Personas and Emotional Design for Public Service Robots: A Case Study with Autonomous Vehicles in Public Transportation

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***Abstract*—Emerging technologies for future mobility will drastically change the way humans interact with machines and the environment. The common denominator in technologies such as autonomous vehicles (AVs) and artificial intelligence is the absence of the human, which can be addressed with a service robot designed to appeal to human emotion. As service robots tend to operate in environments where there is a diversity of users and thus user requirements, there lies a gap in the definition of how these interactions should be designed. This paper discusses the use of personas in the development of service robots for multi-stakeholder environments through a case study on AVs for public transportation in Singapore.**

Keywords—human-centred design, autonomous vehicles, service robots, emotional design, trust, personas

I. Introduction

Innovative mobility on-demand services, big data and the sharing economy have disrupted traditional transportation business models and regulatory frameworks. Mobility as a Service (MaaS) seeks to ride on consumer demands by offering seamless user experiences across modes and platforms [14]. Major components supporting the MaaS vision are emerging technologies like autonomous vehicles (AVs) and artificial intelligence (AI). A significant concern with these technologies lies in convincing people to accept and adopt them. A common denominator is the absence of the human, changing the way people interact with mobility products and services. How can designers improve the interface between humans and AVs to fulfil the role left vacant by humans? Work in the domain of automotive human-machine interfaces (HMI) tend to focus on advanced driver assistance systems [48] for human drivers, personal entertainment systems or vehicle navigation information [2]. In the personal services domain, the HMI is a core part of the technology-oriented experience between the human user and the service. Consumer products take the shape of home voice assistants like Google Assistant [15] and Amazon Alexa [1], or virtual assistants such as Microsoft's Cortana [26]. Social robots like the humanoid receptionist Nadine [40] or Sony's robo-puppy Aibo [41] perform service, companionship and therapy roles. Service robots are well-placed to fill the space between a driverless vehicle and passengers, where AVs themselves can be considered mobility robots. Research suggests people are open-minded towards AV technology [23], though trust remains a significant obstacle [13]. Concerns centre around the reliability of driverless systems, safety, data privacy and software misuse [11][24][51].

PET Design™ [16] uses persuasion, emotion and trust to move a user from motivation to intention and actual use. However, designing products and services targeting users in the public sphere poses a challenge. When all users must be served equitably, designers run the risk of trying to placate too many people with vastly different and sometimes conflicting needs and wants [44]. Results may end up a chimera of a product or service satisfying no one. A research gap lies in defining the extent and manner to which designers should fulfil myriad user requirements for public service projects, especially when there are multiple stakeholders from both the operators' and users' perspectives.

This paper discusses the use of personas and emotional design in the development of service robots for multi-stakeholder environments. Emotional design is used as a framework for the design process. The aim is to define how human-robot interactions can be designed to arouse and compel specific emotions and behaviours in different users. In the case study, which is about autonomous buses for public transportation in Singapore, the goal is to build trust and acceptance. The elicitation of positive emotions in users is hypothesised to reduce uncertainty and unfamiliarity, and lead to greater trust in the machine.

II. Evoking Trust Through Emotional Design

User-centred research is the backbone of user-centred experiences. Besides traditional market segmentation based on demographics and socioeconomic status, various approaches within user-centred design consider other human factors such as cognition, attitudes, biophysical traits and emotion. Service quality indicators and technical standards help designers address functional requirements, but such technologically deterministic approaches expect the user to inevitably adapt to new technologies [33], when users should be included to develop socially robust robots [34]. People will assign emotional motivations to AI characters regardless of designers' intentions [42], so anticipating and explicitly designing for emotional response is necessary to prevent misleading or unintended interpretations. Emotional design, as an approach within user-centred design, is used as a framework to conduct research at each stage of the design process. Solutions seek to provoke user emotions at the visceral, behavioural and reflective levels [26]. A desirable, coherent user experience is created by aligning a product or service's visual appearance, interaction and features with a deep understanding of user needs and wants [5] and by targeting emotion to influence people's decision-making [20]. By understanding users and their contexts, designers are better

poised to create solutions which can precisely elicit emotional responses in users.

