MOTION SIMULATION AND VIRTUAL REALITY IN V-COMMERCE - HOW THE USE OF MOTION SIMULATION AFFECTS CUSTOMER VALUE, PURCHASE INTENTION, AND TRUST IN AUTONOMOUS VEHICLES

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ABSTRACT

Autonomous vehicles (AVs) have captured the public imagination and may soon become an integral part of smart city concepts. Currently, preparations by city administrators, legislators, and politicians still lag behind technological developments. However, AVs may soon be capable of solving mobility issues and fundamentally extending micro-mobility concepts, including peer-to-peer taxi services such as Uber, in urban areas. As a result, mobility concepts could become more efficient, effective, and sustainable. Price acceptance, fuel efficiency, and mode of use (private or sharing) are relevant factors in determining the benefit of AVs for consumers. This paper focuses on the acceptance aspect. The Yaw 1 motion simulator was used to conduct a randomized control experiment (high vs. low motion simulation (MS)) to determine what driving style leads to higher acceptance and, thus, greater purchase intention. In addition, we examined how other aspects of virtual commerce (V-commerce) (customer value, purchase intention, trust, emotional involvement, and presence) might be affected by MS use. In particular driving style was found to be relevant and should be taken into account when designing mobility concepts that include AVs.

KEYWORDS

Purchase Intention, Smart City, Autonomous Vehicles, V-Commerce, Motion Simulation, Driving Style

1. INTRODUCTION

The technologies involved in creating smart cities, in particular those connected to autonomous vehicles (AVs), could help render mobility more sustainable. Smart mobility and the associated connectivity are ideally suited to meet the needs and expectations of the inhabitants of urban areas. Services such as Uber and micro-mobility (e.g., electro scooters such as Tier, Lime, and Bird) could help decongest busy city streets (Shahidehpour et al., 2018). In addition, AVs might also become a valuable aspect of smart cities as well as reducing the costs related to mobility services by dispensing with costly human drivers.

According to Perveen et al. (2017), societies all over the world are affected on an unprecedented scale by urban growth, and the effect on the environment is enormous. In fact, traffic in modern cities roughly accounts for one-third of emissions, which is why the potential of AVs in terms of their contribution to combatting climate change was found to be highly promising. In the literature, various scenarios have been developed that could help governments with this challenging task (Perveen et al., 2017).

2. LITERATURE REVIEW

In this part of the paper, the relevant constructs and the related literature are introduced from which a conceptual model and hypotheses were derived. While virtual reality (VR) has many useful applications, it can lead to cybersickness, which is especially true for MS due to vection. The paper further covers customer-related constructs such as customer value, purchase intention, trust, emotional involvement, and presence. Hence, these are all introduced in the following.

Vection is the concept of experiencing one's own motion (Ash et al., 2013). The body recognizes acceleration such as rotation, and this feeling of acceleration can lead to the illusion of movement (Colley et al., 2022). Empirical evidence suggests that a combination of rotation impulse and VR heightens the effect of vection (Colley et al., 2022; Rietzler et al., 2018; Wright, 2009), which can also increase motion sickness (Colley et al., 2022). Simulators with 13 degrees of freedom would eliminate the problem, but they come with a price tag of some 80 million dollars (Colley et al., 2022). Conveniently, simulators with lower degrees of freedom are sufficient for participants to experience the sensation of movement (Colley et al., 2022; Danieau et al., 2012; Gugenheimer et al., 2016).

SAE International recognizes six levels of automated driving: 0) No driving automation, 1) Driver assistance, 2) Partial driving automation, 3) Conditional driving automation, 4) High driving automation, and 5) Full driving automation (Kelechava, 2021). Autonomous driving is considered to be Level 5 (Faisal et al., 2019) because only at this level can drivers be considered real passengers in the true sense of the meaning without having to be "on standby to take over from the autopilot" as, for example, Tesla calls it.

