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User-centred design of autonomous mobility for public transportation in Singapore

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Abstract

The paper presents a set of methods for user-centred design of autonomous mobility for public transportation in the context of a multi-disciplinary research programme in Singapore, called TUMCREATE. While traffic engineers plan the operation of the new mobility system, the Industrial Designers of TUMCREATE take on the role of designing the autonomous vehicles (AVs) and infrastructure for greater comfort and a positive travel experience for users. Tasks have been identified to promote user acceptance and facilitate the operation of autonomously driven vehicles for public transport. To fulfil these tasks, conventional design methods have been enhanced with Virtual Reality (VR) technology and with simulations developed by the computer scientists of TUMCREATE. Since public transportation is a complex and broad area, it cannot be investigated with a single design method. First results showed that conventional methods that consider the Universal Design principles guarantee the accessibility, usability and understandability of AVs and stations. VR has been identified as a suitable tool for Industrial Designers to evaluate communication concepts between AVs and pedestrians. This confirms that digital tools (i.e. VR) enhance conventional design methods, especially with regard to technologies that are not available on the market yet (e.g. AVs).

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Keywords: user-centred design; public transportation; autonomous mobility; design methods

Introduction

Megacities like Singapore need a significantly improved public transport system to cope with the challenges arising from increasing population density, such as environmental pollution, energy consumption, and land use efficiency. The Land Transport Authority (LTA) in Singapore has highlighted the need to move towards a “car-lite” society where transit trips make up for 75% of morning peak journeys (LTA, 2013) and the Sustainable Singapore

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Blueprint 2015 outlines the national vision and plans for a more liveable and sustainable Singapore by year 2030 (MEWV, 2014). Furthermore, Singapore's Smart Mobility 2030 (LTA, 2014) roadmap aims to foster the development of technologies within a more user-centred public transport system and to implement them in an acceptable and attractive manner.

In this context, TUMCREATE seeks to develop the ultimate public transport system for the people of Singapore with the introduction of a Dynamic Autonomous Road Transit (DART) system. The DART system, which comprises AVs called DART modules, will complement the existing public transportation system. Since AVs are not yet widely available in the mass market, research is needed for synchronisation with other transport layers, operations, and the development of AV control and deployment strategies.

The Industrial Designers of TUMCREATE have the role to design DART modules and DART infrastructure for greater comfort and a positive travel experience for users. The designed concepts have to fulfil two main requirements: promote user acceptance and facilitate the operation of autonomously driven DART modules for public transport planned by traffic engineers. In this regard, the following tasks have been identified:

a) Improve comfort and travel experience within the DART module,
b) Ensure the fluidity of traffic on the roads and security for AV passengers,
c) Facilitate boarding and alighting at stations,
d) Investigate the impact of the lack of a driver within the DART modules,
e) Manage passenger peak loads at transition points from Mass Rapid Transit (MRT) rail lines to DART-modules.

Conventional methods for design* may not answer all the questions linked with the introduction of new technologies for public transportation (e.g., full automation of vehicles). Therefore, there is a need for methods involving new tools that are not yet widely used within the designer community (e.g. Virtual Reality or simulations).

The aim of the paper is to answer the following questions:

- Which methods can be used for the user-centred design of a new public transportation system with technologies not available yet on the market?
- Based on the first and expected results, which impacts can be expected from these methods to provide efficient operation, high comfort and thus maximum user acceptance of the AVs system?

The paper will present a set of methods for design of public transportation involving new technologies and analyse the first results of specific case studies. The impact of the first results as well as the expected impacts of planned studies will be presented.

1. Design methods and use cases

The approach followed by the Industrial Designers within TUMCREATE is aligned with the Industrial Design process, which constitutes the phases of Research and Analysis, Conception, Design and Refinement (Heufler, 2004; Hirsch, 2014; Archer, 1984; Lawson, 2005). After the Research and Analysis phase – in which problems are identified – information is clustered, correlated, and questioned within the Conception phase. During the Design phases, the concepts and variants for solution approaches are developed to meet predefined requirements. In the Refinement phase, the concepts are evaluated in terms of among others usability, feasibility, and ergonomics.

