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Design elements in immersive virtual reality: the impact of object presence on health-related outcomes

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Abstract

Purpose – Immersive virtual reality (IVR) has been frequently proposed as a promising tool for learning. However, researchers have commonly implemented a plethora of design elements in these IVR systems, which makes the specific aspects of the system that are necessary to achieve beneficial outcomes unclear. Against this background, this study aims to combine the literature on presence with learning theories to propose that the ability of IVR to present 3D objects to users improves the presence of these objects in the virtual environment compared with 2D objects, leading to increased learning performance.

Design/methodology/approach – To test this study's hypotheses, the authors conducted a 2 (training condition: approach vs avoid) x 2 (object presence: high vs low) between-subjects laboratory experiment that used IVR with 83 female participants.

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Findings – The results support this study's hypotheses and show that training with high object presence leads to greater reactions to cues (chocolate cravings) and improved health behaviour (chocolate consumption).

Originality/value – This study shows that increased object presence leads to unique experiences for users, which help reinforce training effects. Moreover, this work sheds further light on how immersive computer technologies can affect user attitudes and behaviour. Specifically, this work contributes to IVR research by showing that learning effects can be enhanced through an increased degree of object presence.

Keywords Immersive virtual reality, Object presence, Dual-process theory, Chocolate consumption

Paper type Research paper

1. Introduction

More than 1.9 billion adults are overweight, which means that this major health issue is prevalent among more than one-third of the world's population (World Health Organization, 2018). These figures are alarming because overweight and obesity constitute risk factors for a range of physiological diseases, including cardiovascular diseases, diabetes and even cancer, and mental disorders, such as depression and attention-deficit/hyperactivity disorder (Ahrens *et al.*, 2014). As a result, the direct costs of overweight and obesity are estimated to be approximately 113.9 billion dollars per year in the United States (Tsai *et al.*, 2011). Furthermore, the coronavirus disease 2019 (COVID-19) pandemic may pose additional challenges to healthy eating, especially for individuals who are already overweight (Poelman *et al.*, 2021). These challenges may arise from the increased stress levels experienced during the pandemic, which may facilitate unhealthy eating among already vulnerable groups. Against this background, investigating how the fight against these challenges can benefit from digitisation constitutes a salient topic in information systems (IS) research (Agarwal *et al.*, 2010), which has already investigated the effects of the digitisation of healthcare on experiential and health-related outcomes, such as doctor–patient relationships (Zhang *et al.*, 2019) and online health communities (Fan and Lederman, 2018; Hur *et al.*, 2019).

In terms of theoretical approaches to the design of training sessions to reduce overweight, research rooted in dual-process theory has shown that one promising route is the approach avoidance task (AAT, Schumacher *et al.*, 2016). Dual-process theory states that human behaviour is guided by a reflective system that is deliberate, slow, and flexible and an impulsive system that is automatic, fast and difficult to change (Strack and Deutsch, 2004). Traditional health training, which aims at the reflective system, is often not effective enough because the impulsive system is more difficult to change than is the reflective system. Therefore, the AAT has been developed as a type of training specifically aimed at changing the impulsive system (Wiers *et al.*, 2010). To achieve this aim, users repeatedly push away pictures of substance-related cues that can have a possible negative effect on health (e.g. high-calorie food), whereas they pull pictures of cues that can affect health positively or neutrally (e.g. low-calorie food) towards themselves. This type of training has been successfully implemented to reduce the consumption of nicotine (Machulska *et al.*, 2016), alcohol (Wiers *et al.*, 2010) and chocolate (Schumacher *et al.*, 2016).

Recent research has successfully adapted AAT training to more immersive technologies, such as immersive virtual reality (IVR), to use the benefits that result from increased presence during the interaction with cues while simultaneously offering a high degree of environmental control (Persky, 2011; Bordnick *et al.*, 2011; Ershow *et al.*, 2011; Hone-Blanchet *et al.*, 2014). Immersion describes the degree to which a technology can present a virtual environment while physically cutting the user off from actual reality (Slater and Wilbur, 1997). As a result, immersion can facilitate different forms of presence (Cummings and Bailenson, 2016). It is proposed that increased presence is one major reason for the effectiveness of IVR in increasing cue reactivity, for example, in the form of craving experiences (Gorini *et al.*, 2010; Hone-Blanchet *et al.*, 2014). Increasing craving experiences during a training situation reduces consumption because such a high-craving training situation is more similar to a high-craving consumption situation than to a low-craving training situation. Furthermore, increased presence facilitates enjoyment (Sylaiou *et al.*, 2010; Nah *et al.*, 2011), which can help increase learning performance by facilitating flow experiences. The first study implementing AAT training in IVR showed that this training can partly reduce unhealthy behaviour relative to the effect of an IVR sham training in relation to smoking (Machulska *et al.*, 2021). Moreover, an IVR AAT concerning high-calorie food can enhance motivation and reduce errors when conducting AAT training compared to less immersive technologies such as a desktop computer or smartphone (Kakoschke *et al.*, 2021).