As has already been stated above, the sensation of motion does not come without pitfalls. If the body's sensory perception is not completely in line with the movements seen in the head mounted display (HMD), motion sickness can occur (Caserman et al., 2021; Colley et al., 2022). Symptoms range from nausea and headaches to dizziness (Caserman et al., 2021). Similar problems can occur if technical details, such as the inter-pupillary distance, are not adjusted for correctly (Seiler et al., 2022). It is hardly surprising that these effects can have a negative impact on customer-related constructs such as customer value, net promoter score (NPS), consumers' trust in a vendor and purchase intentions (Seiler et al., 2022). Brand evaluation and purchase intention can negatively be affected by cybersickness (Breves and Dodel, 2021).

E-commerce has become an important feature of the Internet. As a result, VR is researched regarding its potential for commercial application. Martínez-Navarro et al. (2019) proposed a model which was generated by applying VR to the e-commerce setting. Other researchers, such as de Regt and Barnes (2019), have also conducted research on the topic, mainly focusing on the retail context. As depicted in Figure 1, emotions as well as affective appraisal play a vital role in presence and brand recall. This in turn can significantly affect purchase intention (Martínez-Navarro et al., 2019). Presence is the psychological sense of presence and people to behave like in the real world because the think they are actually there (Martínez-Navarro et al., 2019).

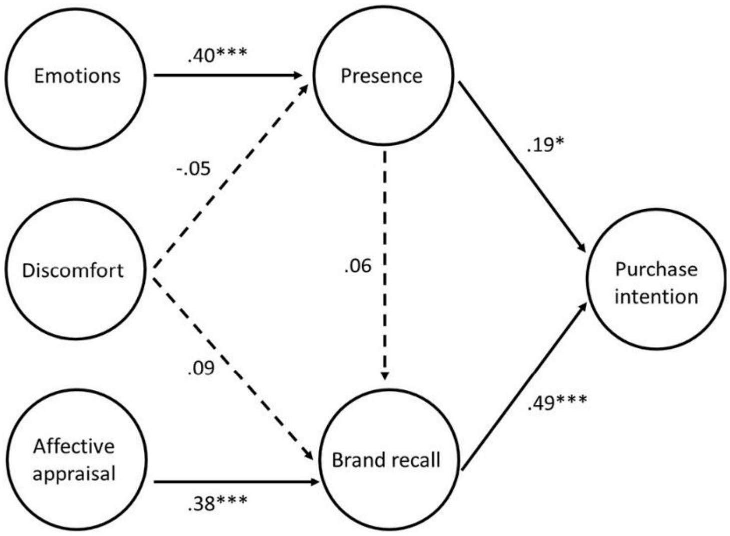

Figure 1. V-commerce model (Martinez et al., 2019)

The acceptance of autonomous driving vehicles depends on many factors according to Nastjuk et al. (2020). However, they considered neither VR nor MS. This study addresses this research gap by examining whether and how VR and MS affect customer value, purchase intention, trust, AV acceptance, emotional involvement, and presence.

We therefore asked the following research question (RQ): How can MS and VR be used in the context of virtual commerce (V-commerce) and AVs? In addition, we also formulated several sub-research questions: *How does the use of VR and MS in v-commerce affect customer value (SRQ1)?, How does the use of VR and*

MS in v-commerce affect purchase intention (SRQ2)?, How does the use of VR and MS in v-commerce affect trust (SRQ3)?, How does the use of VR and MS in v-commerce affect AV acceptance (SRQ4)?, How does the use of VR and MS in v-commerce affect emotional involvement (SRQ5)?, and how does the use of VR and MS in the context of AVs in v-commerce affect presence (SRQ6)?.

Hypotheses were derived from the literature, and an overview of the resulting conceptual model is given below (see Figure 2).