The hypothesis of the paper is that digital tools like Virtual Reality and simulation can enhance conventional design methods in order to address the lack of prototypes for testing the design concepts. It is postulated that digital

* The term "conventional" refers in this paper to state of the art design methods that are taught in universities and are specified in literature like for instance the Delft University of Technology (2017), IDEO Method cards (2003), Kumar (2013), and Martin & Hanington (2012) and thus are successfully established in the profession of Industrial Design.

tools (e.g. VR or simulation) can support Industrial Designers with the creation of scenarios that are not technically feasible yet. Furthermore, digital tools contribute to cost and time savings compared to real-life experiments.

Research questions have been formulated for each task listed in the introduction, highlighting related challenges that need to be resolved with the implementation of the new public transportation system. Design concepts are proposed and need to be elaborated within the Industrial Design process using the right methods (Table 1). A set of methods has been selected to investigate how conventional design can be enhanced with digital tools using VR or simulations in the field of public transportation, especially when no prototype is available.

Table 1. Tasks, design concepts, research questions and methods used by Industrial Designers for the DART system design

Tasks	Proposed DART design concepts	Research questions for designers in relation to DART design	Methods proposed to investigate research questions
a) Improvement of comfort and travel experience	Interior design of DART module	How to design the DART module so that an improvement of comfort and travel experience for every passenger can be expected?	Conventional methods for design in accordance with Universal Design principles
b) Ensure the fluidity of traffic on the roads and security for the AVs passengers	Human Machine Interface (HMI) placed on the vehicle to inform pedestrians by crossing a street and discourage jaywalkers	Is the HMI adapted to the situation regarding traffic conditions and safety? To which extent can the HMI prevent improper behaviour from pedestrians, like jaywalking?	Usability testing of the designed HMI in regard of efficiency, effectiveness and satisfaction
c) Facilitate boarding and alighting at stations	Interior layout of DART module with adequate ratio of seating and standing areas	How to ensure that the designed interior layout of the DART module facilitates the boarding and alighting of passengers and does not cause delay?	Crowd simulation for the investigation of passenger flow while boarding and alighting
d) Impact of lack of driver within the DART modules and how it can be compensated	Virtual/Robotic Companion (V/RC) to fulfil the driver role within DART modules	What value does the human driver provide? Does the satisfaction of this role lead to acceptance and use?	Participatory design workshops to explore what users need and want from a human driver and whether a driver avatar can compensate
e) Manage passenger peak loads at transition points from MRT to DART modules	Innovative Dynamic Guidance System (DGS) in stations, e.g., physical signage (static and dynamic), information displays, personalised information (mobile apps)	The changing spatial arrangement of the DART modules at stations induces a tension between users and the driverless modules during wayfinding, especially	Ideation workshop with VR for the creation of DGS for stations

		under time pressure or in crowded conditions. Which Guidance Systems are suitable for the specific operation of the DART system?

According to the tasks that the team of Industrial Designers wants to fulfil within TUMCREATE, the methods proposed in Table 1 have been clustered depending on their contributions at different stages of the Industrial Design process (Fig. 1).

