-centered design process was used to shape the storyline, the interface's style, and game elements and understand some aspects of the anxiety that should be addressed. In addition to helping gather feedback on design concepts, these studies also investigated basic expectations for a biofeedback-based system, assessed willingness to practice breathing training to cope with physical anxiety symptoms, and collected data about multisensory and breathing training programs. A small group in person and slightly bigger samples online were engaged in this process. The initial design requirements, storyboarding, and personas were constructed from 30 surveys and 6 interviews. The following are the outcomes that contributed directly or indirectly to the project's key features and design.

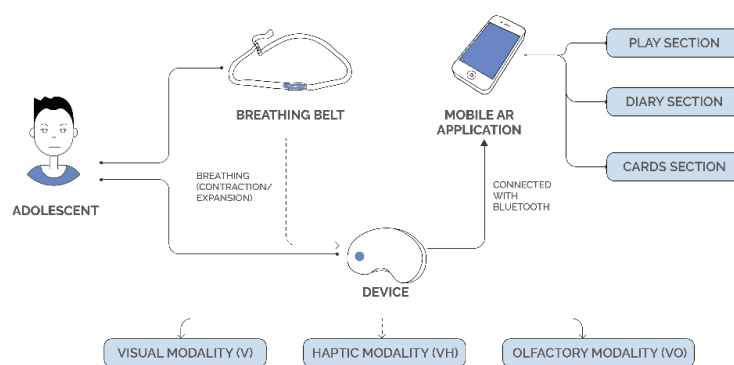


Fig. 1. FeedBreath System Architecture

As Figure 1 above shows, the FeedBreath system is composed of a wearable breathing belt and a device that will allow different modalities of the game. The belt collects the breathing pattern data and transmits it to the device that will elaborate it and send the data to the mobile phone via Bluetooth to be used as input for the game. All the information on the system can be shared with doctors and therapists. In the prototype, all information is saved within the phone and must be manually shared with the physician. In the final version, the data will be saved in the cloud and protected by encryption and passwords to comply with all GDPR security and privacy criteria. The game's story was used as an instrument to explain a little bit about the breathing process to the teenager and create a narrative that could progress with the game. For this reason, Alvi, the main character, was inspired by the pulmonary alveolus. The other two characters, the good particles, and the harmful particles were inspired by the oxygen particles and carbon dioxide particles. There are no other elements in the game itself so as not to distract the teenagers from their primary purpose, which is breathing training. The application is divided into four main sections: Play, Diary, Cards, and Achievements (see Figure 2 below). The play section is where the game is played and where the users can choose the modality they want to play. The cards section was inspired by the anxiety deck cards [21] available today in the market. It was created to allow teenagers to process their thoughts and feelings in a relaxed and playful manner. It combines visualization techniques, mindfulness, and

creative thinking. The users can draw a “card of the day” that inspires action, thoughts, or feelings every day.

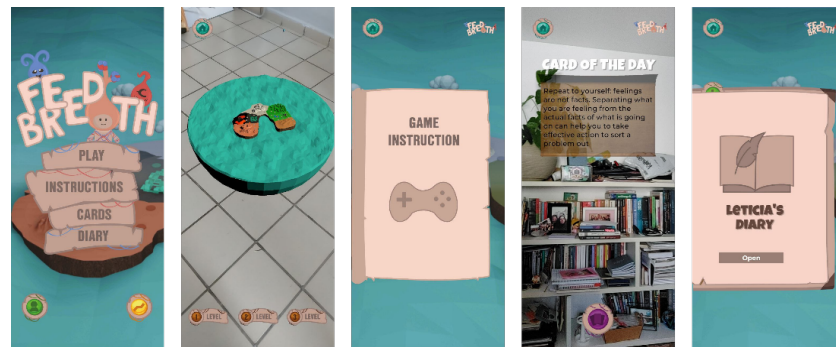


Fig. 2. FeedBreath app sections

The diary section is where teenagers can enter information about their anxiety attacks, allowing them to keep track of their attacks and better understand the triggers that made them happen. It will also provide information to the therapist and the parents.

The achievement section provides an overview of their rewards, breathing sections, and progress so as to encourage and incentivize the continuation of breathing training and the use of the application.

The game can be played in 3 different modalities: visual, olfactory, and haptic modes, based on the user's choice. In all three ways, the character starts the game running automatically without needing the users' input, while the height is controlled by the breathing input provided by the player. When the user breathes in (inhales), the character starts to jump; when they hold, it remains at the same height, and when they breathe out (exhale), the character goes down. The different modalities are related to feedforward. In the visual mode (V), the main character relies solely on visual cues with oxygen particles guiding them to inhale and exhale based on their position in the game. The vibration modality (VH) can have both haptic and visual cues to jump, hold, and go down, having a multisensory experience while playing the game. Different waveforms create vibration cues with different meanings to indicate to the users which action to take. The same goes for the olfactory modality (VO), which has both visual and olfactory cues to guide the player in the game. The score point system of the game is based on collecting oxygen particles that add points to the users and avoiding the carbon dioxide particles that subtract points from the score. As a reward system, every time the player collects 200 oxygen particles, they will unblock a character's new dance so that the player can learn and record dancing with the character. To collect the user's breathing pattern, a wearable sensor taking the form of a conductive knitted stretch was developed. It was designed to be wrapped around the user's chest/stomach, and when the chest/stomach expands and contracts, the sensor will follow the movement. The electrical conductivity will be altered, allowing for the identification of these two movements. Compared with other breathing stretching sensors available today, the smart textile is more comfortable, easy to use, and less invasive, and so is not perceived as a medical device but as just a piece of clothing.

A wearable pulse sensor is included in the prototype in order to measure heart rate variability. From the sensor, it was possible to extract the heart rate, inter-beats intervals, and HRV which is widely considered one of the best objective metrics to determine the body's performance [22]. The increase or decrease of the heart rate variability can indicate success or failure in altering the breathing pattern. It can function as a performance indicator to evaluate the application's efficiency and breathing exercises objectively. For the vibration game modality, the haptic motor driver was used to control

the mini-vibration motor, allowing the creation of different waveforms for the feedforward. The haptic controller is activated by the mobile application with the vibration button. A fogger transducer mist maker made with a piezoelectric, a humidifier atomization module, a small recipient with the fragrance (which can be selected by the user), and a cotton stick were used to create an aromatic mist for the olfactory display. As for the haptic model, the humidifier is also activated by the mobile application. A device form was idealized to hide the elements and create a more comfortable and practical component that the users can hold while playing. The shape was considered easy to hold, sustain, and comfortable in the hands. The material used was “felt”, which is soft and malleable, allowing the curves in the prototype.

4 Prototype's test

The tests were executed individually and in a private room where all the equipment was set up to create a calm and undisturbed environment. The FeedBreath software was installed on an Android cellphone and placed on a tripod for the convenience of the participants. The FeedBreath hardware was given to the participants, where they could wrap the belt around their chest and hold the device. A total of 20 teenagers participated in the usability test and the game evaluation (14 females and 6 males) aged from 12 to 16 ($M = 14.05$, $SD = 1.099$). All participants had already experienced an anxiety attack in their lifetime, but not all had been diagnosed with anxiety disorder. The participants were chosen randomly from among those in the first questionnaire survey who had indicated a willingness to test the application in the future. The participants had no experience with breathing biofeedback techniques or any other biofeedback practice. All participants and their legal responsible gave written informed consent. The experiment was conducted on three consecutive days, so the participants experienced one of the three modalities each day. For each breathing training modality, the participants performed the exercises for 3-minutes.

Before the experiment, the participant explored the application and watched the video instructions to understand the game's mechanism. At the beginning of the experiment session on the first day, the HRV of each participant was collected for 1 minute; the procedure was repeated on the last day following the exercise. The number of oxygen particles (participant's performance data) was collected during the training. After completing the activity, the participant filled out a game evaluation form. When the participant had completed all three experimental sessions, a follow-up interview was conducted in person. Qualitative and quantitative data were collected during the experiment to: evaluate the physiological benefits of the breathing training; evaluate the impact of the multisensory approach during the breathing training (number of oxygen particles collected during each of the game modalities and the participant's expressed their opinions and preferences about the different modalities); evaluate the user experience in terms of engagement, motivation, and game experience (40 questions across five categories). A SUS questionnaire was also performed to evaluate the application's usability.

5 Results

The changes in HRV generated by the application were used as a performance indicator to evaluate breathing training efficiency. HRV before and after had a significant change, $p < 0.001$. The comparison showed that the HRV after ($M = 593$, $SD = 88$, $SE = 19.7$) was significantly better than the HRV before ($M = 420$, $SD = 71.6$, $SE = 16$), which demonstrates the efficiency of the breathing training. In some users, the changes in HRV could be perceived more than in others which can be explained by a range of factors that include not performing the breathing exercise correctly, having

outside factors changing the HRV, and the potentially anxiety-inducing requirement to perform the test and be recorded.

The particles of oxygen collected for each of the three modalities show that participants' performance increased in the haptic modality, which indicates that the addition of the vibration increased the performance in the breathing training. The questionnaire responses further confirm the results, where 50% of participants choose the haptic modality as the preferred modality. The multisensory approach helped the teenagers to achieve a higher score and have a better experience. However, not all multisensory approaches have the same effect, as shown by the insignificant difference between the olfactory and visual modalities. Even though the performance was slightly better in the olfactory modality compared with the visual modality, the results do not suggest a significant change.

5.1 Subjective Engagement

During the interviews, the participants expressed their opinion on the system more subjectively. These collected insights are reported below.

Biofeedback system to promote self-regulation. The participants of the experience expressed their positive experience with the biofeedback system during the exercises mainly because it made them focus on the breathing training as their data directly influenced their performance on the game. For example, a participant said, *"I liked the biofeedback because it makes me interact more with the game and concentrate on what I am doing"*. The biofeedback added a new layer to breathing training and created a sense of ownership in the individuals recognizing their control over their health and disease and allowing them to practice self-regulation. A participant reported, *"I think it would be helpful not only for those who suffer from anxiety, but everyone as breathing is an essential aspect of our lives."* One of the participants commented that biofeedback played an essential role in her involvement in the game because she could see the *"effect of her breathing and the changes it could provoke in the game's character"*. It gave her a real-time cause-and-effect measure to actively check if she was breathing correctly.

Gamification for engagement. Participants appreciated the game mechanism and elements, and the *"innovative and funny way to deal with anxiety"*. Beyond engagement with the game mechanism, participants' engagement with the storytelling was also perceived. Participants were interested in exploring other levels and worlds and seeing the development of the character, although it was not so visible in the prototype – e.g., *"I would love to see Alvi change based on the changes I see in myself. That would reflect my improvements and give me the motivation to continue"*. Most participants appreciated receiving positive feedback when completing sessions and achieving specific goals. The reward system, such as the characters' new dance used as a celebration for their progress and time of playing, was found to be encouraging. FeedBreath avoids giving negative feedback since positive reinforcement is more motivational, and the lack of negative feedback was not perceived as a problem or limitation. Finally, participants demonstrated a strong interest in the multisensory features of the game as *"stimulating and different from any other game I have ever played"*. The different modalities allowed the participants to test other senses, understand which type of interaction works better for them, and improve their performance. The olfactory element was perceived as unusual and *"produced a calm effect during the game"*

Integration with traditional treatments. During the interviews, users found the diary section a critical feature and valuable for their anxiety treatment. The diary was seen as an opportunity to share more about their episodes and create a bridge between the two types of treatment. 80% of the participants demonstrated a strong interest in the game, while the remaining 20% showed some interest. Also, 60% expressed an interest in playing at a high frequency, while 30% of participants said they would play at a regular frequency. Just 10% responded that they would not play very much, but none of the participants said they would never play again. Moreover, 90% appreciated the graphic style and illustrations, especially the instruction video and the island. They felt that the game could have more elements such as more characters, more environmental features, and more rewards. An average score of 80.5 was given to the application using the SUS evaluation, which is considered good, especially considering the missing elements of a complete game. The score reveals that the game was understood and appreciated as a concept but still needs improvement in the graphics and the variety of game elements.

6 Discussion and Results

This article presents the design and evaluation of FeedBreath, a wearable device-based biofeedback system that supports the self-regulation of physical symptoms presented by anxious teenagers. A user experiment was conducted to evaluate the effectiveness of FeedBreath in supporting breathing exercises and to investigate the role of system interactivity in enhancing motivation and engagement in treatment, user experience, and providing psychological benefits. Three breathing training modalities of FeedBreath were created and used in a within-subject experiment with 20 participants. The interactivity of FeedBreath is provided in three ways:

1. FeedBreath provides users with real-time biofeedback on their breathing performance through the character animation and playing.
2. It allows a choice of different playing modalities with additional stimuli.
3. FeedBreath offers users a virtual reward (in the form of dance character animations to learn and record) to enhance motivation for doing the exercise.

The results demonstrated that FeedBreath is effective in facilitating breathing training exercises and self-regulation, particularly increasing adhesion rates by making practice enjoyable. These outcomes are likely to be associated with the interactive exercises and the real-time biofeedback performance, which puts a greater focus on the activity. Participants stated that exercising with FeedBreath considerably enhanced their user experience due to perceived competence, increased enjoyment and motivation, and the multisensory experience. The results suggested that the multi-sensorial stimulus created the best user performance and experience. The user responses also supported this affirmation during the questionnaire survey, in which 14/20 participants stated that the VH modality was their preferred modality and the most health-beneficial modality for breathing exercises. Furthermore, they defined their experience as “exciting,” “challenging,” and “fun.” The quantitative results analyzed above and qualitative results from the interview helped generate valuable insights on the interactive system design and its future improvement.