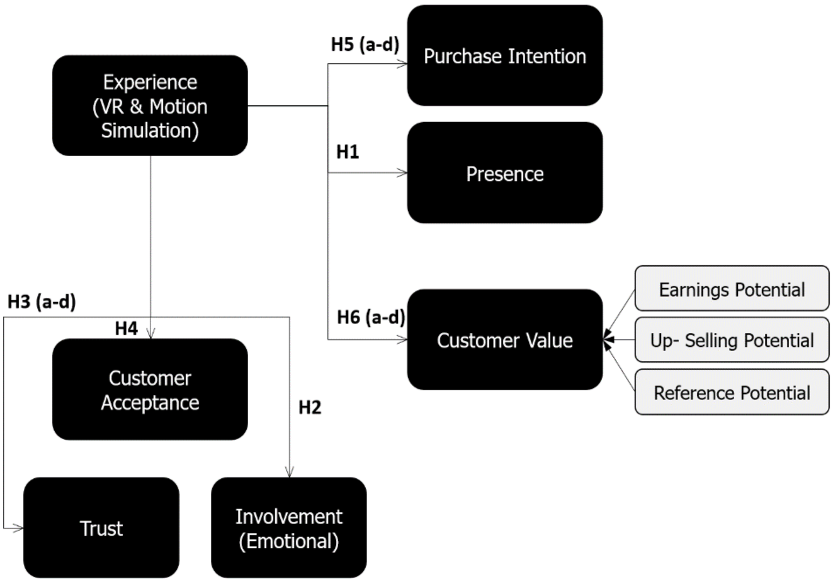

Figure 2. Conceptual model used in this paper

3. METHOD

We decided to conduct a randomized control experiment using the Yaw 1 motion simulator[1] (see Figure 3) and two speeds (driving styles) to take participants through a scenario. The parameterization of the intensity of the motion experienced in the one scenario is high (fast driving style with high levels of motion) and in the other one low. This is how the two speeds of driving styles are implemented. Previous research on the topic had been conducted by Yildirim et al. (2020), whose findings laid the foundations for our study as the source code was kindly provided. With the help of the authors of the source code (Cymmersion GmbH), the application was extended and adapted for our experiment. The application runs on Unity Engine (2019). The following adaptations were made: We reduced the time of the ride with the AV, integrated the Yaw 1 software development kit, and extended the ride to include a market scene.

The scenario starts at an open grocery market during a thunderstorm. Ginny, a digital companion, explains how the participant can get home by ordering an autonomous taxi. After this monologue, the participant uses a tablet to order an autonomous taxi (see Figure 5). After the taxi arrives (see Figure 5), the participant raises the HMD a little to sit in the motion simulator. The taxi then drives autonomously (without driver or passenger interaction) along the predefined route. The journey of the autonomous taxi is physically mapped by the motion simulator. After the car stops at the side of the road, the sequence ends.

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[1] The Yaw 2 motion simulator (see Figure 4) is more advanced. Its design resembles that of a car seat, which makes it more comfortable than the half-sphere used for Yaw 1. However, at the time of conducting the experiment, Yaw 2 was not yet available.

Figure 3. Yaw 1 motion simulator

Figure 4. Yaw 2 motion simulator

To start the experiment, participants were asked to draw a random number (even numbers were assigned the parameterization of Script 1, odd ones of Script 2). Next, they were asked to fill out a pre-VR-experience questionnaire to serve as a base line. Then were they introduced to the VR gear (HTC Vive Pro Wireless) and strapped into the Yaw 1 for the actual experiment. After completing the driving sequence, participants filled out a post-VR-experience questionnaire.

Figure 5. Autonomous taxi app in VR scenario

Figure 6. Picture of AV in VR scenario

The operationalization was based on existing literature (see Table 1). Three constructs are noteworthy as they are our own or were created based on constructs found in the existing literature. We used our own demographic variables and questions regarding mobility use. Customer value was adapted to the context of our study. The construct “customer value” was operationalized using three subdimensions: earnings, referral, and up-selling potential. Reichheld's (2003) NPS, recently extended for measuring emotions Müller et al. (2021) as net emotional value (NPV), measures referral potential and is often used in the context of customer satisfaction. Satisfaction is an antecedent to referral (Meilatinova, 2021). We decided to use NPS in this study because emotional value is already captured by a separate construct, and to enable comparisons to prior research.