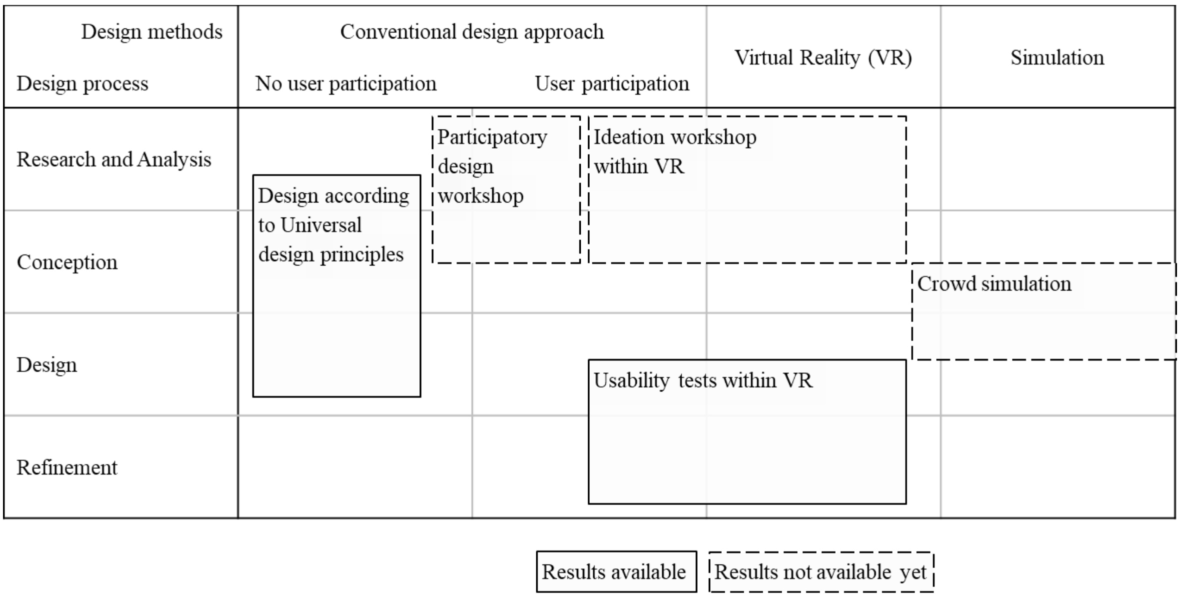

Fig. 1. Set of methods used by the Industrial Designers at TUMCREATE along the Industrial Design process

This paper elaborates on a set of methods that can be used at different stages of the Industrial Design process. Some methods have been already applied and first results are available, while some of them are in planning.

1.1. Design according to Universal Design principles

Task: Improve comfort and travel experience.

The term Universal Design has been used for the first time at the Center for Accessible Housing at North Carolina State University in the 1970s (Null, 2013). A definition of the term has been proposed and defined by the Committee of Ministers of Council of Europe in (COE, 2001): “Universal design is a strategy which aims to make the design and composition of different environments and products accessible and understandable to, as well as usable by, everyone, to the greatest extent in the most independent and natural manner possible, without the need for adaptation or specialised design solutions.” It comprises seven principles (The Center for Universal Design, 1997):

1. Equitable Use: The design is useful and marketable to people with diverse abilities;
2. Flexibility in Use: The design accommodates a wide range of individual preferences and abilities;
3. Simple and Intuitive Use: Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level;

4. Perceptible Information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities;
5. Tolerance for Error: The design minimizes hazards and the adverse consequences of accidental or unintended actions;
6. Low Physical Effort: The design can be used efficiently and comfortably and with a minimum of fatigue;
7. Size and Space for Approach and Use: Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Until now, the consideration of Universal Design Principles for the improvement of public transportation services has been mainly focused on accessibility. For example, Zajac (2016) in Warsaw focused on designing public space and transport infrastructure aimed at securing the rights of passengers with reduced mobility. Similarly, specific bus stops have been highlighted in some cities for their lack of accessibility for wheelchair-bound people, which could be perceived as discrimination for disabled people and lead to safety issues, reduced quality of life and social exclusion (Souza & Post, 2016; Soltani et al., 2012; Sze & Christensen, 2017). Beyond the consideration of users with reduced mobility, Fearnley et al. (2011) underlines that Universal Design can provide benefits to not only special needs groups, but to all passengers. Moreover, even if improved accessibility is the main application of Universal Design for public transportation facilities, it should not be the sole focus. Indeed, providing comfort and information are part of Universal Design principles, and their improvement leads to increased user satisfaction of public transport facilities.

The Universal Design principles are used within the team of Industrial Designers by TUMCREATE for the interior design of DART modules and platform access. This task is done together with a team of mechanical engineers and has been described by Ongel et al. (2018). It integrates advanced vehicle technologies (e.g., electric powertrain, autonomous driving technology, and interconnected communications to infrastructure and other vehicles) with the design of the DART module in order to improve public transport service quality.

1.2. Usability tests within Virtual Reality

Task: Ensure the fluidity of traffic on the roads and security for the AVs passengers.

The goal of this method is to guarantee that the Human Machine Interface (HMI) on the vehicle can be understood by everyone and can discourage jaywalkers. However, when designing communication concepts that involve AVs and humans, tests in real traffic conditions would be complex and potentially dangerous for test subjects. As alternative, Virtual Reality (VR) is proposed to be combined with existing design methods. VR enables rapid prototyping for a fast and cost-effective method of producing fully functional samples (Heufler, 2004). Berg and Vance (2017) state that VR is already implemented in product development in various industrial fields like aerospace, automotive, military and construction. Other than the advantages of time and cost effectiveness, VR also improves safety for test subjects and is a useful alternative when physical prototypes are unavailable (Berg & Vance, 2017; Feng et al., 2015).