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Short Papers / Demo Sessions

Mixed Reality (MR)-assisted Spatial Logistics Facility Layout Design

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Abstract. With the recent advances of digital transformation, the development of logistics automation has been accelerated to further improve operational effectiveness and efficiency. In particular, the Automatic Storage & Retrieval System (AS/RS) has been widely explored to revamp inbound and outbound operations in logistics facilities. By doing so, space utilization can be further optimised, but not all warehouses are suitable and, as the initial investment is substantial, the long-term benefits must be comprehensively evaluated. This paper proposes an intelligent system that combines an evolutionary algorithm and mixed reality to optimize and visualize warehouse layout design. With the use of AS/RS, the system aims to improve the operational efficiency and space utilization of logistics facilities. The evolutionary algorithm (EA) optimizes the layout by minimizing the total traveling distance between functional areas, while the mixed reality (MR) component visualizes the AS/RS through a Microsoft HoloLens. This approach provides an immersive experience of the optimal layout design and enables the implementation of smart facility layout design with warehouse automation technologies.

Keywords: Warehouse, Layout Design, Automatic Storage & Retrieval System (AS/RS), Evolutionary Algorithm (EA), Mixed Reality

1 Introduction

In recent years, e-commerce has become an increasingly important consumption trend, with the global retail e-commerce market generating over US\$5.2 trillion in sales in 2021 and projected to increase by 56% by 2026 [1]. E-commerce not only offers consumers convenience but also alters their purchasing behavior. Logistics management plays a crucial role in the e-commerce supply chain, connecting warehouses and distribution and serving as the backbone of the e-commerce ecosystem. The operational efficiency of warehouses depends on the layout design, which includes functions such as receiving, putaway, picking, packing and dispatching. Effective warehouse planning is essential to meet the complex demands of the market and satisfy customers' stringent requirements [2]. Customers expect to receive their purchases promptly, with same-day/next-day delivery becoming increasingly common [3]. Any faults or delays at the warehouse can result in customer dissatisfaction and damage the company's reputation. An ideal warehouse layout can improve operational efficiency, shorten operational time, and increase effectiveness, resulting in a more efficient e-fulfillment process [4].

With the advent of warehouse automation, Automated Storage and Retrieval Systems (AS/RS) have been introduced to sort products by conveyor belts and manage the products using data-driven algorithms to reduce order picking time and storage space [5]. However, AS/RS configuration requirements and operating modes may limit scalability and flexibility in warehousing operations.

Once the warehouse layout with AS/RS has been designed and deployed, the entire layout can be changed only with considerable difficulty. For this reason, studies have formulated combinatorial optimization problems to achieve the optimal logistics facility layout design [6], which accurately determines the most appropriate position for each facility.

However, existing facility layout optimization approaches may not fully consider physical and infrastructural limitations. This limitation has led to the consideration of using extended reality (XR) to visualize the optimal facility layout design. The use of mixed reality has been increasing over the past decade [7]. Implementing mixed reality in warehouse operations can provide an immersive experience, particularly for inventory management, resulting in more accurate put-away and order-picking processes. However, there is a lack of research and application on mixed reality-based warehouse layout design. To bridge this gap, this study proposes an intelligent system for optimal warehouse design and visualization by considering the traveling distance between functional areas and other physical constraints. This is achieved by using an evolutionary algorithm to solve the combinatorial optimization problem for facility layout design. Subsequently, the optimal design of the facility layout is visualized using mixed reality to create an immersive experience for logistics practitioners.

2 Literature Review

2.1 Overview of Mixed Reality

Mixed reality (MR) is a technology in which virtual and physical worlds can interact in real time to create new environments and visualizations. In terms of the definition of MR, Milgram [8] proposed a linear spectrum of Real Environment that gradients to Virtual Environment, as shown in Figure 1 below. The Augmented Reality (AR) is located in the left of the middle of the spectrum, indicating that it should take the real object as the environment subject and the virtual object as the additional object. Despite the obvious potential of AR, it is challenging to merge the real and virtual worlds. The level of user immersion in AR scenarios is reduced due to the low level of integration of real and virtual objects. The development of the MR environment enhances user engagement and interaction with the virtual object and the actual environment. This setting extends the viewer's view of the physical and digital worlds by fusing them together [9]. Six existing types of MR are identified: continuum, synonym, collaboration, combination, alignment, and strong AR [10]. As an emerging technology that deals with maximum user interaction in the real world, MR can be used as a new decision-making tool to solve the problems of daily life. In the field of warehousing planning, MR has been applied as a strategic tool. Existing MR application in warehousing planning mainly focuses on optimizing the use of warehouse space with the help of a 3D interactive layout.

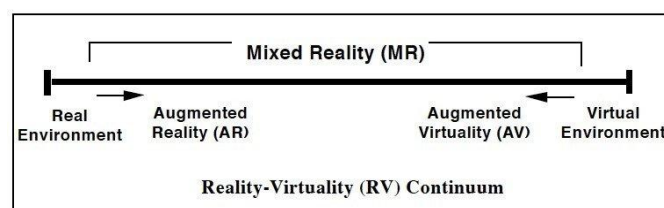


Fig. 1. Mixed Reality Spectrum [8]

1.1 Overview of Warehouse Planning

Warehouse planning is a critical activity in the supply chain to outperform competitors in customer service, lead time and cost control, and includes the planning of: material flows, conveying and handling equipment and warehouse infrastructure [11]. Storage location and order picking are often referred to in warehouse planning and, typically, warehouse layout planning is related to the location of facilities such as machinery and material storage in a warehouse for optimal impact on operational effectiveness. For example, random storage of items required for First-in First-out makes pick up a time-consuming process. Efficient warehouse layout can solve such challenges to the smooth movement of inbound and outbound materials. However, it is hard to simulate this process and design the warehouse layout effectively in reality because of the variety of production, the locations of the pick-up and drop-off points and the individual shapes of facilities [12].

1.2 Overview of Robotic Warehouses

The deployment of robots, automated systems, and specialized software to carry out various tasks for streamlining and automating warehouse operations leads to the creation of the "robotic warehouse." A number of companies have been at the forefront of smart warehouse development in recent years, operating their businesses through the utilization of automated warehouse robots. The internet-connected robots have been deployed to assist human labor in complicated warehousing operations, for example, order picking and cycle counting, which has led to process re-engineering and cost reduction [13]. The process of order picking can be enhanced by arranging for a group of cooperative robots to go to different locations to fetch specific items. Automated Storage and Retrieval Systems (AS/RS) are most commonly used in distribution facilities and are a variation of computer-controlled systems. Such systems make use of the synergies that exist among various technologies and vehicles to facilitate automatic retrieval and disposal of high-volume loads from predetermined storage places with precision and speed.

2 Research Methodology

A systematic approach is proposed to identify and visualise the optimal warehouse layout, which consists of three components: (i) formulation of the warehouse layout optimisation problem, (ii) development of the optimisation strategy using the evolutionary algorithm, and (ii) use of mixed reality for layout visualisation.

2.1 Formulation of the Warehouse Layout Optimisation Problem

The warehouse layout optimisation problem (WLOP) addresses the static quantification requirement to determine the relative positions of facilities and minimize the trip fraction. The Quadratic Assignment Problem (QAP) model is used to solve the multi-row layout problem [14]. QAP is proven to be an NP-complete problem [15], equal numbers of departments and locations are needed for QAP formulation. QAP is an assignment problem where the objective function is a quadratic function of the variables. It involves the product of two variables, and the constraints are linear functions of the variables.

The objective function is defined in Equation (1):

$$\text{Minimize } \xi = \sum_{j=1}^n (\sum_{k=j+1}^n D_{j \leftrightarrow k} \cdot F_{j \leftrightarrow k}) \quad (1)$$

where n is the total number of functional areas in the layout. $D_{j \leftrightarrow k}$ is the distance from location j to k as in Equation (2), where (X_j, Y_j) and (X_k, Y_k) are the coordinates of the measurement points of any two functional areas j and k . $F_{j \leftrightarrow k}$ is the merged move frequency between functional areas j and k as in Equation (3). The decision variable (X_i, Y_i) represents the coordinate of the functional area i in the Cartesian coordinate system, which must be different to other functional areas.

$$D_{j \leftrightarrow k} = |X_j - X_k| + |Y_j - Y_k| \quad (2)$$

$$F_{j \leftrightarrow k} = T_{j \rightarrow k} + T_{k \rightarrow j} \quad (3)$$

2.2 Optimisation Strategy Using the Evolutionary Algorithm

The concept of the evolutionary algorithm is a computing model established by imitating the behavior of biological intelligence in nature to search for a near-to-optimal objective function value. It can be applied to solve a variety of challenging combinatorial optimization problems and find the best solution by using Darwin's evolutionary theory of "survival of the fittest" as a search mechanism in a vast space [16]. Among different EA, the genetic algorithm (GA) is the typical approach to mimic the genetic engineering, such as crossover and mutation of the chromosomes. In an evolutionary calculation, a fitness value must be specified for each member of the group. This fitness function $f: R^m \rightarrow R$ depends on the requirements of the environment. Each $\underline{x}_i$ is composed of m real number components, where $\underline{x}_i = [x_i(1) x_i(2) \dots x_i(m)]$, each real number added a random number Δx to each component when it carried out mutation actions. The typical distribution for this random integer is Gaussian or Cauchy, that is, $\Delta_x^- = \Delta_r \cdot \underline{N}(0,1)$. A comprehensive evolutionary algorithm emerges by repeating the steps below after synthesizing the traits of various evolutionary algorithms [17].

Step1: Population Initialization

Create potential vectors in the m -dimensional vector space as individuals of the group, that is, $\underline{x}_i = [x_i(1) x_i(2) \dots x_i(m)]$, $i = 1, 2, \dots, n$.

Step 2: Fitness Test

Evaluate the fitness values of all individuals within the parents' population pool.

Step 3: Reproduction Process

Select the best parents to generate offspring, which includes reproduction, crossover, and possibly mutation. An individual child $\underline{x}_i$ is copied from this parent. Then use the Gossi-style random number which has a standard deviation of $\Delta_r = \sigma$ and an average value of 0, while performing mutation on each offspring. The Cozey random numbers C make up the random variable vector R , which has the formula: $\underline{R} = [C \ C \ \dots \ C]$.

Step 4: Create offspring

Compare the fitness values of two individuals, $f(\underline{x}_i)$ and $f(\underline{x}_i')$, in the parent generation and the offspring, and generate the individual with the highest fitness to keep for the next generation by crossover and mutation operators.

Step 5: Termination

The algorithm terminates when it either reaches a performance threshold or reaches its maximum runtime.

2.3 Module 2: Mixed Reality for Layout Visualisation

A MR application is developed on the Microsoft HoloLens in this study, which is a standalone and head-mounted holographic display. It combines real and virtual environments and offers users an immersive experience and interactivity, including visualisation of item information, interaction with objects, and control of gadgets [18]. Users can concentrate on an object and use a tapping motion to detect it, while the HoloLens creates a detection instance to identify and show the display and the associated data of an object from a particular database [19]. Operating and interacting are aided by built-in gesture and voice recognition capabilities. Figure 2 below shows the architecture of the developed AS/RS application. First is 3D asset creation, to create the 3D models for the pallet of goods and the ASRS rack, as well as the robot in the aisle between the racks. The AS/RS hologram application development process comes next. It requires API programming and the use of the Unity game engine with the MR Toolkit or plugging. Finally, the app can be deployed after it is built with a visual studio and compiled into a holographic application. Users can interact with the packages using hand gestures and view detailed inventory information with a HoloLens, as well as performing pick up and put away for storage.

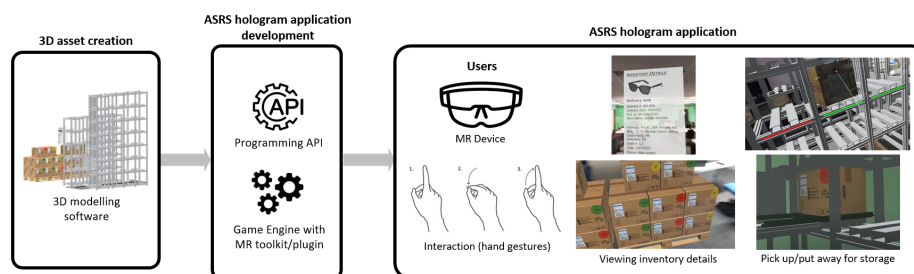


Fig. 2. Architecture of the MR-based AS/RS visualisation

3 Case Study

In this section, a case example is performed on the identification and sequencing of warehouse layouts. Based on the research methodology presented in Section 3, this case example is divided into two subsections.

3.1 Warehouse Layout Design

Warehouse layout is created to meet the demands of warehouse management and production, and planning is needed for all facilities in the entire warehouse. This case example describes the key elements that must be taken into account during the design process, and Table 1 below illustrates a warehouse layout distributed into 8 different areas: I/O, Sorting Area (A1&A2), Inventory Storage (A3&A4), Staging (A5), Service Area (A6&A9), Packaging (A7), Inbound/Outbound (A8), Workstation (A10&A11). Following the establishment of the space function in accordance with the general warehouse, the warehouse is divided into 4x4 small square units with equal areas, and only 11 of the 16 units will be included in the functional area. The workstation, inventory storage, and AS/RS occupy two units of space each. I/O is a fixed ingress and egress channel. Next, we define the frequency from 0 (lowest-not frequent/ no relation) to 25 (highest-totally frequent/same item) that is separated by five points, and formulate the corresponding matrix. To make the total number of functional areas equal to the total number of available positions and to determine the most practicable facility configuration, it is necessary to designate empty positions to D locations within the warehouse, that is, D1-D4, whose frequency is 0. Using the data in Table 2 and equation (1), the variables for each functional area are calculated to determine the order of the warehouse design.