The first step to generating motivation to use new mobility technologies is the establishment of trust, where users perceive significant uncertainty and risk in unfamiliar agents, i.e. AVs [32]. Trust in a product or service contributes to the credibility of a product or service, which in turn persuades and influences [12]. Designers can provide trust signals in new technologies by manipulating product semiotics, contextual properties and adhering to intrinsic properties of user behaviour [32]. Trust in AVs can be built through several ways, such as by countering the effects of information asymmetry [7][38][46][47]. The authors suggest service robots will increase trust by compelling specific emotions in users. Additionally, the form which the mobility service robots take can foster trust. Anthropomorphism has been found to increase trust in nonhuman agents [17][50]. Strong anthropomorphic characteristics lead to increased user expectations of a system's performance [6]. Recent developments in automotive HMI focuses on integrating human emotion into the experience. Toyota's Yui AI [9] analyses drivers' emotions to build a relationship over time; the Luxoft User Interface (LUI AR) [30] is a humanlike machine companion combining augmented reality with the vehicle's HMI; Nvidia's AI Co-Pilot acts as a virtual driver's assistant aimed at helping people drive more safely [28]. These are developed for long-term use of private cars, where the target user is a single individual or household. HMI for public transport have vastly different requirements because there are hundreds of passengers over the course of a day, each with their own unique concerns.

III. Methodology

Emotional design can be used to address the subjective nature of affect in users. Subjectivity is a complex endeavour in multi-user environments. Personas are proposed as a tool to overcome this challenge, going beyond traditional user segmentation [3][33][39] based on aggregations of demographic and socioeconomic data. They are a part of goal-oriented design where designers create fictional, believable archetypes of users and identify use cases for a product or service [4]. Personas act as conduits for conveying a range of qualitative and quantitative data to bridge the gap between designers and users and within product development teams [31], by making tangible the abstract notion of various user needs and wants. Each persona represents a set of user goals, motivations and frustrations with mobility, and is accompanied by traits to detail the character, such as age and occupation. A detailed narrative containing a backstory and quirks makes the persona more realistic and inelastic [4]. This section describes the application of personas to each stage of an iterative design process: understanding context, defining requirements, and developing and evaluating solutions. The design process is adapted from common stages found in [18][21][35][45][45][49].

A. Mapping Context through Personas

The first stage investigates the local context to understand the parameters, requirements and limitations in the problem space. Due to the public nature of public transport, the first stage is key for the definition of design requirements from different users. The study sample is drawn from a range of demographics and socioeconomic backgrounds to represent people across a wide spectrum of objective traits. User research tools like surveys, interviews, probes and user journey mapping [45] provide insights into the lives of individuals in local communities regarding their current mobility experiences and expectations of future mobility systems.

Surveys are conducted to investigate attitudes to AVs in Singapore across different users. Questions are based on similar studies [19][24][28][37] which gathered data on the perceived likelihood of AV implementation, expected benefits, intention to use, and barriers to AV acceptance, as well as their links to sociodemographic variables and personality traits. In general, most studies on attitudes to AVs focus on personal AVs. As the case study is on AVs for public transport, questions are adapted to focus on the scenario of shared, higher capacity AVs. The survey aims to gather perceptions on a projected future timeline, i.e. when AVs are deployed.

Several tools and techniques are utilised to capture insights from the present time. Semi-structured interviews lasting between 15-30 minutes are carried out with individuals to acquire in-depth data about their mobility experiences, particularly with regards to their goals and motivations for travel decisions. More data on mobility experiences is obtained through probes and user journey mapping. Probes provide a way for participants to share their experiences, feelings and attitudes, building empathy in designers [8][36]. A probes kit sensitises participants and provoke recollections and reflections on their travel experiences. After about one week, participants will take part in a workshop. During the group workshop, participants create user journey maps, which are visual timelines chronicling a user's goals, actions and the elements of a product or service they interact with [22]. As a continuation of the probes kit, participants are asked to chart the stakeholders, elements and interactions involved in their current mobility experiences, noting both pain points and positive elements, as well as how they felt and why. In this way, designers gain inspiration on gaps in current or future mobility services where a service robot can step in to improve the user experience.