Table 1. Overview of operationalization

Construct	Variable name (scale)	Author(s)
Demographic	ID (0-60) Age in years Gender	Own item
Mobility	Which means of transport do you use? (MC) [Car, electric car, public transport, car sharing, e-scooter, e-bike, bicycle, or other (open text)	Own item
Presence	6 items (Likert scale)	Usoh et al. (2000)
Emotional involvement	5 items (7-point Likert scale)	Martínez-Navarro et al. (2019)
Trust	6 items	Nastjuk et al. (2020)
Acceptance	Sum of trust and emotional involvement	
Purchase intention	3 items	Vieth (2008)
Customer value	Earnings potential Referral potential (NPS) Up-selling potential	Based on the existing literature

LimeSurvey was used as survey tool and R as well as R studio as tools for statistical analysis. openxlsx [Excel import], tidyverse [visualization], magrittr [linking of commands], psych [Cronbach's Alpha], broom [visualization], and reshape2 [restructuring and aggregation of data] were used as packages.

The highly parameterized setting (treatment group) had 25 participants (56.8 percent), the low parameterized scenario (control group) had 19 (43.2 percent). Highly parameterized means that the script controlling Yaw 1 hand X = 5, Y = 2, and Z= -3 and for the low parameterized version X =2, Y = 1 and Z = -1 as vector that is multiplied with a velocity vector.

4. RESULTS, DISCUSSION, FURTHER RESEARCH, AND LIMITATIONS

44 people participated in the experiment. Nobody had to abort due to cybersickness, and both questionnaires were completed in full by all participants. 36 percent were male and 64 percent female. The average age was 24. Regarding mobility, the following was reported: 77 percent (car), 0 percent (electric car), 95 percent (public transport), 7 percent (car sharing), 5 percent (e-scooter), 7 percent (e-bike), and 45 percent bicycle. One participant stated that they also walk.

Table 2. Comparison of pre- and post-VR-application questionnaire (mean values)

	Pre-VR (baseline)		**Post-VR**	
	Treatment	*Control*	*Treatment*	*Control*
Presence	*NA*	*NA*	2.88	2.88
Emotional involvement	*NA*	*NA*	3.81	3.75
Trust	4.12	3.96	4.19	3.93
Acceptance	*NA*	*NA*	4.05	3.87
Purchase intention	2.54	2.84	3.24	3.02
Earnings potential	3.58	3.12	3.26	3.24
Up-selling potential	3.42	3.64	3.32	3.44
Referral potential	*NA*	*NA*	3.55	3.60
Customer value	3.50	3.38	3.38	3.43

Cronbach's Alpha was used to check whether the constructs are reliable or not. Most constructs were above the cut-off value of .8 (Cronbach, 1951) and, except for "presence", all constructs were above the cut-off value of .7, proposed as sufficient by Nunally (1978). The Cronbach's Alpha values were as follows: .53 (presence) .71 (emotional involvement), .83 (trust), .7 (acceptance), .9 (purchase intention), and .76 (customer value).

A Shapiro Wilk test was also conducted. Presence, acceptance, and purchase intention were found to be normally distributed whereas emotional involvement, trust, and customer value were not. For further analysis of non-parametric or non-normally distributed constructs, a Wilcoxon test was used, as well as the t-test for normally distributed constructs (see Table 3).

The Hypotheses H1 to H7 (see Table 3 below) were tested accordingly, and the test statistics as well as the results were reported. Except for H5b and H5c regarding purchase intention, all other hypotheses were found not to be significant (H1 to H4 and H6 and H7).

It was found that neither high nor low parameterization in combination with VR affect presence or lead to emotional involvement, nor do they foster trust or customer value. Furthermore, a higher parameterized MS in combination with VR does not foster acceptance or purchase intention.

However, low parameterized MS positively affects purchase intention (H5b), and MS in combination with the VR experience presented in this study positively affects purchase intention (H5c). Earlier research pointed in the same direction, suggesting that VR positively affects purchase intention (Martínez-Navarro et al., 2019) or purchasing decisions (Harren et al., 2019).