Table 1. The Matrix for the merged move frequency between I/O and functional area

From / To	I/O	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
I/O	-	0	0	0	0	15	0	0	10	0	0	0
A1		-	25	20	20	0	0	0	0	0	0	0
A2			-	20	20	0	0	0	0	0	0	0
A3					25	15	0	0	0	0	0	0
A4					-	15	0	0	0	0	0	0
A5						-	0	0	15	0	20	20
A6							-	0	0	0	0	0
A7								-	0	0	15	15
A8									-	0	0	0
A9										-	0	0
A10											-	25
A11												-

Table 2. The positions with coordinates of optimal layout planning

	A 1	A2	A3	A 4	A5	A6	A7	A 8	A9	A 10	A 11	D 1	D 2	D 3	D 4
X	2	2	3	3	3	0	1	3	0	2	1	1	0	1	2
Y	1	0	1	0	2	0	1	3	1	2	2	3	2	0	3
Position	7	3	8	4	12	1	6	15	5	11	10	13	9	2	14

The best solution for the warehouse layout is to perform the EA calculation for the functional areas that meet the conditions in the initial layout using Excel's evolutionary solver. The final optimization scheme for the entire warehouse's total travel score is 420, as shown in Figure 3 below. According to the results of the proposed method, the functional area closest to the doorway (I/O) is first the service area, including the office and toilet, which is located on the left side of the warehouse in order to reduce walking distance and avoid affecting the main working area. Second, the inbound and outbound are situated at the far right of the warehouse doorway and connected by a horizontal route, separated by two units in the middle, which is conducive to the smooth flow of the passage and ensures that staff can move to each functional area of the warehouse. The staging area, close to the inbound and outbound routes, which serves as a location to gather resources, must be located near workstations and storage areas to facilitate the diversion and distribution of goods. The storage areas are positioned at the edges and corners of the warehouse to guarantee proper speed of movement around the building. Since the workstation needs materials and personnel to assist in a reorganization, the packaging area is placed around the office and workstation for rest and to count personnel. This positioning offers greater flexibility and a more human-centered design than the initial layout.

Initial layout				Optimal layout			
I/O	13	14	15	I/O	13	14	Ib&Ob
IS	ASRA	Office	12	9	Workstation	Workstation	Staging
IS	ASRA	Staging	Ib&Ob	Office	Packaging	ASRS	IS
Toilet	Workstation	Workstation	Packaging	Toilet	2	ASRS	IS
Total score 445				Total score 420			

Fig. 3. Initial layout planning & Optimal layout planning

3.2 Mixed Reality for Spatial Layout Planning

This project makes use of HoloLens as an AS/RS showcase to simulate its operation in a warehouse layout. The 3D virtual AS/RS digital model can be exhibited in a real-world environment and manipulated with the aid of mixed reality technologies. It not only enables managers to preview the layout of the warehouse in advance, but it also simulates the operation of the entire warehouse. In this spatial layout planning, users can use digital content and spatial mapping to experience the AS/RS digital model in the lower right corner of the optimal warehouse, as shown in Figure 4 below. First, hand gestures and voice instructions can be signaled to move 3D virtual AS/RS to different units. Then, place the 3D virtual AS/RS in a specified location in the real environment to experience both the digital model and the real interactive environment. This allows managers to preview and examine the layout to avoid operation failure or delay. Managers can, based on the optimal layout and HoloLens system, conduct mock operations and quality tests on the development strategy of the AS/RS location to ensure the operations run smoothly.

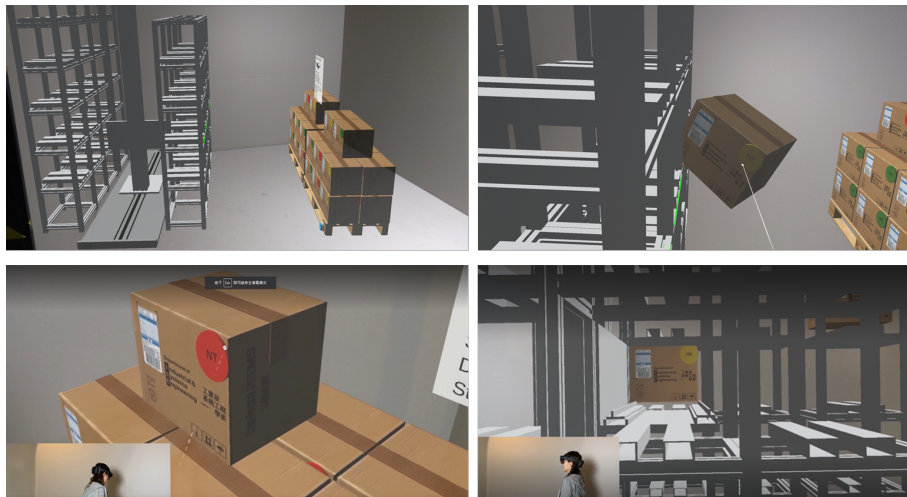


Fig. 4. The AS/RS demonstration and simulation using HoloLens

4 Discussion and Managerial Implications

With the advent of the digital technologies, customer needs and service expectations are constantly changing. It is necessary for companies to commit more resources to systematically develop and improve their services. Optimizing the warehouse layout design allows for better facility utilization and service innovation. AR helps logistics practitioners examine existing layout problems and potential areas for improvement. Additionally, management can become more familiar with the flow of the new warehouse layout and further enhance the operational strategy and adaptability. Taking into account customer perspectives, such as achieving zero waiting time and increasing satisfaction and long-term cooperation willingness. They can make use of the latest AR technology to improve future financial performance or profitability.

In addition to the warehouse scenario discussed in the previous case study, the proposed solution can be applied to other layout design problems such as manufacturing plants and real estate. Typically, end users rely solely on drawings and domain experts for facility design,

leading to a knowledge gap between the end users and contractors, which can result in unsatisfactory outcomes. The proposed solution can help bridge this gap by reducing it, resulting in greater satisfaction and a lower likelihood of the need for reconstruction. Furthermore, stakeholders can gain first-hand experience of facility design and planning, allowing them to fine-tune the design before construction begins. Thus, the proposed solution can achieve sustainable facility design and deliver broader value and benefits to society.

5 Conclusion

This study has presented a proposed research methodology for optimizing warehouse layout design. Evolutionary algorithms can be considered as optimization techniques for warehouse design, while MR assists facility design that reliably eliminates the possibility of warehouse flow delays. . The use of MR-based facility layout planning and embedded simulations allows for the inspection and visualization of machine placement on existing layouts. This approach provides flexibility and ease of modifying virtual content and displays, enabling increased adaptability and leading to significant long-term cost savings. The development of a mathematical model that better aligns with actual requirements can reduce the complexity of 3D modeling and the transformation cost of warehouse logistics relationships. This approach can be applied by companies operating in a range of fields to assist users in creating precise construction plans visually. This methodology provides improved guidance for decision-makers to address potential design mistakes and optimize layout.

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Appendix A. A list of functional areas in warehouses

I/O	I/O refers to the entry and exit points of a warehouse that facilitate the flow of products.
Inbound/Outbound	Inbound/Outbound areas are where goods enter and exit a warehouse, usually located on opposite sides to minimize detours for storage and retrieval.
Staging	Staging is the process of waiting for the next stage of delivery while determining the specific location in the warehouse. It is typically situated near production facilities, raw materials, and finished products.
Workstation	Workstations are used for repackaging products or providing other value-added services based on customer requests. This area modifies delivered goods as necessary.
Packaging	Packaging areas mainly store materials required for packaging products, such as cartons or gummed paper.
Inventory Storage	Inventory Storage is where products are kept until they are delivered, usually set up on mobile shelves to increase storage density.
Sorting Area	Sorting Areas are a critical step before dispatching goods, typically using automated or semi-automated systems (e.g., AS/RS) to place and retrieve products. They are located in or adjacent to the storage area.
Service Areas	Service Areas support facility activities such as offices, restrooms, and equipment battery charging.

The Effects of Body Shape, Garment Size and Silhouette on the Visual Effect of Body Image

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Abstract. Clothing is a vital tool in shaping the image and character of a person. In many cultures, people enhance their body image by wearing particular garments. In recent decades, researchers have explored indices that affect body image, such as BMI, WHR, VHI, etc. Novel pattern-making systems and size recommendation systems have been developed to cater for the wide range of human body shapes. This research aims to investigate the impact of garment size and silhouette type on perceptions of body image. We divide the human body into five typical body shapes and explore the visual effects of five silhouette types and sizes on body image. The results reveal that each silhouette does have specific effects on different body shapes. Results also showed that size fit does not equate to style fit. The study results can be used to create custom designs of the right size and style for image enhancement. This research has we believe great potential for informing and enhancing the online shopping experience.

Keywords: Fashion, Body image, Garment size, Silhouette

1 Introduction

In contemporary life, daily dressing not only achieves basic functions such as providing warmth and shielding, but also for enhancing the body image and shaping the personality. Malcolm Barnard (2002) introduced fashion and styling as a way of performing and challenging social identities like gender, sexuality, race, and class. [1]

Undoubtedly, it is human nature to pursue a more attractive body image. It was found that the cathexis of a dressed body is much higher than the body image in the nude state [2]. Besides, as the gestalt effect indicates, the overall perception will be better than the sum of the partially perceived effects [3] if clothing is well-styled. However, many consumers still find it difficult to choose appropriate clothes, as evidenced in a cross-cultural study, more than 50% of females and 60% of males reported that they had difficulty choosing a suitable style [4]. Thus choosing garments that confer a better look has now become a significant issue.

This research investigates the visual influence of clothing size, silhouette, and other design elements on body image enhancement. The study may further optimize existing fashion product recommendation systems to filter suitable apparel based on the individuals' body shape and size. We have also provided a mock-up of a recommendation system design called "iFit", which applies our findings to apparel product recommendations for consumers based on body shape and measurements.

2 Background

Numerous studies have demonstrated the effect of clothing on impressions of the body over the centuries [5]. It has been widely recognized that differences in dress style affects the formation of social impressions of the wearer [6]. Mentally, the enhancement of one's self-esteem is related to the degree of satisfaction with body image [7][8]. Conversely, dissatisfaction with body image may over time cause mental and physical disorders [9][10]. For that reason, researchers have studied the indices of garment patterns and body measurements in recent decades. The researchers have aimed at precisely quantifying the indices that will affect the body image. BMI (body mass index) and WHR (waist-hip ratio) are commonly applied for clinical body composition measurement in individuals [11]. Thompson & Gray (1995) created a 9-point-scale to describe BMI ranging from thin to obese [12]. These two indices have also been regarded as crucial influencers for physical attractiveness [13]. Specifically, a comparatively low WHR tends to be perceived in various cultures as attractive, regardless of the BMI level [14]. In addition, the types of body shapes were defined according to different parameters such as shoulder-to-waist ratio, waist-to-hip ratio, shoulder-to-hip ratio, etc. Female body shapes were classified into triangle(A), inverted triangle(V), rectangle(H), hourglass(X), and oval(O) shapes [15]. However, there is a lack of research focusing on male body shape classification. The one most adopted by other studies divides male body shapes into triangle, inverted triangle, rectangle, inverted trapezoid, and oval shapes [16].

Research has explored the design of garment patterns that achieve customized fit for an individual. Fan et al. (2003) and Liu et al. (2006) studied the fit impact on visual body size and trained artificial neural network models to predict the perceived size of men while wearing different sizes of garments. The result suggested that large size of T-shirts tended to visually increase body size when the wearer's BMI was less than 20. In contrast, the wearer looks thinner in large garments if the BMI ranges from 20-28 [17][18]. Nevertheless, the former study has only analyzed the effect of apparel fit on male body size perception, and the aesthetic impact has not yet been examined. This present research investigates the impact of size on the human body while exploring the effect between body shape and silhouette. The research results reflect contemporary aesthetics and the values of the recommended system application.

3 Methodology

The methodology of this research involves two experiments. The first experiment explores how T-shirt size affects the perceived body size. The second experiment was designed to investigate the impact of garment silhouettes on body enhancement.

3.1 The visual effect of T-shirt size on body size

Scanned Avatar & Digital Pattern. In this experiment, a database of digital avatars was built for taking body measurements, patternmaking, 3D fitting, and analyzing. 32 females and 25 males scanned via TC2 were converted to avatars in CLO3D, following which the avatars were divided into 6 groups by bust girth at intervals of 10cm. The median for each group was taken as the general bust girth to make patterns of T-shirts. Sizes of T-shirts from small(S), to medium(M) and large(L) were then graded, with ease allowance ranging from 3cm, 10cm, and 17cm respectively. Next, the graded T-shirts were fitted on avatars of different sizes. Both standing and walking postures of fitting images

were taken for rating. The settings of all image properties were arranged using the same specific standard.

Rating system. Participants aged between 23–33 were invited to rate the fitting images visually. The participants were first trained to understand the Thompson and Grey 9-point scale to recognize the 9 different levels of body mass. After training, they were presented with images of experimental avatars wearing different sizes of T-shirts. The pictures were randomly presented and only stayed on the screen for 3 seconds. After viewing the images, the participants were required to use the Thompson and Grey 9-point scale to award a score (of 1 to 9) for each model.

3.2 The visual impact of garment silhouette on body shape

Avatars of 5 Typical Body Shapes. Digital avatars representing five typical body shapes were created with varying ratios between shoulder, bust, waist, and hip. We classified female body shapes into five typical shapes: triangle, inverted triangle, rectangle, hourglass, and oval, and grouped male body shapes into triangle, inverted triangle, rectangle, trapezoid, and oval. Each body shape also has three levels of body build.