At TUMCREATE, a Virtual Design Laboratory has been developed. The method has been described in detail by Stadler et al. (2018) and is summarized as follows. The laboratory itself consists of a test area of approximately 4.5 m x 4.5 m, so that the test subjects can move freely (Fig. 2). This area is equipped with position tracking hardware. With the help of Head-Mounted Displays (HMDs), test subjects are fully immersed in virtual environments.

Fig. 2. Possible setup of the Virtual Design Laboratory

In order to guarantee that the Human Machine Interface (HMI) on the vehicle can be understood by everyone, Usability Tests are conducted within the Virtual Design Laboratory.

Usability testing employs techniques to collect empirical data while observing representative end users using the product to perform realistic tasks and has its roots in classical experimental methodology (Rubin & Chisnell, 1994, Van der Bijl, 2012).

The use case for the presented method constitutes the communication between AVs and pedestrians in ambiguous situations, such as at zebra crossings. AVs that are equipped with different HMI concepts approach the test participant during the test. The HMI concepts indicate if it is safe to cross the road or not. A control unit (i.e., an AV without any HMI concept) enables the identification of how the HMI influenced behaviour. The objective is to test whether HMI concepts can improve the crossing situation to be more usable in terms of *efficiency*, *effectiveness*, and *satisfaction.*

The Usability Tests are conceptualized as "Within subjects design"[†]. One person is immersed at a time. Prior to the tests, an initial questionnaire is conducted. Then, participants are introduced to the VR setup through a tutorial in order to get familiarized with the technology. After the tutorial, the Usability Tests are conducted. Here, the test participant receives their task and has to react accordingly. The sequence of HMI concepts tested is randomized to rule out distorted results caused by the testing order. After the tests, a final questionnaire is conducted in order to gain insight into the feelings and perceptions of the test participants.

1.3. Crowd simulation

Task: Facilitate boarding and alighting at stations.

While designing the interior layouts of the DART modules, the Industrial Designers need to consider the passenger movement within the vehicles. The passenger flow has to be optimised through the vehicle's interior design in order to support the efficient operation of DART with minimal dwell time.

[†] Within subject design: Every test participant conducts all parts of the Usability Test (Rubin & Chisnell, 1994)

To reduce the need for cost-intensive real-world experimentation, the passenger flow can be analysed using crowd simulation. Crowd simulation is commonly used in the domain of architecture with the dominant application of analysing evacuation scenarios (Thalmann 2013, Zhong 2014). It is a useful tool to "understand the relation between space and human behaviour" (Okazaki, 1993). The underlying crowd models can take a macroscopic or microscopic perspective. According to Xiong et al. (2010), "The macroscopic method focuses on the movement features of the whole crowd; whereas microscopic models […] emphasize the issues of individual characteristics, including pedestrian's psychological and social behaviours, communication among pedestrians, and individual decision making processes". For the investigation of passenger movement within the vehicles, microscopic modelling enables the simulation of decision making processes for different users groups (e.g. commuters, elderly, and people with children). In TUMCREATE, Industrial Designers collaborate with computer scientists for the modelling of pedestrian flows in order to evaluate the impact of DART-module interior design layouts on station dwell time.

Several DART-module layouts have been selected for the simulation with different arrangements in terms of the number of seats, as well as their orientation and position in the vehicle (Fig. 3). For each layout, areas with different functions have been defined. For each area, the passenger (referred to as an agent) is assigned a specific behaviour: The agent moves through the door (red) from the platform into the vehicle. Areas are defined as non-walkable (i.e., vehicle walls and interior segregation surfaces, dark grey) or walkable. Agents cannot linger in certain walkable areas (intended for seat selection, grey). Seats and leaning seats are represented by squares (orange and yellow, respectively). After entering the vehicle, each boarding agent moves towards a seat, a leaning seat, or a standing position. The agent stops moving once it has reached its target position.

