Emotional Response to Extended Realities: The Effects of Augmented and Virtual Technologies in a Shopping Context

Mila Bujić
Gamification Group
Tampere University
mila.bujic@tuni.fi

Nannan Xi
Gamification Group
Tampere University
nannan.xi@tuni.fi

Juho Hamari
Gamification Group
Tampere University
juho.hamari@tuni.fi

Abstract

Extended reality (XR) technologies such as Augmented Reality (AR) and Virtual Reality (VR) are facing mixed expectations. XR is often touted to offer deeply engrossing experiences but it can also lead to cybersickness, disappointment, and frustration. Moreover, research has not kept pace with how these technologies may affect users' emotions. Therefore, to understand emotions in XR, this study employs a 2 (virtual: yes vs. no) ×2 (augmented: yes vs. no) between-subject experiment (N = 162) in the shopping context. Effects on emotions are assessed by measuring changes in emotional valence and examining them using Median Tests and exploratory data analysis. Results suggest that emotional responses in XR are similar to those in a physical store. However, there is an unexpected effect of the augmented experiences where negative emotions markedly vary. Implications are presented both for retail businesses and simulations, and emotionally engaging experiences such as immersive journalism and psychotherapy.

1. Introduction

Customer emotions are considered an important aspect of marketing [1, 2] and customer relationship [3]. Customers do not only look for emotional and hedonic value from the products they consume but also from the experience of shopping itself [4, 5] which is considered to play a key role in the formation of the overall shopping experience [6], attitudes related to it [7], repurchase intentions [8], and memorable experiences [9]. Thus, there is a long tradition in retailing and marketing to create as appealing shopping experiences as possible, for example, by providing rich multifaceted experiences, optimizing and minimizing unpleasant emotional responses in terms of in-store/online store atmosphere [10], communication quality and service [11], and social interaction [12].

Today, extended reality (XR) technologies, mainly including virtual and augmented technologies, have received a lot of attention from the retail industry and seem to have opened the door to the future of technology-mediated shopping that combines the benefits of online shopping with the experience of physical shopping [13]. While there have been both hyperbolic and depressed expectations towards virtual and augmented technologies, little empirical results exist on effects on consumers' emotions when engaging with them. There have been several voiced concerns over possible discomfort, usability, lack of graphical fidelity, cybersickness and so forth that may hinder the general reception of XR in the shopping context [14]. Most previous studies in the retail area have addressed customer emotions in shopping environments such as physical store [15], online store [16] and mobile app [14]. Even though a few emotion-related studies have been conducted in XR shopping environment (e.g. [17, 18, 19]), the employed methods (i.e. the lack of controlled randomized experiments) have thus far made it impossible to infer about the differences in effects both between traditional shopping as well as between using different XR for mediating the shopping scenarios. Moreover, the measurements employed for emotions have lacked the ability to differentiate between qualities of negative and positive response [20]. Considering the growing tendency of using XR technologies to *replicate* physical experiences in support of sustainability, practicality, and accessibility, it is increasingly relevant to examine the basic effects of different XR systems.

Additionally, the relevance of emotions in XR does not end with the retail context. Similar replications of the physical or traditional experiences have been used extensively, for example, in simulation and training (e.g. [21]). All of these are similar in that they often do not specifically target users' emotions and inadvertently affecting them due to the technology could have ramification on the overall user experience and desired outcomes. As a step further, some applications purposefully affect emotions, for example,

URI: https://hdl.handle.net/10125/70688
978-0-9981331-4-0

psychotherapy [22] and immersive journalism [23, 24]. In these cases, where significant emotional responses are affected and even desired, the simple choice of XR can pose a threat to how controlled the effects are and even become unethical. Therefore, *this study aims at addressing this gap in the core understanding of how the choice of XR technology affects emotions and investigates the effects of XR experiences on emotional responses in the retail context*. It is meant to provide a baseline understanding of how technologies themselves affect emotions without adding more stimuli.