Silhouette & Rating Image. The silhouette types of garments were summarized by letter category, including A, V, H, X, and O for females, A, V, H, and O for males. The silhouette designs are classified by the location of extra fullness on the shoulder, biceps, waist, hip, and button edge, respectively (see Figure1 below). The sizes of patterns were graded according to the measurement data from US-ASTM [19][20][21].



Fig. 1. The extra fullness on each silhouette of male(right) and female(right)

Rating of visual perception. Two sessions were involved. 61 participants aged between 23–30 were recruited to rate the fitting images visually. First, the participants were trained to recognize the five typical body shapes in the first session. They were then presented with images showing the body in a nude state and the same body dressed in garments of different silhouette types on a single page.

4 Results and discussion

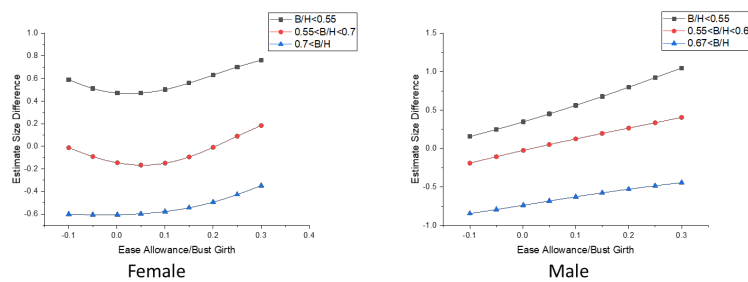


Fig. 2. Impact of garment ease allowance on male and female body size perception

The results showed that the correlation between perceived body size and garment size was different for men and women. The data in Figure 2 above show that increasing ease allowance/ bust girth makes the perceived male body larger. For the female group, with ease allowance in the proportion of bust girth between 0.0-0.1, for example, 0-10 cm for a 100cm bust girth, the perceived body size tended to be the lowest.

In the second experiment, the hourglass body shape in women and the inverted triangle in men were seen as the most attractive in their respective gender groups, which explained why all dressed hourglass female models and inverted triangle male models were perceived to have smaller (fitter) body size than the naked body under clothing. On the other hand, the oval silhouette provided the best male body image enhancement. The reason for this may be that the garment covered the belly, or other less attractive characteristics of the body, especially in regular sized and obese men.

The results reflect the effect of garment sizes and silhouette types on various body shapes from a visual perspective, and provide a new way of evaluating 'fit' with respect to aesthetics and style. The results reported here endow the aesthetics of fashion design with functionality and purpose, allowing fashion designers to help their customers to modify their body shape to create improved body image. Our recommendation system, iFit, helps build a bridge between consumers and apparel designs by giving recommendations based on analysis of users' body image and our research results to enhance body image. This research is ongoing and in future work, more design elements and apparel categories will be investigated, and more raters will be recruited to validate the results.

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AI Ethical Issues (AIEI) Cards: Supporting Responsible AI-Enabled Solutions Design in Healthcare

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Abstract. Despite the existence of various ethical guidelines for AI design, ethical concerns remain in the healthcare sector. To address this challenge, we developed the AI Ethical Issues (AIEI) cards based on recently identified ethical guidelines specific to healthcare. These cards are designed to assist designers in integrating ethics into the design process of AI-powered healthcare applications. In this paper, we demonstrate the design process and evaluate the usefulness of the AIEI cards through a pilot study. This study involved a co-creation workshop with four design students with varying AI design experience. The students used the AIEI cards to identify ethical concerns and propose design improvements for Strava, an existing health application. The results demonstrate the potential of the AIEI cards to guide designers in creating responsible AI-enabled solutions.

Keywords: AI Ethical issues (AIEI) cards, Responsible AI, Healthcare

1 Introduction

Machine Learning (ML) is a significant component of AI that has propelled its development to new heights [1]. The healthcare industry is one of the most promising sectors for AI deployment [2]. However, it is crucial to recognize the potential risks and unintended consequences associated with the use of AI in healthcare applications [3]. Policymakers and professionals have established numerous guidelines to help stakeholders and practitioners address the ethical risks of AI development. Nevertheless, these guidelines focus on developing, deploying, designing, and applying AI technology in a broader context and lack a domain-specific approach, particularly in healthcare [4]. To address this gap, Li et al. (2022) conducted a systematic literature review to examine the ethical issues and strategies in the creation of AI-based solutions for healthcare. The review identified 12 main ethical issues and 19 sub-issues, along with related strategies [5]. These guidelines encourage researchers to turn the current guidelines into actionable design guidelines for the development of ethical AI solutions. To achieve this goal, it is necessary to develop ethical tools that support ethics by design [6]. Recently, there has been an increased focus on incorporating ethical considerations into AI systems through the concept of ethics by design [6]. Cards are an effective and affordable tool to aid the design process, provide information, methods and good practice in a convenient form [7]. This paper describes the creation of a card-based tool, the AIEI cards, that help designers assess and redesign the ethical risks associated with AI-powered applications in the healthcare domain.

2 Turning Principles into AIEI Cards

Ethical considerations play a crucial role in accepting AI in healthcare, where AI applications must comply with laws, regulations, and privacy principles [8]. To ensure that AI can support critical decisions in healthcare, specific ethical issues must be addressed to avoid misinterpretation of AI, which could have severe consequences for humans [5]. Li et al. (2022) have identified 12 main ethical issues, 19 ethical sub-issues, and related strategies for creating AI-powered healthcare solutions [5]. In this study, we aim to transfer their work into a card-based tool to support designers in designing ethically responsible AI solutions.

Firstly, two design researchers have benchmarked several card-based tools developed to support ethics by design. These include the “Moral-IT deck” [6], “IDEO cards” [9], “Privacy by design ideation cards” [10], and “AI Blindspots healthcare” [11]. All these existing cards were made either specifically to address one ethical issue or general ethical issues. From benchmarking the card structure, we found that General Content, Questions, Case Illustrations, Images, Categorization, and Format are the essential components of card structure design. Secondly, according to the defined six components, the two design researchers first converted the 12 main ethical issues and 19 ethical sub-issues from Li’s work [5] into the General Content presented on cards. They formulated Questions to address the specific ethical issues listed on the cards. They selected healthcare examples as Case Illustrations from various sources [12–21] and Images from “Openverse” [22] to explain the main and sub-ethical issues in healthcare. They also determined the Categorization and Format of the cards by brainstorming with 5 design students according to the categories of ethical issues proposed in Li’s work. Eventually, the AIEI card deck was created and is shown below (Fig. 1, available at <https://bit.ly/40yZYRP>).

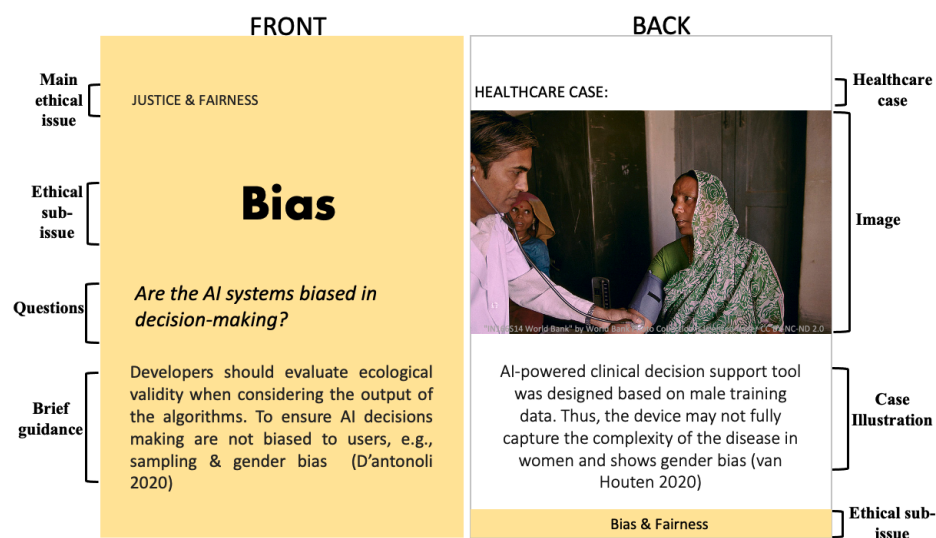


Fig. 1. AIEI cards of the main ethical issues and sub-issues

General Content. Each AIEI card includes a front and back page. The front page features text describing each main and ethical sub-issue, questions, and brief guidance. The back page contains healthcare cases, images, and illustrations for each ethical sub-issue.

Questions. Like existing card decks [6,9,11], questions related to each ethical sub-issue were listed in the card application process to trigger the discussion during the evaluation process. Ethical

concerns and solutions emerge from the practical level [23], and ethical decision-making is mediated through design practice [24].

Brief guidance. Similar to [9–11], the AIEI cards include brief guidance based on strategies from Li et al. [5], which guide users' design process with AI.

Case Illustration. Like the three cards described earlier [9–11], we applied cases in healthcare to explain the related ethical considerations of each card. This helps users comprehend each issue and use the card competently.

Images. Images are applied on the back page of the cards to support the understanding of the linked ethical issues. In card design, images serve aesthetic and thought-provoking purposes [25]. Like most cards [6,9–11], the AIEI cards include images that illustrate healthcare cases and further explain the ethical sub-issues.

Categorization. Like existing card-based tools [6,10,11] AIEI cards were colour-coded by different main ethical issue categories, with sub-ethical issues corresponding to the associated main issues.

Format. The cards are approximately 3.0" by 4.4" in size, providing flexibility for various design activities.

3 Evaluation

We conducted a pilot study with four design students with various experience in designing AI solutions to assess the value and usability of AIEI cards. The study evaluated the ethical issues and created redesign suggestions for Strava, a sports app tracking physical exercise through GPS. The study was conducted via "Miro," an online workshop platform. Beforehand, we analyzed the users' journey map and the interactions with the back-end AI technology of Strava. During the workshop, participants used the AIEI cards to identify ethical issues and propose related design improvements. The AIEI cards were displayed on sticky notes on the Miro platform. Participants copied and pasted the relevant cards into the related user journey of Strava (see Figure 2 below). Similarly, the design improvements were also written on the sticker notes and pasted next to the user journey. After the workshop, we interviewed participants to reflect on their experience with the AIEI cards. We collected data through participants' final deliverables on the Miro board, and we also interviewed them to obtain their reflections on the usefulness of the cards in identifying ethical issues. The data analysis revealed that data privacy and cyber security were the most addressed ethical issues in the workshop. Strava collects user profiles, health, and exercise data, which raises privacy concerns. Using GPS also raises cybersecurity considerations as it can leak a user's exercise habits and home address. However, it is essential to note that the validity of identified issues may have been influenced by reported news or academic literature. The interview also revealed that the AIEI cards helped the designers categorize identified ethical issues and improved their understanding of such issues.

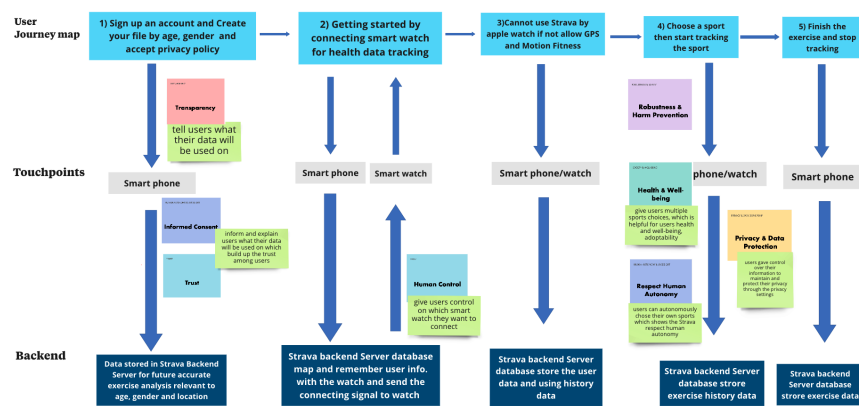


Fig. 2. Results of identified ethical issues of Strava on Miro

4 Conclusion

Considering the outcomes of our study, we can conclude that applying a care-based tool with design actions based on existing guidelines in healthcare helps designers to identify the ethical issues and propose design improvements at the design stage. The AIEI cards provide participants with a broad understanding of various ethical topics, thereby enhancing their knowledge. However, it is uncertain whether the cards supported the identification of real and valid ethical issues related to Strava. In future research, we will include an ethical issue list for Strava to verify the findings here. Additionally, the user experience and usability of the AIEI cards also need to be evaluated with a larger group of designers in a future study.

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New Design Concepts to Enhance Communication and Interaction among Unsociable Young People in Co-living Spaces

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Abstract. The theme of this research is to explore and suggest solutions to the communication and interaction problems of unsociable young people. Co-living may well become increasingly common in the future, with young people residing in co-living apartments or school dormitories that increase the chance of interacting with strangers. Unsociable or less sociable residents may find it difficult to interact with their flat mates, and may fail to adopt behavior appropriate to common areas in shared living spaces and public areas. The researchers have proposed a design called the SO Chair to help such people communicate with others.

Keywords: interaction, young generation, co-living space, public, private

1. World-Wide Young Generation Social Problem

Unsociable people outnumber sociable people in the world according to Agrawal [1], who pointed out that the young people struggle to have interaction. After the turn of the millennium, the number of unsociable young people appears to have increased rapidly. They feel stressed, uncomfortable and insecure in public place and find it difficult to communicate with others. As a result, they may avoid communicating and interacting, which is deleterious to both their social life and mental health. However, Agrawal also saw that these young people more frequently interact with others online. The BBC carried out world-wide research [2] in which they found that 40% of young people (16-24 years old) either often or very often feel lonely. Loneliness will occur for anyone who lacks social contacts and relationships. "I am surrounded, but I feel so lonely" is often heard. The mental health charity Mind found that currently the loneliness problem is getting more common globally [3].