Fig. 3. Layouts of the DART modules and respective areas for agent behaviour

Beyond the variation of vehicle interior layouts (i.e., the standing and seating areas as well as seat and door orientations), the effects of the following parameters are investigated with the crowd simulation:

- Number of people inside the vehicle
- Number of people boarding
- Number of people alighting
- Crowd mix in terms of age, people with children, people with disabilities, seat preferences, etc.

The overall outcome desired by the Industrial Designers is a ranking of the layouts depending on the time needed for boarding and alighting. The microscopic modelling approach allows interactions such as agents blocking others from entering the vehicle door to be reflected in the measurements. From an operational perspective, scenarios are investigated in which the time is measured for a certain crowd to enter and exit the vehicle (assuming DART operates its doors like a bus does at a station, which enables every passenger to board or alight) in comparison with the measurement of the number of people that are able to enter and exit the vehicle in a definite time (assuming DART operates its doors like the MRT does at a station, where doors close after a fixed time).

1.4. Participatory design workshops

Task: Impact of lack of driver within the DART modules and how it can be compensated.

The main difference between a conventional vehicle and an AV is the presence, or lack thereof, of a human driver. Beyond driving the vehicle, what role does a human driver play? Does this role differ across private and public vehicles (buses, taxis, MRT)? This study focuses on operator-passenger communication within the AV's Human Machine Interface (HMI) to foster user acceptance of AVs. The case study centres on the development of a Virtual/Robotic Companion (V/RC) to fulfil this human role in the context of AVs for public transportation in Singapore.

Understanding the concerns of people in context is critical for the identification of key attributes of the V/RC to foster user acceptance. In order to explore what users need and want from a driver avatar, participatory design workshops will be conducted with the local community. Less a technique and more an embodiment of user-centred design, participatory design employs one or more representative users on the design team (Steen et al., 2007). Often used for the development of in-house systems, this approach thrusts the end user into the heart of the design process from the very commencement of the project by tapping the user's knowledge, skill set, and even emotional reactions to the design (Rubin & Chisnell, 1994). Observing participants' thought processes in the confines of a design workshop also enables researchers to uncover people's tacit knowledge, i.e., knowledge that cannot be readily expressed in words, and thus their latent needs (Sanders, 2002).

Preliminary insights will be obtained with regard to (i) definitions of the human driver's role; (ii) preferences for operator-passenger communication; and (iii) design insights for the V/RC and HMI for AVs. As the participatory design workshops will take on an inductive approach, precise results cannot be anticipated.

The nature of participatory design workshops requires smaller sample sizes for more in-depth investigations. The workshops will have to be repeated with different user segments in order to obtain a complete map of people's needs and wants. The V/RC is only one component of the AV HMI, so there will be other issues to address for a holistic HMI design. The results will be limited to the Singapore context as sociocultural influences, among other human factors, will determine local preferences. Finally, there will be other confounding variables driving user acceptance of AVs. Future research could determine the weight of HMI on user acceptance of AVs.

1.5. Ideation workshops within VR

Task: Manage passenger peak loads at transition points from MRT to DART modules.

In order to receive immediate feedback on the potential of concepts in an immersive way, Virtual Reality will be used in ideation workshops. Especially for the ideation of future scenarios, immersion can lead to enhanced solution approaches and concepts. In order to have a holistic approach within the ideation workshop, test participants from various professions are required to form an interdisciplinary panel of participants. It is planned that design methods like cognitive walkthroughs, construction test scenarios, and contextual inquiry are combined with Virtual Reality. The aim is to allow the ideation participants immersion and thus direct experience and feedback within VR. A future scenario will be created in a virtual environment. As soon as the participants come up with a concept, a VR expert can place a rough sketch of the concept in the scenario. This allows direct experience of the concept within the actual environment of application. Consequently, participants get direct feedback of how the concept works within the environment.

It is anticipated that this leads to innovative concepts and variants with improved potential of feasibility.

Aligned with the problem statement that was defined in the first phase of the Design Process, solution approaches in the form of concepts and concept variants are expected. Thanks to the immersion, it is anticipated that the concepts are improved in terms of assessed feasibility and usability. Furthermore, the suitability of using VR as an ideation tool in the Conception Phase of the Design Process will be assessed within the investigation.

One limitation is the required competency for using Virtual Reality within the ideation workshop. There are various HMDs on the market that require different competencies and effort to build up environments. Hence, at least one VR expert is required to attend the ideation workshop so the solution approaches and ideas can easily be translated and implemented in the virtual environment.