1.1. Extended reality technologies

One of the most common ways of presenting the spectrum between the physical and virtual is the reality-virtuality continuum [25]. The continuum has been essential in conceptualizing different categories of technologies as they were developing and entering the commercial arena. However, in a way it is a simplistic representation as it only presents the extent to which an environment is virtual. The categories apart from the physical are commonly referred to as *extended reality*. However, a different tool is needed to differentiate other properties that might be of relevance for investigating various experiences that they provide.

Therefore, one richer way to delineate and conceptualise these different technologies and ensure clarity in the interpretation of a study would be to use the *EPI cube* [26]. The advantage of the EPI cube is that it places technologically-mediated experiences inside a 3D model based on three criteria or dimensions of the technology - technological *Embodiment*, perceptual *Presence*, and behavioural *Interactivity*. Additionally, the EPI cube presents some examples of ”extreme” technologies in its corners as starting signposts. The cube is only used for virtual environments and extended reality technologies and not, for example, an experience in a physical store, what would be called a *core experience* [26].

In this study, the EPI cube model is adopted as a tool for positioning the technologies and their experiences, as well as for interpreting results. For example, presence has been shown to correlate with emotional responses (for a review in VR, see [27]), and interactivity modes and complexity can evoke frustration and negative experiences. The technologies are positioned on the model and in relation to one another in the following manner:

Augmented reality (a physical environment overlaid, or *augmented*, with additional content) - AR is positioned as high interaction and embodiment, albeit low presence. The latter is due to users' predominant environment being the physical, non-technologically mediated environment, which is overlaid with digital content using AR.

Virtual reality (a fully visually immersive *virtual* environment) - VR shares the high interaction and high embodiment vertical where AR is positioned. However, it is at the other end of it, indicating high presence by users' vision being completely engulfed in a completely virtual environment. This type is often referred to as immersive virtual reality [28].

Augmented virtuality (a *virtual* environment overlaid, or *augmented*, with additional content) - AV shares VR's position on the embodiment and presence dimensions, but higher on interaction. It presents technology that merges virtual and augmented elements or, in other words, a VR that introduces an additional layer of augmented content and interactivity. As such, it is more complex than AR and VR individually.

1.2. XR and emotions

The existing literature is not indicative of what outcomes could be predicted when examining non-emotional content and experiences, such as a store or a simulation delivered through different XR technologies. Previous studies on affective responses in XR have been primarily focused on highly engaging experiences. One of the popular applications of XR and particularly VR is phobia exposure therapy [29] and other similar content that is likely to evoke intense emotional reactions [22]. On the other hand, VR content has successfully been used to evoke emotions of particular valence, positive and negative, and even specific emotions [30]. However, studies of emotions in XR are predominantly based on individual XR technology and even application, and the affective outcomes are studied with non-experimental methods or only collected after the experience with no baseline or comparison score from another XR experience (e.g. [31, 32]).

Considering that business research interest lies in using XR technologies for constructing shopping experiences comparable to the core experience, or shopping in a physical store, this should be the first point of investigation. This entails both positive and negative emotions across a spectre of XR-mediated technologies that aim at replicating the core shopping experience. Therefore the following two null hypotheses are presented:

H_0a: There is no difference in shoppers' changes in *negative emotions* when comparing a physical and XR stores.

H_0b: There is no difference in shoppers' changes in

positive emotions when comparing a physical and XR stores.

Furthermore, there is a dearth in understanding how different XR applications that are not specifically designed to manipulate emotions might, in fact, influence them in unpredictable ways. The relevance in controlling the users' emotional responses lies mostly in their mediating effects on various final outcomes of the experience. Due to the lack of previous research in similar contexts, the exploratory approach seems to be the most appropriate as it provides the greatest breadth of insight into the data. The following two exploratory research questions are therefore to be used for informing further exploratory and confirmatory studies. The first is focused on the complete ways of delivering content: a physical store, AR, AV, and VR. The second then serves for a more rigorous examination of the effects of the involved factors - augmented and virtual. Considering how multifaceted each of the full experiences is, it is difficult to truly understand them and deduce their different factors' roles in users' affective experiences without examining them specifically.

Exploratory 1: How do comparable XR-mediated shopping experiences affect users' positive and negative affective responses?