Table 3. Overview of hypotheses, tests and results

#	Path & test statistics	Result
H1	High parameterized MS leads to higher presence values than MS with low parameterization (T[42] = 0.012, p = 0.495).	Rejected
H2	High parameterized MS leads to higher emotional involvement than MS with low parameterization (T[42] = -0.924, p = 0.361).	Rejected
H3a	High parameterized MS leads to higher trust than MS with low parameterization (T[24] = -0.511, p = 0.693).	Rejected
H3b	Low parameterized MS leads to higher trust than MS with high parameterization (T[18] = 0.794, p = 0.219).	Rejected
H3c	MS leads to higher trust in AV (T[43] = 0.081, p = 0.468).	Rejected
H4	High parameterized MS leads to higher acceptance than low parameterized MS (T[42] = -1.279, p = 0.896).	Rejected
H5a	High parameterized MS positively affects purchase intention (T[24] = 0.633, p = 0.266).	Rejected
H5b	Low parameterized MS positively affects purchase intention (T[18] = 2.466, p = 0.012).	Accepted
H5c	MS positively affects purchase intention (T[43] = 1.972, p = 0.028).	Accepted
H6a	High parameterized MS positively affects customer value (U = 140, p = 0.482).	Rejected
H6b	Low parameterized MS positively affects customer value (U = 96, p = 0.492).	Rejected
H6c	MS positively affects customer value (U = 454.5, p = 0.488).	Rejected
H7	High parameterized MS affects reference potential more than low parameterized MS (U = 253, p = 0.358).	Rejected

4.1 Further Research

Our study backs up earlier research and literature in suggesting that further research needs to be conducted to gain a deeper understanding of the constructs as well as their relationship to each other in the context of VR and MS. This is rather important as well as relevant because, in our study, VR and MS not only appear to have a positive effect on purchase intention but also on other business-relevant constructs such as customer value, trust, and emotional involvement. Positive effects have also been reported according to the empirical evidence. Hence, further research could focus on qualitative approaches to complement this study and identify the underlying reasons for its findings.

The low Cronbach's Alpha score of the construct "presence" may be addressed in further research by other forms of operationalization or qualitative research as to why this occurred in contradiction to prior research.

Further research may replicate this study using a representative sample as the sample in this study consists of rather young participants. Finally, replicating this study using more realistic hardware and haptics (e.g., the Yaw 2 rather than Yaw 1 simulator) may yield different results.

4.2 Limitations

The number of participants is rather low compared to other quantitative research and therefore, results may not be generalized unconditionally. Nevertheless, these results may be considered early stage and regarding method as well scenario a starting point and opportunity for further research. Also, the low Cronbach's Alpha score of "presence" must be mentioned because this construct is not reliable in the context of this study and one may speculate that this could be linked to the following point affecting the experience and thus the concept of presence.

Concerning the participants in the experiment, it could be possible that not everybody had the same experience because the motion simulator had to be adjusted for taller or larger participants (e.g., 1.90 m or 90 kg) to enable the motor to bring participants back into a centered position. Similarly, due to the physical dimensions of Yaw 1, not everybody (especially taller participants) could take the same seated position. Whereas smaller participants had no issues in sitting in an upright and seated position, taller participants were forced to lean back a bit (which may have been a further reason for the limitation regarding the position just mentioned, occurred, as the leverage increases and leads to a more imbalanced setting).

Finally, all participants were rather young, and results might have been different for a representative sample of the population.

5. CONCLUDING REMARKS

Our findings suggest that businesses looking to increase purchase intention among their customers might want to consider the use of VR and MS. However, a low parameterized MS is advisable because higher levels do not have the effect of increasing purchase intention. In addition, positive effects could not be reported for customer value, trust, and emotional involvement.

These preliminary results show that VR and MS can be relevant to businesses. In the light of the trend of consumers shopping in electronic settings, MS may be a further sales channel to complement classic retail showrooms or other forms of analogue sales approaches.

It must be pointed out that the results of our research apply to the context of AVs only. Results may vary if VR and MS are used in a consumer goods or B2B setting.

We hope our research may be of interest to the initiators of smart cities concepts considering autonomous vehicles as part of their mobility concept. In particular, cities planning to use AVs to fight climate change may find these results useful, especially considering that traffic accounts for a third of emissions in urban communities (Perveen et al., 2017).

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