B. Defining and Refining Personas

The next stage focuses on analysing the results from the initial discovery phase to define personas and identify key requirements for the design solution. The personas act as a bridge to combine data on current and future mobility needs and desires, leading to actionable insights for design. As this is itself an iterative process, the development of personas moves back and forth between the first (comprising the interviews, probes and user journey mapping) and current stage before the data obtained reaches a reasonable saturation point and no significant new information is uncovered. Test runs of the methodology have yielded rich data for the construction of a number of personas so far, pinpointing areas where the line of questioning can be explored further. Interview, probes and user journey mapping data yield information on the motivations and goals behind travel decisions. Pain points in the travel experience and the root cause of the problem – which could be far removed from the mobility service itself – are also identified. Attributes like preferences for comfort, affordability, and other service quality indicators [10] place the different personas in relation to each other. For example, a number of personas may list information as an important factor, but the degree of

importance and the specific aspect of information could be different, like the availability of routes or timings, or the medium in which information is communicated. Sociodemographic and other personal detail, such as a name and personality quirks, help to make the representation of a typical user as realistic as possible. As public transport serves the masses, a fairly large number of personas is expected. Depending on the scope of the generated personas, it may be possible to identify overlaps in user needs and wants, as well as prioritise features. This is the advantage of using personas [25], which ensures the development of features that can satisfy the requirements of user groups who need it most, instead of trying to cater to the entire user base and failing to satisfy anyone. Taken together with the AV attitudes survey and relevant standards, a clear design brief for the development of a service robot emerges, indicating directions for the form and function of the service robot.

C. Developing and Evaluating Solutions for Personas

Idea generation, testing and refining run iteratively within this stage and seek to address each persona's requirements for a service robot while retaining a cohesive design concept and identity. In understanding what makes each persona tick, designers can incorporate cues through the robot's appearance or behaviour to evoke particular emotions in users. Tools used in this stage include traditional low-fidelity and high-fidelity tools such as sketching and computer-aided design (CAD), and new technologies like virtual reality (VR). VR allows the design concept to be tested in an immersive, realistic simulation of the actual service environment, which makes it an effective tool for quick design iterations where physical prototyping is too complex, is resource-heavy, or compromises the safety of test subjects [43]. Participants can evaluate the design with a greater level of accuracy than if they had to fill the gap between the prototype and reality with their imagination. Researchers can observe how the participant and prototype behave in a 3-dimensional space, or vary elements to create different scenarios of use. Design concepts are tested with subjects who embody each persona to validate the design concept and identify weaknesses. At least one final, refined design solution should be attained at the end of this stage. Solutions generated in the previous round are shortlisted so that only one or a handful remain. In the final stage of the design process, proposed solutions are evaluated for robustness and whether requirements are fulfilled. The mobility service robot developed for the case study will be validated in the local context to test the effectiveness of the robot in evoking specific emotions and behaviours in target users, reflecting the proposed methodology's effectiveness for the case study.

IV. Limitations and Future Research

A challenge remains in validating the personas developed with the general population, as personas are based on subjective, qualitative data influenced by countless variables which may change over time. The issue is compounded by the lack of actual environments reflecting the case study, as AV technology is still in the early stages of development. While VR provides an environment as close as possible to reality, it cannot account for edge cases in live public transport environments, so prototype testing is limited to scenarios devised by researchers. As a first step towards further research directions, the prototype will also be tested in a foreign environment with similar economic and urban conditions to determine the extent to which the sociocultural dimension influences the effectiveness of personas. Results could reveal universal HMI design concepts for service robots in mobility systems or identify areas where locale-specific design is required. Future work could focus on validating the proposed design method for the case study by evaluating the acceptance levels of service robots designed based on traditional design and engineering processes against those developed using personas.

V. Conclusion

Robots in public service roles face a challenge in how to fulfil varying user expectations. Personas, based on in-depth qualitative data from users' contexts and lived experiences, help structure the emotional design process by prioritising user needs and desires to target specific behavioural and emotional responses. Challenges remain in the validation of the proposed design method, which present opportunities for future research in human-robot interaction for service roles.

Acknowledgment

TUMCREATE Ltd. is supported by the National Research Foundation, Singapore, under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.

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