Exploratory 2: How do augmented and virtual factors in XR-mediated shopping experiences affect users' positive and negative affective responses?

2. Method

The randomised between-subjects experiment used in this study was conducted using a factorial 2×2 design, or a total of four conditions. The factors were virtual and augmented, distributed so to enable a detailed investigation of their effects (see Table 1). The study design and experiment procedure comply with the National Advisory Board on Research Ethics' guidelines.

Before conducting the experiment, a within-subjects pilot study with N = 20 was ran to test and polish the procedure.

Table 1. Experiment conditions and their corresponding factors.

Condition	Factor	
	Augmented	Virtual
Real	-	-
AR	+	-
VR	-	+
AV	+	+

2.1. Participants

Participants were recruited through advertising on University campuses, including calls on tri-folds in cafeterias, TV screens in the corridors, and University's internal communication channels. Three participants out of those 165 who agreed to participate were omitted from the dataset due to not being students or having technical difficulties during the experiment. The final sample consisted of N = 162 students (Real, n = 41 ; AR, n = 42 ; VR, n = 40; AV, n = 39).

Age was recorded using age brackets as it is not used in the analyses but is only illustrating the sample composition (Table 2). Females constituted 46.9% of all participants, indicating an approximately even distribution between male and female genders. Participants were predominantly Bachelor level students (56.8%), followed by Master (37%) and Doctoral level (6.2%).

2.2. Materials

2.2.1. Stimuli The experiment was held in an adapted University office 5.09m × 4.24m in size. The office was restructured to resemble an LP vinyl records store. Three-level shelves were mounted on three walls in the space, and equipped with old second-hand LP records. These were chosen as a suitable product as were likely to be a product type familiar to students, but with a low probability of participants recognizing distinct artists and influencing the results. Average mean previous product knowledge on a 7-point Likert scale [33] was 2.67.

The record covers with all the presented information were shown the same in all conditions as a physical one. However, additional information retrieved from Discogs (https://www.discogs.com/) was presented differently in non-augmented and augmented conditions. In non-augmented ones, it was placed on a piece of paper in front of the corresponding record, whereas in the augmented conditions it would be prompted to display as additional information when the gaze was aimed at the record.

The office space reshaped as a store was used as the space for conducting all conditions, although in VR and AV conditions the participants wore an immersive 6-DOF HMD with two controllers and did not interact with the physical store. Specifically, for the AR condition, participants used Microsoft HoloLens 1 and interacted with the physical products in the shop; in the conditions with the virtual factor (VR and AV), participants used Valve Index to visually immerse them

Table 2. Participants' distribution by gender and age.

		Real	AR	AV	VR	Total N (%)
Gender	Female	14 (34.1%)	23 (54.8%)	20 (50.0%)	19 (48.7%)	76 (46.9)
	Male	27 (65.9%)	19 (45.2%)	20 (50.0%)	20 (51.3%)	86 (53.1)
Age	15-19	5	5	6	6	22 (13.6)
	20-24	20	27	22	22	91 (56.2)
	25-29	10	7	7	10	34 (21.0)
	30-34	4	2	4	0	10 (6.2)
	35-39	1	1	0	1	3 (1.8)
	40-44	0	0	1	0	1 (0.6)
	55-59	1	0	0	0	1 (0.6)

in a complete replica of the physical store, but interacted with the virtual products within a virtual store.

2.2.2. Measurements *Emotional state* was measured using the The Positive and Negative Affect Schedule (PANAS) scale [34]. It consists of two dimensions which represent positive (PA; Cronbach's alpha: pre = .86, post = .90) and negative valence (NA; Cronbach's alpha: pre = .84, post = .83) introduced with "*Please indicate to what extent you feel this way right now*". The items are single-worded and presenting different emotions, such as *excited* or *ashamed*. The answers were given on a 7-point Likert scale with *Not at all* (1) and *Extremely* (7) anchors.

The scale was administered both during pre- and post- survey in order to establish the baseline state before starting the experiment and the consequent change in the emotional valence. Mean pre- and post-scores were calculated for both PA and NA. These were used as paired samples to investigate whether there are changes in single conditions. Additionally, the difference mean scores (mean post minus mean pre) and used as independent samples for comparing the effects of different conditions.