We would like to help solve this problem with a design that can increase privacy, security, and comfort, while also increasing the interaction with others. These two functions seem to be opposed, but a combination of technology and with the right materials can create a design that resolves apparently conflicting functions.

2. Human Experience in Public & Private, Interaction & Alone

The co-living may well be the future for the young generation who want to be independent and need to rent low cost accommodation.

According to research done by Youth I.D.E.A.S (2019) about co-living in Hong Kong [3], the most popular reason for young people renting their own place is to increase their privacy and independence. However, renting a private apartment or a public housing flat is difficult, especially in countries, such as Hong Kong and the United Kingdom. Co-living apartment or school dormitories for students may

be the only options. Therefore, we have chosen co-living space as the main background to investigate interaction and how to help unsociable young people feel safe when using shared facilities like the living room, and increase their chances to interact with people. In the other words, the design we have developed allows for non-traditional interaction so that unsocial people can make friends and interact with strangers in a more comfortable way. People tend to spend a lot of time around furniture, for example, seats on public transport, benches in public places, the sofa at home and most of all the bed. The Smartphone is essential to the research, and according to statistics from 2023 [4], young people on average spend 3.25 hours a day using their Smartphone.

We have used a specially designed chair with Bluetooth technology to help unsociable people use their phone to connect to the chair so as to enhance the interaction between them and the design.

3. Research Method

To understand the habits and preferences of unsociable people indifferent situations, it was necessary to conduct a questionnaire survey and interviews. The primary research was conducted online from September to December 2002, with 109 respondents under the age of 40 years, and most 20 to 30 years old. In the questionnaire we used co-living spaces and public places as examples to explore interviewees' living habits. Before asking questions, we asked the interviewees to define themselves in terms of sociability on a 5-point scale. Most respondents chose 1 (totally not a sociable person) or 2 (a little bit unsociable), which means that over 75% of respondents reported themselves to be unsociable. Only about 23% interviewees ($n = 4$) reported that they were totally sociable and 3 felt they were quite sociable.

After dividing the interviewees into two groups: the sociable and the unsociable, we asked the seating preferences of these two groups of respondents. According to the responses to Question 2 (see Figure 1 below), asking about the seat they would take if there was nobody sitting at the same table, we can see that seats 3, 5 and 7 are the most popular for these two groups of interviewees, with 1, 3, 5 and 7, the "corner seats", being the most popular for the unsociable group.

Which seat do you choose? 你選哪個座位? *

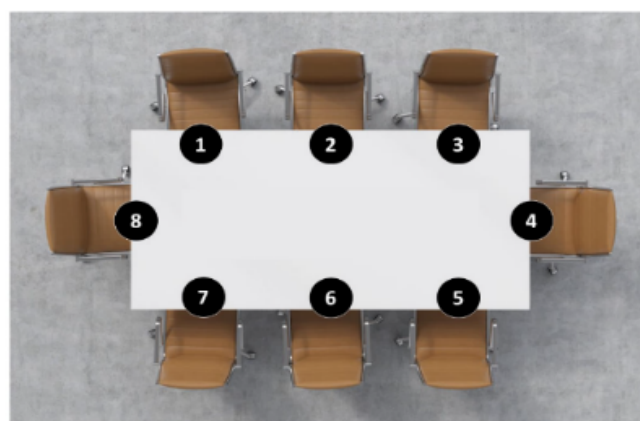


Fig. 1. Question 2: "Which seat would you choose?" Studying the young generation's seating habits

Seat 7 is the most popular seat preference in both sociable and unsociable groups. To examine the different reactions and preferences of these two groups, we assumed a situation in Question 3: a stranger is sitting in seat 1, and the interviewee must choose a seat at the same table. From the

results of Question 3, we can see differences in seat preferences of the groups and the differences are based on distance from the stranger: unsociable people mostly choose 3 and 5, the seats furthest away from the stranger, and which are also “corner seats”. Compared with seat 4 which also is a longer distance from the stranger, seats 3 and 5 allow them face away and prevent making eye contact. They feel safer and more private sitting in a “corner seat”. Sitting in the corner draws less attention from others and this helps the unsociable feel more comfortable. From the seat preference question, we learn that when unsociable people do not recognize or do not want to interact with others, they tend always to keep a distance from them, take a seat facing away from others to prevent having eye contact and to avoid feeling embarrassed and nervous. This demonstrates that visual blocking and “corner seat” placement is effective in making the user feel safer in a public area, and so these elements were added to the design.

4. Design Concept: Create a Comfortable Private Area in Public

Unsociable people tend to prefer to stay in their private room, but may still want to make new friends. To encourage them to step into the common area and interact with hall or house mates, we decided to design for them a comfortable, attractive private space within a common area (see Figure 2 below) so that they can slowly adapt to the common area over a period of time.

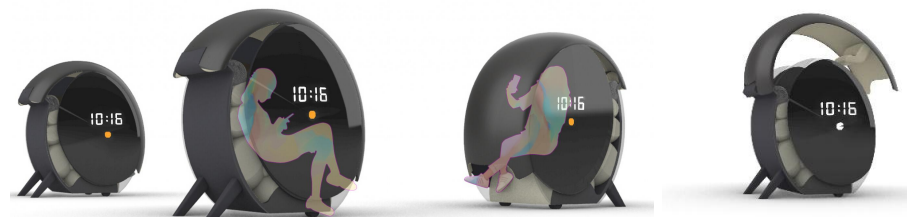


Fig. 2. SO Chair Design

The “SO Chair” is inspired by the airplane cockpit. It is placed in a public space such as the living room. In each public space, we suggest putting 3 to 5 SO Chairs, placed 2 to 3 meters from each other, thus creating a sense of comfort through distance and allowing the unsocial to pay little attention to others’ reactions.

The SO Chair combines the functions of a chair, a speaker, and a mode of communication. The material and dimensions of the chair are based on anthropometric data and the normal dimensions of a 1-seat sofa, with added minor changes to improve comfort. In addition, this chair provides 90% visual blocking with just 10% transparent material to reduce feelings of oppression if the user remains in the chair for long time. It is suggested to place the chair with its back against a wall in the common space. When the SO Chair cover is utilized, the transparent material can let the user still have some connection with the external environment, while at the same time feeling secure.

When the user wants to have face-to-face interact with others, they can open the cover. Due to the design of SO Chair, eye-contact is allowed in one direction to the front, with 2 visual barriers on both sides to block others’ attention. Like the preference for a “corner seat” in public places, this arrangement serves to reduce the user’s feelings of insecurity.



Fig. 3. SO Chair's Bluetooth speaker and phone positions

As can be seen in Figure 3 above, the Bluetooth speaker is placed on both top sides of the backrest, so that the users can use the lowest volume to hear sound clearly and not disturb others in the common space. In the front of the seat, there is a place for a smart phone or iPod so that users can function normally in the chair.

5. Rise the Interaction of Unsociable People and social anxiety people who live in co-living place in the future.

Communication is increasingly changing to a non-face-to-face form, and unsociable people tend to be more willing to have interaction with people through smart devices and in a secure environment, as provided by the SO Chair. Users will use their smart device to link the SO Chair with Bluetooth and the SO app will allow them to interact with others through SO Chair. There are 3 stages of interaction provided by the SO app:

Stage 1: The app will remind the user of the name of the stranger sitting in another SO Chair in the same common area at the same time. The app will also provide some "know more" questions for the user, so he/she can use them to get to know the stranger.

Stage 2: If the app finds that the user can communicate with the others without using "know more" questions, it will stop providing them.

Stage 3: If the user has chatted with the stranger on certain days, the SO app will advise the two of them to use the video call function, thus achieving nearly face-to-face communication. Finally, the app will encourage them to open the cover of the chair to have a real face-to-face interaction.

Unlike normal social apps or software, there will be 3 points to evaluate the user interaction, which helps users decide when to move from Stage 1 to Stage 2 and Stage 2 to Stage 3. In this way, the SO app provides graded, step-by-step interaction. The time between the users seeing a message to when he/she starts responding is a key point. In real face-to-face conversation, according to research published in the Proceedings of the National Academy of Sciences people respond quickly when they feel more connected to each other and also feel happier during conversation.

Jeffrey Hall [6], an expert in communication, published a paper in the Journal of Social and Personal Relationships about the amount of time necessary to make friends [7]. It showed that it takes 40-60 hours to move from mere acquaintance to casual friend. This means that the time of the first 20 to 40 hours messages will be compared with the messages after that, and the app can evaluate the status of the user by his/her speed of response and then decided whether he/she can move from Stage 1 to 2. Moving from Stage 2 to Stage 3 will be decided by the number of texts and whether the texting time totals more than 60 hours.

Building up interaction takes time, and so the app can also be used when the user is not sitting in the chair. However, for the unsociable or high anxiety user, we recommend that they use the app in the SO Chair mostly to help them adapt to interaction in common spaces effectively.

In addition to the assisting function during interaction with strangers, the SO Chair allows people with the same interests and hobbies to connect together. When two users in two SO Chairs are listening to the same song or singer, the SO app can send them a reminder of each others' names. The purpose of the SO Chair is to help unsociable young people to make friends co-living situations. We developed this chair to bring them calm and confidence, and future research will focus on users evaluating the effectiveness of the chair.

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The Connection of Educational Toy and Technology

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Abstract. Games and toys play a very important role in children's lives, contributing to the development of a range of cognitive, motor, psychosocial and linguistic skills. This report describes the design and use of a novel educational activity which combines the classic skill-building features of toys and games, but which also links the real and digital worlds in a creative and interactive way for both preschool children and their parents. The activity is called Un.Blox and it consists of three progressive stages: learning, practice and creation. Interaction is enhanced at every stage by the use of an augmented reality (AR) app.

Keywords: Toy Design, Digital, Children, Creation, Education

1 Introduction

Games and toys play a very important role in children's lives. They contribute to the development of cognitive, motor, psychosocial, emotional, and linguistic skills. Games and toys also play a key role in raising self-confident, creative, and happy children, who can contribute to society as healthy individuals at every stage of their development [1]. . The purpose of the study is to enquire into the direction of the design of children's games and design a toy suitable for children. Finally, the report will describe the toys, which are based on Un.Blox.

There are certain toys that have been around for centuries, such dolls, but they have changed in appearance as time has passed. The way that toys have been made has changed throughout the years too. However, there are some toys that have been and remain particularly important. The very influential LEGO started to become popular during the 1950s; a toy that would allow people to create their own buildings with bricks you could slot together. Barbie dolls and action men then started to become popular in the late 1950s. These are still the top 2 most popular toys. Technology has advanced greatly since then, especially with the rise of things such as video games. Toy makers have played around with toys that use electronics, such as electronic keyboards for young children, phones that can speak back to you when you put them next to your ear, and dolls that are able to move of their own accord.

Parents' views on children's toys were highlighted by the Toy Association in the 2022 Q4 toys trends update. Although today's kids grow up as digital natives, their parents still care about children's real-life memories. Consequently, the trend for screen-free toys is on the rise. Parents are searching for toys that allow children to customize their play experiences; digital worlds that come to life; and family-oriented playthings that supersize and innovate on classic play concepts. Additionally, toys that allow "New Gen Creators" to use their imaginations and customize their own play experience

are on the rise in 2022. These encourage children to create and share their own content, such as artwork, videos, and photos. This trend also encourages intergenerational play, allowing children and their parents to create and play and build skills together through construction, drawing, coding, photography, and filmography. [3]

Playing is an action involving fun and learning in which a child willingly participates, while toys are tools they use while performing these actions. The skills learned during playing will have an important function for the child throughout life. While playing games, they learn to deal with difficulties, show mutual respect and learn to share [1].

3-5 years old preschool kids are in the visual stage of development. Preschool kids can learn to identify and name shapes such as circles, triangles, squares, rectangles, and ovals. By using materials such as posters, blocks, books, and games, teachers can expose children to various shapes and help them analyze two- and three-dimensional shapes in various sizes and orientations.

Teachers introduce children to different kinds of triangles such as equilateral, isosceles, scalene, and right-angle triangles. With the help of colors, children can more easily identify shapes. For example, kids can use colored tape to outline the right-angle triangles in red and scalene triangles in blue. Also, children can also create a space-scape by using cylinders as tree trunks, spheres as treetops, and rectangles as buildings. Parents and children can work together to label the shape-scape, count the number of shapes used, and plan additions to the structure.

Once preschoolers can correctly identify plane figures, such as the square, circle, triangle, rectangle, hexagon, and solid or three-dimensional shapes like the cube, cone, cylinder, or sphere, they are ready to create and then take apart shapes using materials provided by the teacher. For example, children can create a shape with different materials like toothpicks, pipe cleaners, straws, or craft sticks, and they can create a new shape by combining two or more shapes; for example, put two triangles together to form a rectangle. Preschool kids are also able to play with tangrams. Children can start by laying tans on each pattern when they have several sets of tangrams and pattern cards on hand. They can progress to re-creating the pattern on another surface and making up their own patterns. [4]

2 Design Concept Development

Un.Blox introduces children to different shapes in a way that stimulated their creativity and imagination. Our goal is to let children of 3 to 5 years old recognize different simple shapes in plane and stereoscopic forms, and stimulate children's imagination and creativity through building different patterns. To enhance children and parents' interaction, an augmented reality app (AR app) will be utilized to let children and parents learn and create in the virtual world. Un.Blox is divided into 3 parts: Learning, Practice and Creation.