2. First results

2.1. Design according to Universal Design principles

The design of the DART vehicles and stations follows Universal Design principles and provides simple, intuitive, and equitable use for people with diverse abilities. Within the DART module, the dimensions of the seating and standing areas are adjusted to users with different body dimensions and positions. For example, in comparison with the current buses in Singapore, the seat width in DART vehicles is bigger (550 mm instead of 440 mm) and the doors are wider (1500 mm instead of 1200 mm). Furthermore, the vehicle floor height is aligned with the platform height, for which retrofitting may be necessary. All these arrangements provide more comfort to passengers and enable easier boarding and alighting for all users – including wheelchair users – without extensive physical effort. An area in the DART module is dedicated to wheelchair users and is equipped with a locking mechanism to ensure stability and thus safety during the ride. A child seat is available to accommodate people travelling with children, while adjustable leaning seats guarantee more stability for standing passengers.

Fig. 4 exposes a visualisation of the interior design of a DART module and its main features.

Fig. 4. Interior design of the DART module and main features according to Universal Design principles

As a result, the integration of Universal Design principles to the design of DART modules and stations ensure better accessibility and higher comfort for users in comparison to the existing public transportation system in Singapore.

2.2. Usability tests within Virtual Reality

For the work on HMI designs, early concepts have been produced within the Virtual Design Laboratory of TUMCREATE for AVs to pedestrians' communication (Fig. 5). With the help of interdisciplinary workshops and methods like morphological analysis, concept generation led to a palette of potential concepts. The focus was to create a range of concepts differing in semantics used, since they are easier to understand than written text (Kline et al., 1990). Within the Virtual Design Laboratory, behavioural studies validated first concepts exclusively related to the comprehensibility of semantics (Fig. 5).

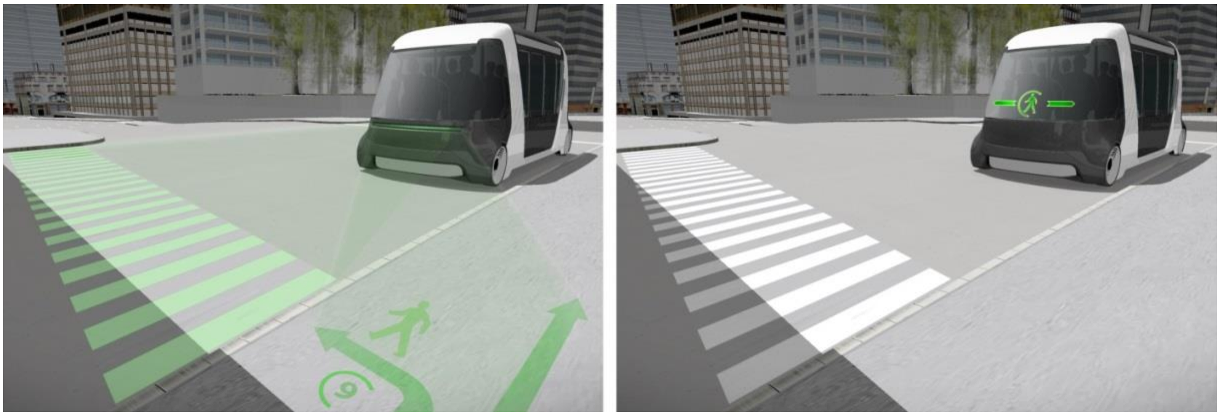

Fig. 5. Early concepts for HMI within the Virtual Design Laboratory (a) Laser projection on the pavement (b) HMI on the vehicle

The initial results of the Usability Tests have been published by Stadler (2018) and gave insight into both, quantitative and qualitative data. Regarding quantitative data, it was revealed that the decision-making time was almost halved when the AV was equipped with HMI, compared to the control unit in which the vehicle was not equipped with any HMI. Even though there were no significant differences among the tested HMI concepts, an overall improvement of *efficiency* was noted.

A further quantitative result showed a decrease in error rates[‡] caused by the HMI concepts (from 72.2% to 3.3%). It became clear that the overall *effectiveness* was improved, even though no significant differences among the concepts were noticeable.