2.3. Procedure

When coming in for the experiment, participants were introduced to the experiment procedure and stages – pre-survey, tutorial, treatment, and post-survey. They were presented with the consent form and then instructed to fill out a pre-survey which consisted of items related to their music hobby and their emotional state (PANAS) This stage lasted around five minutes.

The second stage consisted of step-by-step instructions that were prepared beforehand and identical for all participants. Head-mounted displays and lenses were adjusted to fit comfortably. Participants then had a try-out experience of the store and its functionalities to reduce any confounding effects because of the lack of familiarity with the hardware or interaction techniques. The aim of this stage was for participants to get familiar and comfortable with the experiment environment and the used technology in all but the Real condition.

In the third stage, which consisted of the treatment, participants were given a "gift card" valued at 10 Euros to be spent in the LP record store. The participants were allowed to keep the records bought during the experiment as compensation. They were informed that the store closes in 10 minutes and they are required to make their choices in that time frame, approach the "cashier" who was played by the experimenter, and buy the chosen records.

The fourth and final stage consisted of participants filling out the post-survey immediately after finishing the experiment shopping task. At this time, they again filled out the PANAS questionnaire for measuring their affective state. Finally, they were informed about the purpose and aim of the experiment and thanked for their contribution and time.

2.4. Analyses

To test the hypotheses, there are three reasons non-parametric tests were used: the assumption of normal distribution was not observed for the Negative Affect dimension; Levene's test did not show homogeneity of variance of the pre-test scores for the same dimension (based on Mean, p = .014; based on Median, p = .119); and finally because of the sample size difference between the combined XR conditions and Real condition's samples (n = 121 vs n = 41, respectively).

Additionally, different exploratory data analysis (EDA) techniques were used when addressing the exploratory questions, namely descriptive statistics of the variables and visualizations using boxplot and scatterplot charts.

The results were obtained and visualised using IBM SPSS version 25.

3. Results

As a starting point for analyzing the data, relevant descriptive statistics are presented in Table 3. The statistics refer to the operational variables *Positive Affect Change* and *Negative Affect Change* that were computed by subtracting the PA and NA baseline score from the final score (post- minus pre-score).

Additionally, when assessing whether positive and negative dimensions of users' affective response change, it is pertinent to investigate their relationship. For this purpose, a 2-tailed Pearson correlation coefficient was computed. The results suggest no statistically significant correlated relationship between the two studied outcome dimensions, r = -.076, p = .342 (Figure 1). The results indicate that a change in one emotional valence, positive or negative, does not suggest a change in the other emotional valence.

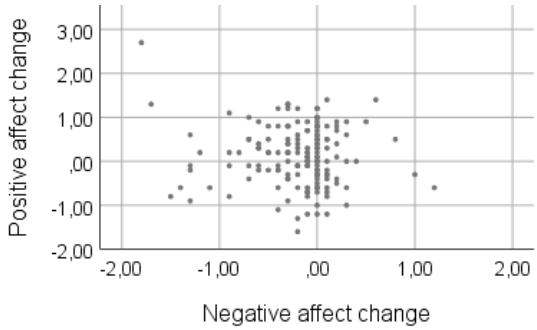

Figure 1. Scatter plot of changes in positive and negative affect across the conditions.

3.1. Emotions in Real and XR stores

Hypotheses H_0a and H_0b were tested using non-parametric Independent-Samples Median Tests. When considering and interpreting this type of test it is important to emphasize that it uses the null hypothesis stating that the groups have the same median, not mean, due to the stated specific properties of the data. The results were further visually examined using boxplots.

The Median tests suggested to retain the null hypotheses when comparing affective responses when shopping in a Real store with those when shopping in the XR stores. When looking into the change in the emotions of positive valence, there was no difference between the Real (*Mdn* = .05, *Q1* = -.60, *Q3* = .30) and XR (*Mdn* = .20, *Q1* = -.20 , *Q3* = .65) conditions, p = .131 (see Figure 2).