2.1 Learning

In terms of learning, children aged 3 to 5 years old are in the golden period of recognizing different shapes and learning how to distinguish the shapes. Un.Blox contains two puzzle boards and over 140 pieces of solid shapes; for example, cones, cubes, cylinders, cuboids, hemispheres and more, and children are guided to recognize different shapes and put the correct shape in the right place on

the puzzle board. The puzzle board not only guides children to place the correct shape on the same shape pattern, but children can also use different shapes to combine together to create a new shape, which helps to train children's elaborative faculty. In fact, an augmented reality app (AR app) and Un.Blox can be mutually coordinated. The app (see Fig. 1 below) introduces different shapes and children can place the correct shape on the puzzle board. AR apps make learning fun and interactive by creating a digital overlay on the physical world, allowing children to see and interact with 3D objects and shapes in real time.

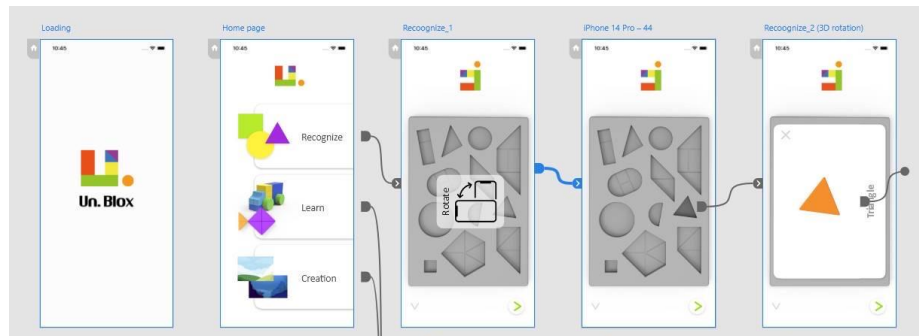


Fig. 1 AR mobile app

2.2 Practice

The second stage of Un.Blox is practice. After learning and recognizing different shapes, it is time to let children have hands-on practice in building different patterns. Un.Blox provides three types of theme cards (see Fig. 2 below): Animals, Transport and Buildings, from the easy to the hard level. The cards are also divided into two types, one provides different patterns which are built by the blocks to guide children to build the shape (see Fig. 3), and the other type consists of real patterns, which help children make a pair with the pattern built by the blocks. This stage not only trains hand-eye coordination, it also helps children learn and recognize different real-world objects.



Fig. 2 Different theme cards



Fig. 3 Build different patterns

The app assists playing and also connects with the real world. AR apps can help children see the real-world applications of what they are learning. For example, they can see how different shapes are used in everyday objects such as buildings, vehicles, and household items.

2.3 Creation

The final stage of Un.Blox is creation. Children can use their imagination to create different kinds of patterns and characters. Un.Blox encourages children to use their imagination to bring their vision to life. Un.Blox provides different empty cards for children to create their own characters and new objects in their everyday lives. Un.Blox provides various scenes such as jungle, sea, desert and more, to allow children to create their own scenarios. This stage not only stimulates imagination and creation, but also helps children develop their storytelling skills.

To enhance children and parents' interaction and retain all the creations that children make, parents can use the app to save all their children's work by taking photos and the app will automatically upload all the blocks to the phone. After uploading all the blocks into the app, AI can take different actions inside the app. so that children can make changes such as by zooming in or out of the blocks or by making the characters move around inside the scene, which makes the creation more realistic and interesting. Parents can share their children's work with others too, and so build up a network of interested parties.

3 Conclusions

Un.Blox combines classic game concepts and technology. Children in this digital era can handle technology products easily but may use the technology in a passive way. Un.Blox is not only an educational game, it also provides opportunities for children to create different objects in the virtual world. It empowers children to connect real life and the digital realm, and so allows them to become active participants in a world of creative and interactive learning.

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Slow Tourism Service System for the Post-Pandemic Decade

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Abstract. The outbreak of COVID-19 and the preventive measures taken to curb its spread have significantly impacted human activities. With the ongoing iteration of the virus, there is growing concern and uncertainty about the prospects for overseas travel. This research focuses on the changes in behaviour among Generation Z travellers in Hong Kong and aims to investigate the impact of the pandemic on their travel activities. One noticeable trend is the rise in solo tourism. The effectiveness of suggested preventive practices is uncertain in travel destinations, simply owing to inevitable local and traveller interactions. Recognizing the precariousness of this situation, this paper proposes a traveller-oriented, slow tourism service system for the post-pandemic decade using the Fego travel app.

Keywords: Sustainable tourism, Eco-tourism, Service design, Digital product

1 Introduction

The development of fast-paced tourism driven by connectivity and globalisation in the economy, culture, and social life came to an abrupt halt with the world-wide surge of COVID-19. Until early 2022, there was no patent solution to opening borders, despite the growing call for opening up. The implementation of quarantine and testing and tracing policies on overseas travellers was both capital and labour intensive. Since that time, even sincere attempts by authorities to encourage movement have failed to restore pre-pandemic levels. However, the unprecedented situation brought about by COVID-19 has presented the opportunity to rethink and redesign tourism. In our work, we consider the early implementation of airline security screening and controls in response to widespread threats of hijackings (Blalock et al., 2005) [1], and propose how a delicate balance between efficient safety measures and smooth travel experience can be achieved for the post-pandemic decade using the Fego travel app.

2 Material and Methods

2.1 Rising travel attitude for slow tourism

With border closures in place for years, people are both excited and anxious about travelling abroad. However, a new travel attitude has emerged whereby people prefer to travel less frequently but for longer durations. Slow Tourism is a modification of travel and leisure which yields more authentic experiences (Clancy, 2017; Dickinson & Lumsdon, 2010) [2-3]. Heitmann et al. (2011, 117) stated that

slow tourism is “a form of tourism that respects local cultures, history, and environment, and values social responsibility while celebrating diversity and connecting people (tourists with other tourists and host communities).” [4] It emphasises connections with local citizens and cultures, reducing our carbon footprint and a shift in perceptions of travel experience compared to traditional tourism (Dickinson & Lumsdon, 2010) [5]. Demographic changes have a close connection to the development of tourism, and understanding these trends can help anticipate future developments (Grimm et al., 2009; Yeoman et al., 2013) [6-7]. A survey was conducted among Generation Z in Hong Kong between December 2021 and January 2022, with 120 respondents, 52% female and 48% male, covering travel preparation, solo tourism, and travel during the pandemic. Results showed a significant increase of 24% in solo tourism, which shares similarities with slow tourism in terms of personal growth and self-immersion. Travellers enjoy greater autonomy in trip planning and embrace unanticipated opportunities and itinerary variations.

2.2 Methodology: Interview with experienced slow tourism traveller on exploring Generation Z travel behaviour

The tourism and travel industry is significantly influenced by Generation Z, which plays a crucial role in its development (Barnes, 2018) [8]. These young individuals tend to challenge themselves, are bucket-list oriented, and seek personal growth (Expedia, 2017) [9]. A survey conducted on Generation Z respondents reveals that 97% of them use social media as their trip-planning source, given their familiarity with smart gadgets, networks, and media as “digital natives” (Grail Research, 2011; Southgate, 2017) [10-11]. With their heavy reliance on social media, they are more inclined to seek traveller-centred online services that are customised and user-friendly.

Generation Z’s travel plans are also influenced by what they see on social media as it allows them to share their experience and get inspiration during their vacation. (Kang & Schuett, 2013; Xiang & Gretzel, 2010) [12-13]. Social media such as Instagram, Snapchat, and YouTube are the mainstream choices. However, young travellers are also aware of the social impact of their actions and choose activities that align with personal values (Abdullah et al., 2018) [14]. Therefore, understanding their personal preferences is crucial in designing customised itineraries that align with their motivation to perform activities that benefit society (Forgas et al., 2009) [15].

To gain insights into experienced solo travellers’ most unforgettable travel experiences, a survey was conducted with the hypothesis that “Covid-19 is unable to clean up to zero cases worldwide, and people have to be vaccinated for travel”. Based on their professional or educational background, individuals tend to choose activities that align with their interests, such as eco-tourism for an environmental science student and museum visits for an art student. Additionally, investigating Hong Kongers’ bedtime behaviour revealed that the majority of teens plan their trips at bedtime, sparking the need for an efficient planner (Trips at Midnight: The Hongkongers Who Book Holidays in Bed, 2018) [16].

2.3 Methodology: Comparing the current similar Apps with Fego

Fego stands out from the current apps in the travel industry with its unique features and approaches to providing personalised travel experiences. Unlike many other travel apps that offer standard packages and limited customisation options, Fego uses an Iterated Local Search algorithm that tailors travel itineraries based on users’ preferences, history, and behaviours. For instance, Trip.com and Klook are mainly designed for ticket purchase and also for booking activities and making

recommendations. By contrast, Fego offers a range of tour options, including physical tours with local guides and verbal tours through podcasts, providing travellers with flexible choices that truly cater to their individual needs and safety preferences.

3 Result

3.1 Introduction and Objectives of Fego

Given the growing demand for slow tourism, there is a need for a comprehensive range of services that cater to private tours. Fego is a customised app that takes into account travel preference and connects travellers with tour providers both verbally and physically. The app creates tailor-made itineraries based on personal preferences and past travel history. Fego's tour guidance is powered by the Iterated Local Search (ILS) algorithm, which ensures precise calculations, providing real-time customization through mobile apps and using a mathematical model for the Tourist Trip Design Problem (TTDP) (Gunawan et al., 2016) [17]. Computational outcomes based on preferences generate efficient choices of products and itineraries.

Apart from benefiting travellers, Fego is also a boon for tour guides who have suffered heavy losses due to the pandemic. By registering on the app, tour guides can expand their client base and continue their business with a greater range of options. Fego serves as a central hub for touring needs, offering users the flexibility to choose between long tours or multiple short tours within a day. For verbal tours, users can assess recordings or videos that provide travel tips from local experts or seasoned travellers. Fego believes that experiences are precious assets and sources of learning, and virtual interaction is seen as a means to engage newcomers.

With Fego, tour guides have an alternative way to reach potential customers and work during challenging times. Further, as local authorities recognise the importance of sustainable tourism in the wake of the pandemic, Fego's services are helpful in maintaining the industry, even when borders are closed.

3.2 Implementation of Fego

The platform comprises five key phases, namely understanding, scheduling, generating, matching, and touring. During the onboarding phase, Fego collects user data to understand their preferences, budget, travel history, and other relevant information. With frequent usage, the AI-powered system generates more precise recommendations tailored to individual preferences.

In the scheduling phase, users input their destination, date, and travel duration to the system filter, which presents users with the most relevant data (see Figure 1 below). The destination history feature tracks users' past activities and serves as a reference point for future travels. The AI generation tool is a key feature of the platform, allowing users to generate optimized travel routes with a single click. Seasoned travellers can create their own plans on the app and explore more places that they have not visited.

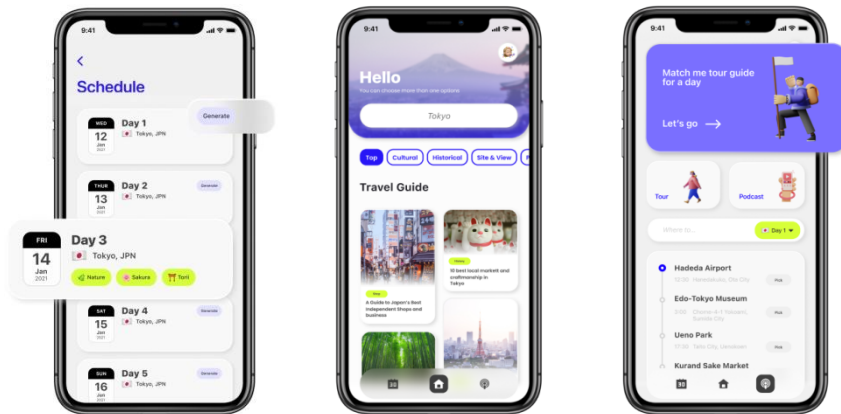


Fig.1. User Interface for service system – Fego

The Fego user interface is designed with themed tags that showcase the journey features, with sub-tags that include map-guide routes. Private customised tours match travellers with local tour guides, allowing them to experience the local culture and expand their horizons through in-depth exploration. The platform prioritises planning tours that are meaningful, and a review system is in place for quality assurance. Users can cancel tours in advance if a guide's rating and reviews are subpar. Fego caters to the new normal in travel by offering contactless options such as verbal tours. Podcast tours are perfect for those who prefer in-depth tourism experiences while still adhering to pandemic-related precautions. Users can enjoy walking around the city and enjoying a guide's stories. Like physical tours, the podcast or video is reviewed by customers to ensure quality. In view of the rising demand for solo tourism, Fego's personalised features help users to create their own experience. The app provides travellers with a choice of where to go and confirms that it is worth going there.

4 Conclusion

The proposed system is a transformation for future touring combined with AI assistance. Fego proves that tourism development can be enhanced by technology rather than being replaced. The app utilises advanced algorithms and real-time customisation to generate efficient choices based on users' preferences. The user journey in Fego is designed to be intuitive and seamless. By promoting sustainable tourism and providing a platform for local tour guides, Fego aims to create an authentic travel experience for tourists while supporting the local economy. With the current trend for solo tourism and the need for contactless interaction, Fego's offering of a new media form allows users to explore a city at their own pace and on their own terms. Overall, Fego is an innovative and user-friendly app that makes private tour booking easy, safe and enjoyable for tourists, while also benefiting travel destinations negatively affected by the pandemic.

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Designing a product that imitates and substitutes a guide companion for the visually impaired

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Abstract. When designing a product for visually impaired people, considerations of their emotional struggles commonly go unaddressed. To counteract this, several studies conclude that having a companion - whether pet or human - reduces negative emotions in the user. Providing companionship is a key factor in training guide dogs. However, the lack of guide dogs in Hong Kong is a long-term issue, and the number of guide dogs is significantly below the recommended average ratio of 1:100. White canes are a useful tool but completely lack any quality of companionship. This brief research paper documents findings that could be used as considerations in the design of a conceptual product that could ultimately act as a substitute for guide dogs.