Beyond quantitative data, qualitative data was collected with the help of questionnaires. The questions were focused on the subjective effort for each test participant to cross the road considering each HMI concept and the control unit. Further questions addressed the ease of detection and comprehensibility of the HMI concepts. The results revealed that the subjective feeling of crossing the road was positively influenced by the HMI concepts.

There are no results available yet for the other methods presented (crowd simulation, participatory design workshop and ideation workshop within VR) since their developments are still on-going or the tests with participants are planned but not executed yet.

3. Discussion

The paper showed the necessity for Industrial Designers to use several methods for user-centred design of public

[‡] In this context, making an error means that the test participant crosses the road when the HMI concept displays that it is not safe to cross the road and vice versa.

transportation facilities. Public transportation is a complex and wide area and cannot be investigated with a single method. Digital tools like VR enable the creation of scenarios that are not technically feasible yet (e.g. a pedestrian crossing a road in front of an approaching AV) while guaranteeing a safe environment for participants involved in the experiments. This supports Industrial Designers in testing design concepts before going to physical prototyping, reducing the time and cost expended.

Since technological systems and human beings are involved, quantitative and qualitative data are necessary. A set of quantitative and qualitative research methods is therefore required: For quantitative analyses and in the specific case of using new technologies that are not deployed on the market yet (e.g., full automation of vehicles), new tools can be combined with conventional methods for design in order to reduce the need for cost-intensive and potentially unsafe real-world experimentation. For qualitative analyses, the paper shows the necessity to involve users within the Industrial Design process. User integration supports a more accurate identification of the problems (cf. guidance system that is not visible and understandable, or symbols that are not comprehensible by everyone) and it helps to understand in detail the needs and wants of people.

Regarding the first results presented in the paper, it has been shown that the integration of Universal Design principles within the Industrial Design process guarantees that the DART modules and stations are accessible, usable and understandable. As underlined by COE (2001) the consideration of Universal Design principles promote an emphasis on user-centred design by following a holistic approach and aiming to accommodate the needs of people of all ages, sizes and abilities, including the changes that people experience over their lifespan. As a next step, the conventional approach can be enhanced by integrating the user thanks to surveys or field observations. This would result in the consideration of users as a source of information, first-hand experience and professional competence, as suggested by COE (2001).

Furthermore, the paper underlines that VR is a suitable tool to conduct Usability Tests for the mentioned case study of communication between AVs and pedestrians in ambiguous situations. The method works as a quick, preliminary validation method when no functional AV prototype was available. Nevertheless, there are drawbacks in using VR, like the limited immersion and absence of haptic feedback. The participants' awareness of being immersed into virtual environment could influence their behaviour. This could lead to riskier behaviour and thus distorted results. Therefore, it has to be tested to which extent the data collected within VR are reliable and valid. A prior selection of test participants, who are for instance not familiar with the technology of VR, could improve the reliability of data. This has to be investigated in further studies.

The impacts of the methods used and described in this paper are visible on several layers: they ensure that the design concepts facilitate the DART operation and they support user-centric design of concepts that increase the comfort of passengers. Both aspects (efficient operation and high comfort) are the basis for good service quality of public transport, as defined by the European Standard 13816 (EN 13816, 2002). The following quality criteria are indeed improved by suitable user-centred designs presented in the paper:

a) Interior design of DART module in accordance with Universal Design principles: Accessibility is improved in term of entrances/exit (flat floor and wide doors) as well as comfort in term of (i) seating and personal space in vehicle, (ii) ride comfort and (iii) ergonomy.
b) Human Machine Interface tested for usability within VR to inform pedestrians and discourage jaywalker: Comfort is improved for passengers (no sharp breaking) as well as security in form of freedom from accident is guarantee for passengers and pedestrians.
c) Interior layout of DART module tested with crowd simulation for boarding and alighting: Accessibility is improved for the entrance/exits and internal movement.
d) Virtual/Robotic Companion developed within Participatory design workshops: Information is improved in regard to general and travel information and customer care is ensured for assistance.
e) Innovative Dynamic Guidance System at stations developed during ideation workshops in VR: General information about accessibility from the station to the DART module is improved.
f) With the improvement of these criteria, the user-centred design of the DART system promotes user acceptance of public transportation, which becomes a more attractive option for travelling reducing the reliance on private vehicles.

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