Similar results were obtained for the difference in the change in the emotions of negative valence in Real (*Mdn* = -.10, *Q1* = -.20, *Q3* = .00) and XR (*Mdn* = -.10, *Q1* = -.40, *Q3* = .00) conditions, p = .129 (see Figure 3).

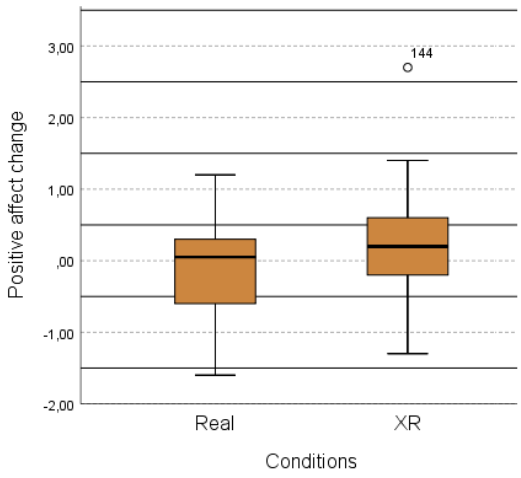

Figure 2. Boxplots of positive affect change in Real and XR conditions.

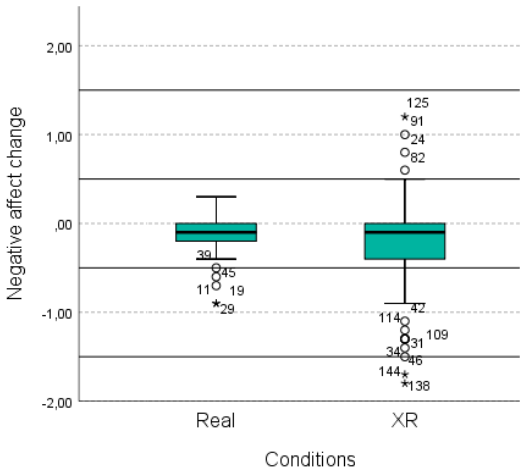

Figure 3. Boxplots of negative affect change in Real and XR conditions.

Therefore, the results support hypotheses H_0a and H_0b, indicating that there is no statistically significant difference neither in negative nor positive emotional valence between the physical and combined XR stores, suggesting that the null hypotheses should be retained. However, interquartile ranges, whiskers' width, and the data points outside the boxplot for the NA dimension in XR all suggest a much higher variability in the sample distribution for the XR than for the Real condition and especially long tails of the distribution. These were

Table 3. Descriptive statistics for the emotional change in individual conditions.

Affect	*Condition*	*Mean (SD)*	*Mean 95% CI*	*Variance*	*Median*
Positive Affect Change	Real	-.023 (.68)	-.239, .194	.458	.050
	AR	.124 (.62)	-.071, .320	.385	.200
	AV	.255 (.63)	.049, .462	.395	.350
	VR	.194 (.74)	-.049, .438	.548	.150
Negative Affect Change	Real	-.143 (.27)	-.227, -.058	.070	-.100
	AR	-.256 (.52)	-.421, -.091	.274	-.300
	AV	-.203 (.54)	-.379, -.026	.288	-.050
	VR	-.213 (.42)	-.352, -.074	.180	-.100

Note. *SD* = Standard deviation; *CI* = Confidence interval.

not removed even though they do not fall under the computed boxplot as it would artificially trim the data set, which can particularly be harmful for exploratory studies.

3.2. Emotions in XR stores

Similarly, as with previous investigations of this data set, the positive affect dimension seems to follow a similar pattern between the conditions. There might be a slight trend that could put the AV condition as the most positively affecting experience. However, considering the relatively large variance of distributions and a very inconclusive trend, if these effects are detected in another, larger sample, they are likely to be very small.

On the other hand, the negative affect dimension again shows more variance and a less clear effect of the conditions. In this case, the trend suggests AR as with relatively low variance, but a high possibility for extreme values and a skew in the distribution. AV is again showing the greatest variance as well as a significant skew.