Keywords: Visually impaired, companion, guide dog, design criteria, conceptual product

1 Introduction

The dog has long been called “Man’s Best Friend”. In fact, one of the present researchers can strongly attest to the truth of this saying. Two years ago, a personal incident caused the researcher to be physically incapacitated for several months, leading to rapid mental health decline during that time. The major source of support that provided some stability came from a pet dog. Personal experience confirms the effectiveness of the companionship of a dog in keeping negative emotions at bay.

Regardless of the kind of impairment, being impaired is usually a lonely experience, and so the impaired person can greatly benefit from different sources of companionship. Not only do these sources provide psychological support, they also bring additional benefits such as physiological and social help. Physiologically speaking, visually impaired people (VIPs) have a higher risk of physical inactivity [1], and more so for those who acquired visual impairment rather than were born with it. Social aspects are strongly related to the psychological aspects, and studies have shown that poor mental health is produced by visual impairment [2]. The effects fall into 4 categories: Anxiety, Depression, Discrimination and Loneliness.

To address the physical struggles, current users are able to rely on conventional tools such as the “white cane” or the “guide dog”. Statistically, many visually impaired in Hong Kong (HK) have acquired blindness, and most use a white cane, though there are few that can rely on a guide dog. Although the ideal ratio of guide dogs to visually impaired persons (VIPs) stated by the International Guide Dog Association should be at least 1:100, the Local Guide Dog Association (GDA) states that there are only approximately 50–100 guide dogs currently active in HK [3]; a ratio of nearly 1:2000 guide dogs to VIPs. The lack of guide dogs can generally be accounted for in terms of lack of government support and space.

2 Previous Studies

A number of studies have shown that dog ownership, or simply getting into contact with a dog, can reduce anxiety, depression, discrimination, and loneliness [4-6]. They can be great companions that boost self-esteem and encourage outdoor activities (all of which s VIPs tend to lack), whilst at the same time being suitable for providing guiding services.

Guide dogs are trained to lead the visually impaired around obstacles, yet by being innately red-green colour blind, there is still potential for misunderstandings or misinterpretations at street signs and traffic lights. Due to this, basic training for simple navigation is done especially based on the target user's daily routine. Otherwise known as "Socialization Training", is a process of introducing new things to the puppy as they grow, so that they are capable of adapting to new situations without fear or anxiety when their services become active.

The most important quality for a guide dog is that it is able to lead the person from point A to point B. Several key obstacles that can be avoided with a guide dog include changes in elevation or overhead obstacles. Again, the benefit of guide dogs is not just limited to mobility assistance, but also companionship, social interaction, and the person's overall well-being and quality of life.

2.1 Social Interaction

In terms of social behaviour, VIPs tend to be more introverted in nature [7], but reportedly feel more accepted by society when accompanied by a guide dog. Additionally, given HK's lack of guide dogs, they bring attention, which results in people interacting with the user more. In this sense, it could be accurate to describe them as the social bridge between VIPs and the community.

2.2 User Well-Being

Psychologically, having a canine companion can help relieve depression, stress and anxiety, which in turn highly improves cardiovascular health. A study has shown that dog owners are 31% less likely to be affected by cardiovascular conditions than those who do not [8]. A guide dog stays by its owner 24/7, and so provides a sense of security and confidence for the person through the forging of personal bonds [9].

2.3 Quality of life

Visual impairment can generally be differentiated into two types; inborn or acquired. Studies show that people born with blindness, or who acquired it at a young age, generally have a higher quality of life than people who acquired blindness at a later age [10]. Regardless of the degree of visual impairment, physical activity can help to improve the quality of life of the visually impaired as it allows them to explore their own personal traits and creativity [11].

From another perspective, when VIPs become the owner of the guide dog, they are accepting responsibility for the well-being of the guide dog. They now need to accommodate the needs of their companion and this encourages them to participate in more exercise, especially walking.

An observed characteristic of VIPs' explorations is that they tend to avoid visiting new areas for fear of unnoticed obstacles. A well-trained guide dog is able to safely bring their user around these locations, and so promotes the confident exploration of unfamiliar places, which a white cane cannot do [12].

3 User Studies

3.1 Method 1: Empathy Test

Empathy tests were conducted to better understand the process of exploration for the visually impaired. This was done with two dogs of different sizes and performed at a local yacht club due to familiarity with the 400m route (see Figure 1 below). Route and tester are control variables, while independent variables include sudden events involving cars or other people en route. The test involved:

1. Casual walking without a blindfold
2. Blindfolded walking with a small dog
3. Blindfolded walking with a big dog
4. Blindfolded walking with a cane

A supervisor followed at a distance and with minimal contact to limit any major accidents. It should be noted that neither the tester nor the dogs had done any guiding-related training in these circumstances, and so results can only provide a basic understanding of exploration as a VIP based on newly acquired visual impairment, and the effectiveness of untrained companions.



Fig.1. Empathy Test Route (Start = Red, Orange = Route, Blue = End)

Mode	Actions	Getting ready	Walking straight	Vehicle incoming	Turning	Walking down the bridge	Arrival
Walking	Pain Points	/	/	Standing still // Walking by the side	/	Need to be careful // Could slip very easily	/
	Emotions	😊	😊	😬	😊	😊	😊
Walking with small dog (blindfolded)	Pain Points	Lost of directions // Leash too loose // whether attach to dog	/	Walking too slow // dog get scared very easily // dog walk much faster pace	Am I on the right directions	Walking too fast // fall very easily // hard to determine when the flat road start	Making sure steps in front
	Emotions	😬😬	😬😬	😬😬	😬😬	😬😬	😬😊
Walking with big dog (blindfolded)	Pain Points	Loss of directions // whether attach to dog	Dog get distracted // Follow other people // Not following the	Walking too slow // Blocking the vehicle	/	Walking too fast // fall very easily // hard to determine when the flat road start	Making sure steps in front

			original route // Bumping on stuff				
	Emotions	😊	😊	😬😬	😬😬	😊	😊
Walking with cane (blindfolded)	Pain Points	Getting use to the stick // Finding a comfortable holding posture	Cane getting stuck in cracks // Hitting things // Damaging things	Walking path or vehicle path	Time to turn // facing the right direction // whether following the correct route	Too steep // Lack of information = Fear	/
	Emotions	😊	😊	😬😬	😊	😊	😊

Table 1. The results of the empathy test: an emotional journey map.

The results in Table 1 above show that blindfolded walking with the dogs was comparatively better than with the white cane in terms of the overall experience. The ability to feel more confident is to be noted, though the lack of environmental information is still clear; the user will have to completely trust their guide companion and will have virtually no information on their surroundings beyond the immediate surroundings.

3.2 Method 2: User interviews

The user interviews aim to further understand psychological and physical issues, as well as clarify additional daily challenges faced by VIPs. Interview participants include a local VIP, and 2 guide dog users (one local and the other international). Note that the results are biased due to the low number of participants, and so acts to provide basic insights into VIPs' thoughts and feelings. The first interviewee acquired visual impairment, with complete loss of vision in one eye and 40-50% vision left in the other. Though the VIP does use a white cane, this is only during travelling or visiting unfamiliar places. Interestingly, the VIP described the white cane more as a tool for others to identify them by, rather than for their own benefit. This is mainly done to avoid unnecessary conflict and accidental physical contact with others, though they still do not prefer to use it when possible due to its disadvantages, such as dealing with potholes and water puddles. For the guide dog users, one was born visually impaired, whilst the other acquired impairment. The innately visually impaired was able to use a guide dog from a young age, whereas the acquired one took approximately two years to successfully apply for a guide dog. Both agreed that their guide dogs are more beneficial compared to a white cane in terms of guidance, though it has the potential to get lost if the route has not been planned ahead. When both were asked about their thoughts on substituting guide dogs with technology, they agreed it would benefit in terms of guiding but would be lacking in terms of companionship, as the researcher hypothesised.

4 Developing a Proposed Concept Design

Based on the above research, a proposed concept design for a portable handheld guiding device was designed as a solution to the current lack of guide dog services in Hong Kong (see Figures 2-4 below).



Fig.2. Foam models testing the design form and identifying contact points.



Fig.3. Hero Shot of the Proposed Concept Design and Annotations of the design.



Fig.4. Obstacle detection and potential ways of gripping onto the device

4.1 Proposed Concept Design

This concept underpins an existing technology known as the Control Moment Gyroscope (CMG) and involves multiple haptic motors to give feedback to the user. Form-wise, the proposed concept design is inspired by the form of a Japanese ornament believed to bring good fortune. Through extensive testing and adjustment of the form, it is able to fit into a person's palm with a gripping angle of approximately 155°-157°.

The flow of information processing can be summarized as follows: Camera (Real Time Information) → AI to process the information → Gyroscope (Control Moment Gyroscope) (Directs the user) → Haptic motors (guide and give direction to the user). The camera in front of the device uses image recognition to avoid obstacles and control how the user moves through the use of the control moment gyroscope (see Fig. 4). When obstacles are detected, the device creates physical feedback for the users through their fingers and palms. This can be achieved through multiple haptic motors creating a range of vibrations and centrifugal forces, and the use of a linear motor to mimic the feeling of getting pulled by a dog, potentially providing the sense of pseudo companionship.

4.2 Control Moment Gyroscope // Proof of concept

CMGs are commonly applied in spacecraft altitude control systems. Alternatively, multiple studies have shown that such technology can be used as a guiding system for VIPs; however, the current CMG found in the market is still specifically designed for spacecraft and which are larger and heavier. In order for the product to be of handheld size, the CMG has to be smaller and lighter. A study done by Walker and her team carried out a study of the effectiveness of a smaller CMG in which multiple users were provided with cues for rotations about the six cardinal torque axes. Results are shown below in Table 2:

	User Responses on Directional Identification					
Correct Directions	Left	Right	Forward	Backward	Clockwise	Anti Clockwise
Left	100%	0.0%	0.0%	0.0%	0.0%	0.0%
Right	0.0%	97.8%	0.0%	2.1%	0.0%	0.0%
Forward	0.0%	0.0%	100%	0.0%	0.0%	0.0%
Backward	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Clockwise	2.1%	0.0%	0.0%	0.0%	97.9%	0.0%
Anti Clockwise	0.0%	0.0%	0.0%	0.0%	0.0%	100%

Table 2. The results of the user responses on directional identification of the double gimbal CMG [13]

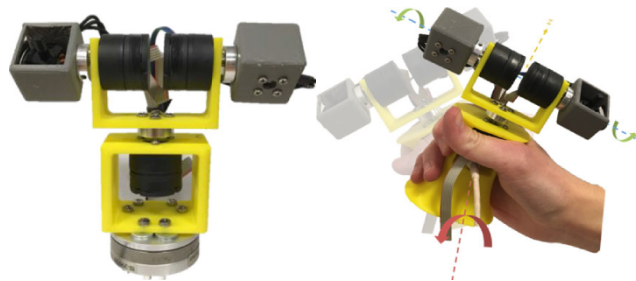


Fig. 5. A model of a double gimbal (grey) CMG which is lighter in weight and smaller in size [13]

Size and weight are the major concerns of the technology being applied to realize the conceptual design. From the results, users were able to respond to the correct directions, despite the size and weight reduction the technology was able to provide kinaesthetic haptic feedback to users. While the potential effectiveness of such technology in assisting VIPs has been demonstrated, it remains important to conduct trials to evaluate its full effectiveness when applied in practice.

5 Conclusions and Future Work

To conclude, it has been identified that common problems VIPs face include the lack of guidance through real-time information and risk potential physical impact from third parties while exploring new areas. The proposed design concept mainly aims to tackle the lack of guide dogs in HK, as well as to simultaneously improving guidance information. The next step will be to produce a functional

prototype in the near future to test its effectiveness in guiding VIPs, including the addition of features that allow users to gain a pseudo sense of companionship, and finally design a digital interface for the user's phone to be paired with the device.

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An Interactive Neural Network-Based System for Confined Stylization of Product Design

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Abstract. Deep learning technology has significantly improved image style transfer. The present techniques, however, do not explore the challenge of enabling users to control the confined transfer region of an image, such as separating particular clothing from a figure. To accomplish this goal, this research describes an interactive image stylization technique. The Grab Cut Algorithm was employed to extract additional image from the content image. The product designer can simply drag a rectangle around the desired product image. A distance loss function was introduced to preserve the shape of the product during stylization. A GUI application that implements the suggested stylization strategy was created. The experimental result shows that the original shape of the clothing is conserved well, and this demonstrates that our suggested approach is feasible to design initial product images.

Keywords: Image Style Transfer, Fashion Design, Convolutional Neural Network, Tangible Product Visualization, Image Segmentation

1 Introduction

Image Style Transfer is a computer vision technique to recompose the content of an image in the style of another. The problem of image style transfer via deep neural networks has received considerable attention in recent years due to the recent rapid growth of machine learning. In 2015, Gatys et al. [1] introduced a revolutionary method to transfer an artistic visual style of a style image into a photorealistic image using a Convolutional Neural Network (CNN). The fundamental concept is to use the VGG convolutional network (see Fig. 1 below). [1]'s work has served as a basis to support successive research and development of image style transfer.



Fig. 1. Example of Image Style Transfer [1]

Apart from Image Stylization, CNNs have recently been effective in a number of computer vision applications, including texture generation, image segmentation, and object recognition. In the area of fashion, this has supported numerous research projects and innovations, including clothing classification, clothing parsing and recommendations. This paper focuses on the self-control of clothing style in confined position during the product design phases. Our approach allows fashion designers to select a photorealistic clothing image as content image, and find an art picture that they appreciate as a style image. The stylization algorithm in confined position during the product design phases. Our approach allows fashion designers to select a photorealistic clothing image as content image, and find an art picture that they appreciate as a style image. The stylization algorithm is then adopted to generate another unique clothing design, which combines the style of the style image and the clothing shape of content image, while the shape of the original preserving clothes.