Additionally, although there are numerous apparent outliers, these were not removed as they are a significant portion of the data. This is most notable for the AR negative affect change, where 7 out of 41 observations (17%) are characterized as outliers. Instead of marking them as such and omitting them, they are useful when using exploratory data research as they do not interfere with statistical inferences but aid in gaining a more refined sense of the full data (Figure 4).

3.3. Emotions and augmented and virtual factors

As the study was designed as a factorial 2x2 experiment, the specific individual factor's effects are examined (see Table 1). Therefore, the following results refer to data groups that are based on whether a participant was in a condition that employs or does not employ augmented and virtual factors. It serves to provide nuance and, to an extent, an explanation to the exploration of data across the conditions.

Descriptive statistics that depict this data are presented in Table 4). There are several important points to consider solely from these descriptive statistics.

The *augmented* factor overall is indicated to predict a greater variance in the scores compared to the virtual factor, and particularly so for the positive affect. It seems to have a similar although not as strong effect on the negative affect. Additionally, for the latter it predicts the greatest change toward lower negative affect.

Figure 5 visually presents the unpredictability of the effects of the augmented compared to non-augmented XR. Both the interquartile ranges and the whisker lengths differ significantly, indicating a much higher likelihood of anticipating no or very small changes when there is no augmented factor.

On the other hand, the *virtual* factor scores appear less volatile and hence more predictable. It also might provide for a somewhat stronger effect on the positive affect than the augmented factor. This difference in the data appears as a trend rather than a clear indicator of statistical significance and the effect size is likely to be extremely small, if existent. The similar trend is visible for the negative affect when compared to experiences that do not employ a virtual factor.

Finally, combining the data for the positive affect for non-augmented and non-virtual experiences, results indicate that the Real condition, or the core experience, shows in the trend as having the most unpredictable effect on the positive affect, when compared to XR conditions. These effects, if real, might again be very small but worth investigating further.

4. Discussion

Many XR applications, such as different simulations and training, aim at replicating the "real-life" experiences without specifically affecting users'

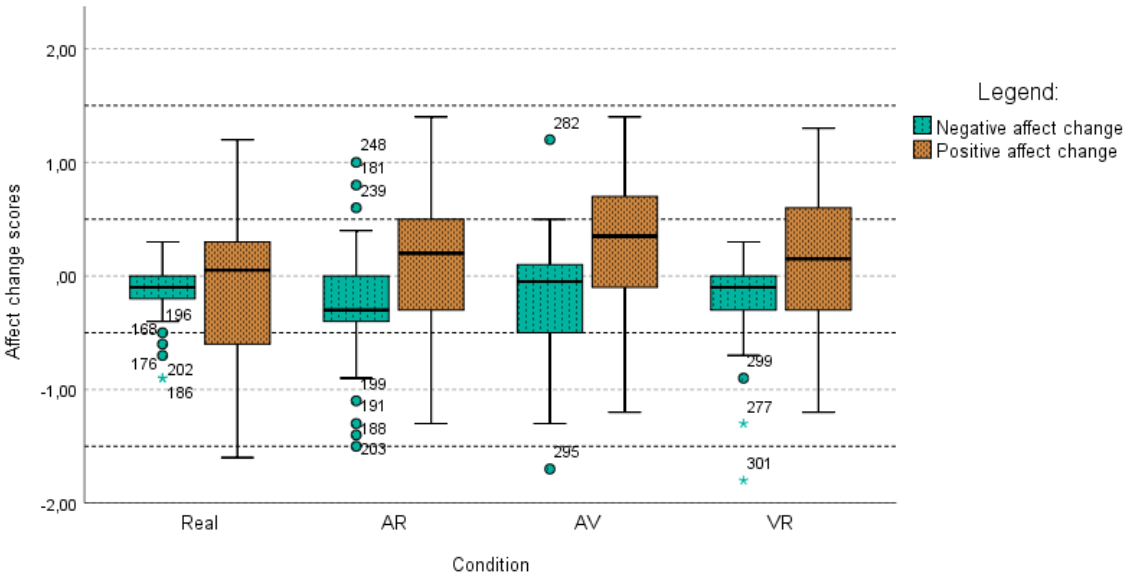

Figure 4. Positive and negative affect change across the conditions.
Note. One outlier (ID: 144) with value of 2.7 was omitted from the representation of VR positive affect change in favour of conservation of space.

Table 4. Descriptive statistics for the emotional change in individual factors.

Affect	*Factor*	*Mean (SD)*	*Mean 95% CI*	*Variance*	*Median*
Positive Affect Change	Augmented	.187 (.62)	.048, .328	.389	.200
	Non-Augmented	.083 (.71)	-.077, .244	.507	.100
	Virtual	.225 (.68)	.069, .381	.250	.250
	Non-Virtual	.052 (.65)	-.092, .195	.421	.100
Negative Affect Change	Augmented	-.230 (.53)	-.348, -.112	.278	-.200
	Non-Augmented	-.177 (.35)	-.256, -.098	.123	-.100
	Virtual	-.208 (.48)	-.318, -.098	.231	-.100
	Non-Virtual	-.200 (.42)	-.292, -.108	.174	-.100

Note. *SD* = Standard deviation; *CI* = Confidence interval.

emotional responses. In business and retail, these are mainly satisfaction with the experience [35, 36], repurchase intentions and loyalty [8], and word of mouth [37]. Hence, possible inadvertent effects on emotions due to the specific technology used for the mediated experience could have significant ramifications. This study investigated how comparable XR-mediated shopping experiences including AR, AV, and VR might produce distinct effects on users positive and negative affective responses. An additional layer of examination considered the effects of augmented and virtual factors of those XR technologies for a more nuanced identification and understanding of where the emotional variance in the four conditions originate from.

Independent-Samples Median Tests supported H_0a and H_0b which stated that there were no differences in emotional responses in participants who visited a physical or an XR store; it is in line with the a few findings of emotion-related psychological outcomes in other XR contexts (e.g. [38]). Next, exploratory data analyses using descriptive statistics and boxplots provided an in-depth examination of the full breadth of the data. EDA provided a more nuanced understanding of how different XR stores are experienced emotionally, but also of how the two factors, augmented and virtual, ripple users' emotions in specific ways.

The stimulus itself was purposefully task-based and, as expected, did not cause any significant changes in users' emotions. However, this study suggests that even in a shopping context XR can affect users' affective responses, and particularly that of negative valence. Conditions with the augmented factor, AR and AV, seemed to be most volatile, with a relatively high

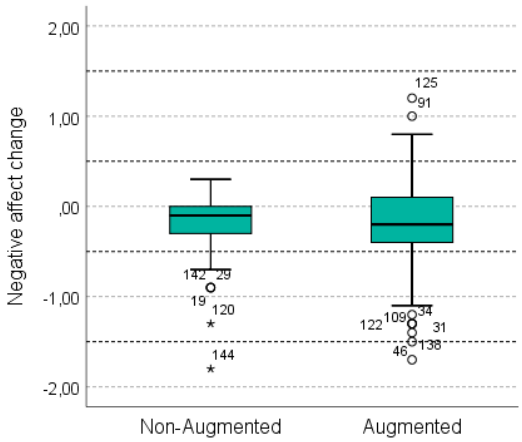

Figure 5. Boxplots of negative affect change without and with the augmented factor.

probability of users' experiencing very low or very high negative emotions. This might be primarily explained by the more complex interactivity of the augmented factor which by definition overlays an existing environment, physical or virtual, which lead to high cognitive load, anxiety and distress. The complex interaction combined with the low presence dimension of the AR condition could bring on significant cognitive strain which in return heightens negative emotions. Comparatively, the high presence in the AV might lower the discord between the environment and the overlay, easing the interaction. The difference between AR and AV here lies in their skew, which suggests that fewer users of AV experience higher negative affective response than those using AR.

Although changes in positive valence emotions were also not predictable nor stable, they were to an extent more normally distributed with contained tails of distributions, or no extreme values. This suggests that the conditions are not having a detectable influence on users' positive emotions in physical and XR stores. Additionally, no correlation between changes in positive and negative emotions were found, which is in line with previous findings [34]. This implies that these two dimensions operate independently and it is unclear what factors contributed to such high uncertainty whether users would feel overall more or less positively after the experience. It should be emphasized that the effect sizes, in this case, are very small and that the interaction of the dimensions might be detectable at higher effects.