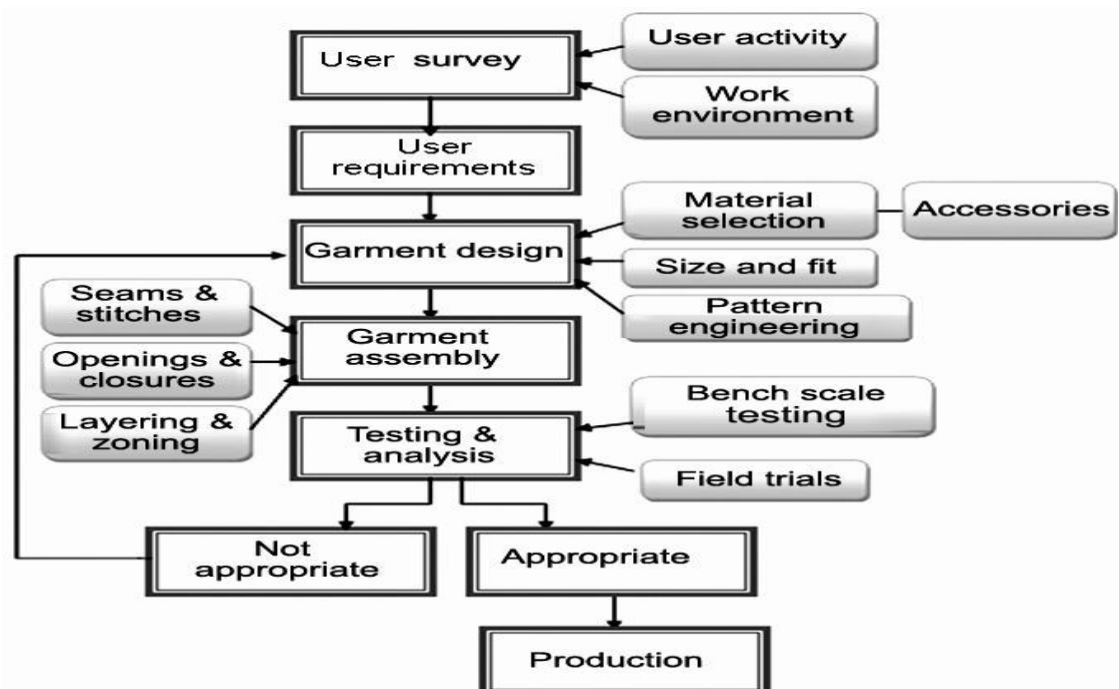


Fig. 2. Flow Chart of Garment Design Process [2]

Our developed GUI application will serve as a fashion visualization tool for the professional designer during the initial garment design phase. While there are already fashion visualization tools existing in the market like Digital Fashion Pro and CLO3D, the major difference between them and our application is obvious: our application can stylize the specific region of the clothes with arbitrary style image provided by designer, whereas the common visualization tools can only provide limited choices of colour and pattern for clothes stylization.

Stylized clothes of different colours, textures or patterns can be visualized by our application. As shown in Fig. 2 above, the fashion designer can determine whether it is feasible to proceed to the next phase by considering different factors, like the production cost of the stylized clothes, material selection for the clothes, customer surveys and requirements. If it is not ideal to produce such a stylized piece of clothing, the designer can give up or find another style image to produce a more appropriate product image. Otherwise, the designer may proceed to the next design phase or the production phase.

2 Related Work

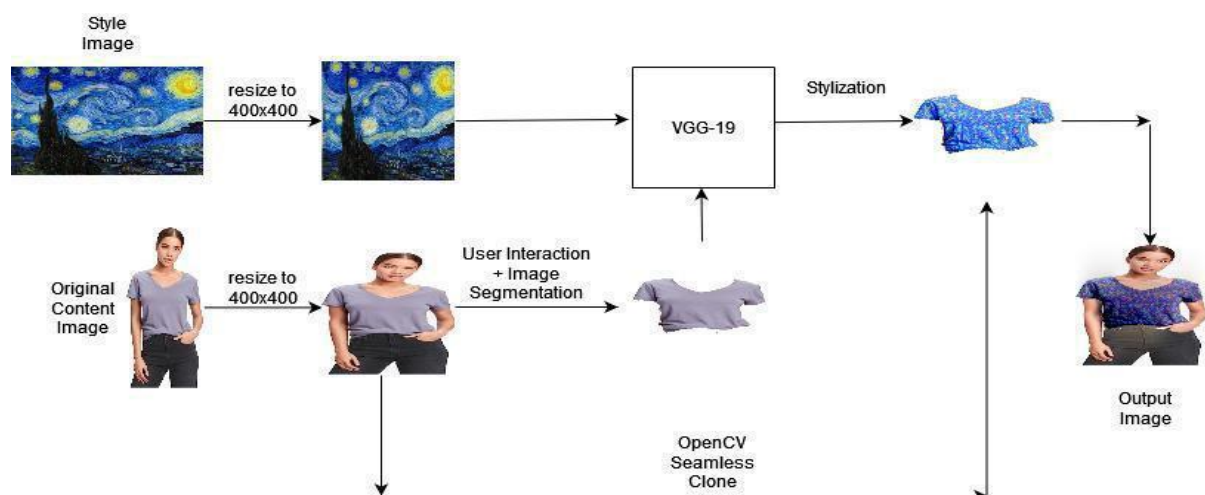
Image style transfer had been studied by Computer Vision researchers. In early research, as image style transfer can be considered as a process of image texture synthesis, [3] proposed a texture modelling method to model the texture by using the image statistics from the texture sample and the summary of statistical attributes. In 2015, the first neural algorithm for artistic style transfer, proposed by Gatys et al. [1], was able to separate and recombine the content and style of images. They created a model based on CNNs, extracting and storing visual features using a pre-trained VGG network. When the new image matches both the style features of the style image and the content features of the content image, the total loss, which is a linear combination of the content and the style loss, is updated. [4] significantly increased the image style transfer speed by including perceptual loss functions for training feed-forward networks. Although these methods produce remarkable style transfer results, they may cause poor content detail retention during style transfer. In contrast to the earlier research studies, this work aims to apply neural style transfer to the fashion industry, giving the fashion designer the ability to create their own distinctive product in accordance with their preference. If normal style transfer is used for fashionable product image, the whole generated image will be stylized. Instead of a simple image without any person or background, it is expected that our proposed method can process a content image with a complicated background. As a result, this study focuses on how users can control the confined transfer position of a content image while matching the style of the style image and the shape of the product inside the content image.

3 Proposed Work

Fig. 3 below shows the overall process of the image style transfer method proposed in this paper. The proposed method was implemented by Python 3 and a GUI application [5] was primarily written. The following operations are performed by the application:

- (1) The dimension of the selected content image and style image is resized into 400x400 to fit the layout of the GUI application.
- (2) The user is required to drag a rectangle around the desired product of the content image to obtain an extracted image. This can be achieved by using the GrabCut Algorithm [6].
- (3) The features of the segmented image and style image will be

Fig. 3. The Proposed Framework for Localized Image Stylization



extracted and stored using a pre-trained VGG-19 network. Apart from the original content loss and style loss as proposed by [1], the additional distance transform loss [7] was also introduced in this model for the calculation of total loss during neural style transfer. This will help to stylize only the pre-segmented region

- (4) The stylized segmented image will be cloned [8] into the resized content image to generate an output image with an unchanged background.

3.1 GrabCut Algorithm

Based on the content image's colour, greyscale and texture, it can be partitioned into multiple pieces called segments by the Image Segmentation Algorithm. After segmentation, the features of the image exhibit disparities in various places yet show similarities in the same areas (see Fig. 4 below). This study uses the GrabCut algorithm [6] to handle segmentation in order to give users the ability to precisely control the transfer position of an image.

Fig. 4. Example of Grab Cut Algorithm [5]



3.2. Stylization for Confined Region

The fundamental idea behind neural style transfer is to take the content and style information from the input image and combine them using a pre-trained convolutional neural network (CNN). The input images used in this study include a content image with a complicated background, an extracted image that GrabCut Algorithm has extracted from the content image, and a style image.

The VGGNet [1] generates a feature map from the filter responses to each layer for a given input image. An input image's content can be viewed as being represented by feature maps on particular layers. A feature space that is made to capture texture information is utilized to extract the style representation of an input image. It is made up of feature correlations that the Gram matrix provides in several layers. Given is the Gram matrix,

$$G_{ij}^l = \sum_k F_{ik}^l F_{jk}^l \quad (1)$$

where F_{ik}^l and F_{jk}^l refer to feature maps i and j in layer l .

For stylization, content image P^* first inputs to the VGGNet and its feature maps in selected layers are stored as the content representation P^l on l^{th} layer. Next, a style image a^* passes through the network. The sum of Gram matrices on every layer are computed and stored as style representation A^l of a style image. The image to be generated, which is initialized as the content image, then passes through the network. Using its feature maps, the content representation F^l and the style representation G^l of the generated image are computed on same layers as the respective representations. With content and style representations, loss functions used for generating images can be calculated. The content loss $L_{content}$ is calculated as shown in Eq. (2)

$$L_{content}(\vec{p}, \vec{x}, \vec{l}) = \frac{1}{2} \sum_{ij} (F_{ij}^l - P_{ij}^l)^2 \quad (2)$$

Style loss L_{style} can be calculated as shown in Eq. (3)

$$L_{style}(\vec{a}, \vec{x}) = \sum_{l=0}^L w_l E_l, \quad (3)$$

where

$$E_l = \frac{1}{4N_l^2 M_l^2} \sum_{ij} (G_{ij}^l - A_{ij}^l)^2 \quad (4)$$

w_l are weighting factors for the contribution of layer l to style loss, N_l is the number of filters in layer l , M_l is the dimensions of layer l . To stylize the confined region of the content image, [7] proposed a new loss function using distance transform of the input images. The distance transform assigns a value—the distance to the closest pixel that is silhouette—to each pixel in a binary image. The distance transform image D has same dimensions as original image, but its pixel values are the values of distance transform. For every pixel d_{ij} of the distance transform image D , emphasis with power n would look like,

$$d_{ij} = \begin{cases} 0 & \text{if inside of a silhouette} \\ d_{ij}^n & \text{otherwise} \end{cases} \quad (5)$$

The distance transform loss $L_{distance}$ would be

$$L_{distance} = \frac{1}{2} (\vec{p} \circ D_{content}^n - \vec{x} \circ D_{content}^n)^2 \quad (6)$$

By simply adding $L_{distance}$ to the total loss with weighting factor γ , we can obtain the following total loss function for model minimization:

$$L_{total} = \alpha L_{content} + \beta L_{style} + \gamma L_{distance} \quad (7)$$

4 Experimental Results

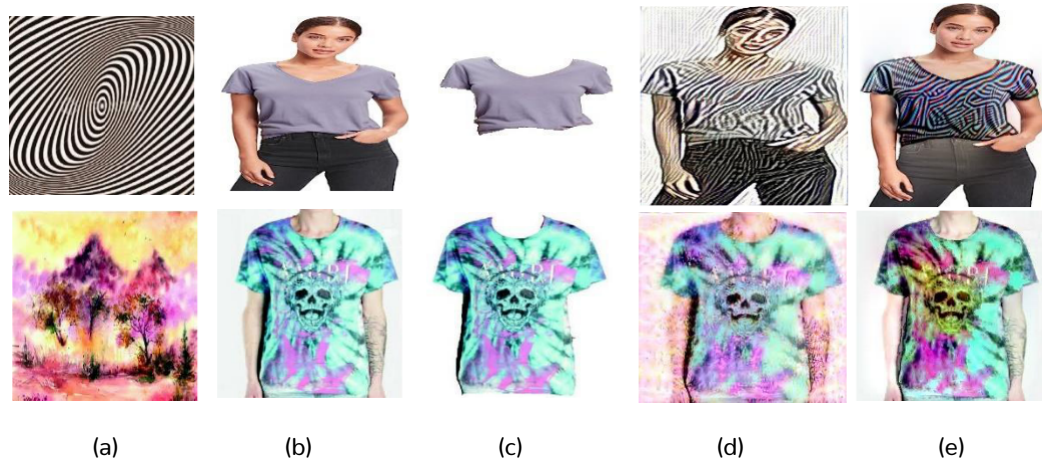


Fig. 5. Results with zebra pattern and watercolour paintings as style images. (a) Style Image. (b) Content Image. (c) Extracted Image. (d) The method proposed by Gatys et al. [1] (e) Our Method

Figure 5 above shows that we picked four pictures randomly from the Internet as content images and style images. The shirts in Figure 5(c) were extracted by our application [5] using the GrabCut Algorithm[6]. We compare our method with the stylization method proposed by Gatys et al. [1]. It was found that only our method keeps the background clean. In [1]’s method, the style from the style image is transferred to the whole content image rather than to the clothes only.

5 Conclusion and Future Work

In this work, an interactive stylization approach was specifically suggested for product images. New clothing designs can be created by merging appropriate style photos, making it simpler for designers to create the initial product image as they want. The designer will determine whether to proceed to the next design phase or go to the production phase if the stylized product image is considered to be reasonable for manufacturing. Additionally, a GUI application was primarily developed [5]. Although the stylization method adopted by this paper was based on [1] and seems initial, the experimental results show that it was effective in creating fashionable clothing images. There is currently little existing research on confined region stylization, and the stylization method described in this paper may be seen as naïve. Given the simplicity of our approach, future research may usefully examine more sophisticated stylization algorithms and carry out experiments to compare their results to those obtained using other algorithms.

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