4.1. Implications

Different XR environments (e.g. AR, VR and AV) can evoke similar emotion-related effects as a physical environment they are based on. For a long time, business practitioners and especially retailers have been searching for effective marketing tools to affect consumer's positive emotions [10, 11, 12]. As an increasing number of business activities gravitate towards being digitised, it is becoming less clear how to replicate the positive experiences from traditional shopping. Based on the findings of this study, an emerging way to do this is using XR technologies, which provide the opportunity for retailers to combine the benefits of online and physical shopping [13]. On one hand, XR stores have the same advantages of online stores in terms of, for example, time cost, economic cost, and convenience. On the other hand, they can enhance or even replace a physical store. However, this study also showed that AR technology itself might have an unpredictable impact on users' negative emotional reaction that can ultimately have undesirable consequences when it comes to users' attitudes towards the store, products, and future visits. Therefore, business practitioners that intend to use XR technologies should pay close attention to the effects that their AR applications might have on users.

Furthermore, the implications potentially go beyond comparable non-emotional contexts. The found differences of how AR, AV, and VR affect emotions should be considered as possible insights for highly emotional applications as well as they very well might be even more prominent and consequential when users' emotions are expected to be affected. For example, immersive journalism [23] (for a review, see [24]) aims at engaging its users as protagonists of the content and the choice of which XR technology to employ for delivering it might be crucial. This is also true for other various engaging contexts, such as games and psychotherapy.

Finally, as seen from the discussion, the dimensions of the EPI cube [26] seem to be an adequate tool for explaining nuanced outcomes in XR experiences. In this study, embodiment of the system interface was not seen as distinct between the XR technologies, but inspecting the interaction and presence in the context of the obtained results aided in deriving at least partial understanding of the mechanisms behind them.

4.2. Limitations and future agenda

This study is limited by the common factors in experimental research, mainly by using non-probability convenience sampling and using subjective self-reports to document the outcomes. The sample consisted of students, which is a group that was possible to access and recruit as participants. As such, it is limited in

its background and the results may not be considered representative of the population. Thus, the future study can recruit participants from regular shoppers. Additionally, subjective reports are susceptible to different faults. Although the measurement instrument used in this study has been extensively validated and the topic of the study is not sensitive, there still remains the possibility of data being somewhat skewed due to the social desirability bias [39]. In the future, objective measures, such as psychophysiological measures [40] and face tracking [41] could help confirm the results.

Similarly, only the valence dimension of the emotions has been discussed. This approach omits arousal and dominance as possibly relevant emotional dimensions in similar contexts. These should be investigated as well as their possible effects on the desired outcomes. It should also be acknowledged that many consumers' factors (e.g. age, education, income, prior experience, and personality), social factors (e.g. single vs group shopping), and product factors (e.g. brand preference, familiarity) play important roles in influencing emotions. These potential factors can be investigated in the future XR-related studies, and particularly how they interact with emotional responses. Furthermore, this study has purposefully used a product that is unlikely to evoke an emotional reaction in itself so as to support the controlled experiment design. Other studies should investigate how different products might moderate the effects stemming from the technology.

In addition, other sensory cues such as auditory, tactile, and olfactory senses can effectively influence emotions [42]. Future studies should also investigate the influence of multi-sensory XR experiences on users emotions. These advancements are still in early stages but should be understood and guided by experimental research.

5. Funding

This work was supported by KAUTE Foundation (Grant No. 20190003 and 20200531), OP Ryhmän Tutkimussäätiö (Grant No. 20200040), Liikesivistysrahasto (Grant No. 14-7798), and Business Finland (Grant No. 5654/31/2018 and 4708/31/2019).

6. Acknowledgements

Special thanks to Juan Chen, Gama Filipe, Korkeila Henry, Henrietta Jylhä and Shuo Yang's contributions to software development, the experiment design and implementation.This work was carried out with the support of the Centre for Immersive Visual Technologies (CIVIT) research infrastructure in Tampere University, Finland. The authors would also like to thank all students participants from Tampere University.

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