However, those studies that have investigated IVR up to now have either examined the differences related to whether cues are approached or avoided or explored the effects of different technologies. In the former case, no conclusions can be drawn on the specific design aspects of IVR because the design of the virtual cues or the environment are not varied, whereas in the latter case, a range of different design aspects are varied due to the different natures of the technology. For example, if a smartphone or desktop application is compared with an IVR application, then not only the environment (physical versus virtual) but also aspects of the cues (3D versus pictures) are varied. Moreover, previous research has focused mainly on either the motivational or performance-related outcomes of AAT training. Thus, whether the designs that are beneficial from a motivational perspective lead also to positive learning outcomes, and vice versa, remains unknown. Even when looking at the research on IVR in general, how different immersive computer technologies can affect a population's attitudes and behaviour remains unclear (Bujić *et al.*, 2020). Although previous studies have implemented a range of potentially effective design elements, they have investigated mainly the overall effect of a complete IVR application compared with that of a desktop computer or traditional training (Gorini *et al.*, 2010; Ferrer-García *et al.*, 2015, 2019). Therefore, the identification of which specific technology-related design elements of IVR are responsible for improving health outcomes and how these effects can be explained theoretically remain unknown. Specifically, studies have often proposed the need for a high level of telepresence in a virtual environment that elicits cravings, but it is unclear what role the virtual design of cues plays in IVR training. Therefore, we pose the following RQ:

RQ. What differential impacts does the design of cues in IVR have on health-related behaviour?

To close this research gap, we draw on the theoretical approach of presence and combine it with dual-process theory to obtain insights into how the design features of IVR AAT training affect behavioural and experiential outcomes. Specifically, we propose that experiencing the situation in which learning-relevant cues are actually present in the virtual environment (object presence) in an IVR AAT training leads to increased motivation and health-related behaviour. To test our hypotheses, we conduct a laboratory experiment to test the effects of designing cues as 3D food objects (reflecting high object presence) vs 2D pictures of food (reflecting low object presence) by using chocolate avoidance training (avoiding chocolate objects and approaching fruit objects) or sham training (approaching chocolate objects and avoiding fruit objects). Our results indicate that designing cues with high object presence is sufficient to influence health-related outcomes, even when the telepresence remains unchanged. Additionally, the results emphasise the relevance of differentiating between processes in the impulsive system when explaining learning in IVR and offer practical insights into the development and application of IVR interventions for overweight prevention and treatment.

The paper is structured as follows. In Section 2, we explain dual-process theory and derive explanations for how design elements can be used to influence impulsive and reflective processes by using an IVR application that can be distributed in the form of online training. Building on this explanation, we use the object presence construct to explain how the representation of cues as either 2D or 3D objects affects these processes. In Section 3, we develop our research model by connecting the theoretical explanations to recent findings on the dual-process model. Subsequently, we explain the setup of the experiment in Section 4 and analyse the results in Section 5. Finally, we elaborate on the implications for dual-process theory and object presence in Section 6.

2. Theoretical background

2.1 Dual-process theory

According to dual-process theory (Strack and Deutsch, 2004; Deutsch and Strack, 2006; Soror *et al.*, 2015), human behaviour is shaped by the interaction between two different cognitive systems, specifically, the impulsive and reflective systems. The reflective system influences behaviour on the basis of deliberately formed intentions and, as a consequence, involves rather slow responses, is goal oriented and can flexibly adapt to change. In the IS discipline, the reflective system is well-known in the form of the theory of planned behaviour (Ajzen, 1991) and the theory of reasoned action (Ajzen and Fishbein, 1980), which form the basis of technology acceptance models (e.g. Venkatesh *et al.*, 2003). In contrast to this perspective based on deliberate decisions, the impulsive system is responsible for rapid, automatic responses to stimuli that have been built by associations with successful behaviour in the past. As such, the impulsive system is goal independent and difficult to control and change. In the field of IS, the impulsive system has been investigated less extensively than has the reflective system but is receiving increasing attention, for example, in relation to decision support systems (Lederman and Johnston, 2011), social networking sites (Polites *et al.*, 2018) and mobile phones (Soror *et al.*, 2015; Chen *et al.*, 2019). Furthermore, a dual-process perspective has the potential to explain the inconsistent findings in previous research on the effectiveness of virtual reality in learning (Lin *et al.*, 2020). Since the impulsive system is considered difficult to change, this paper focuses on the effects of IVR training in this system (see Figure 1).

One way to explain how associations are formed in the impulsive system is classical conditioning (van den Akker *et al.*, 2018). From this perspective, when a stimulus is followed by an unconditioned stimulus (US), it can become a conditioned stimulus (CS), which elicits a conditioned response (CR). For example, an individual watching a TV show while eating chocolate may then associate that TV show (CS) with eating chocolate (US). When he or she watches the TV show (CS) at another time, an appetitive response (CR) may be triggered. This process is also called cue reactivity. It is important to note that almost any cue, including the sight, smell, and sound of food and internal physiological and psychological states (e.g. hunger, emotions or thoughts, van den Akker *et al.*, 2018), can become a US.

When associations in the impulsive system relate to a heightened approach towards certain stimuli (e.g. high-calorie foods), dual-process theory proposes that individuals exhibit approach bias, which reflects the tendency to physically approach or "reach out" to these stimuli (Cousijn *et al.*, 2011). As a consequence, psychological measurements based on reaction times (RTs) to stimuli, such as the AAT, can be used to assess the strength of such approach bias. Similar to psychophysiological and neurophysiological NeuroIS measures (Dimoka *et al.*, 2012, 2010; vom Brocke *et al.*, 2020), the above measures are difficult to influence consciously; thus, they overcome the limitations of self-report measures.

Approach bias towards certain stimuli can be trained through repeated interaction with these stimuli in a desired way (CS-noUS), which forms additional associations in the impulsive

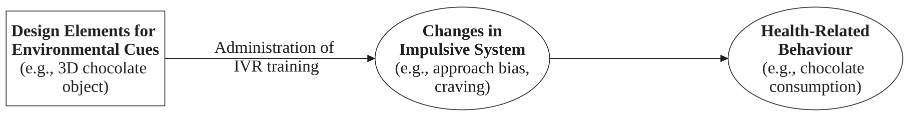


Figure 1. Working mechanism of IVR AAT training in relation to the impulsive system

system. In the context of food consumption, when individuals are trained to repeatedly avoid high-calorie foods, associations to avoid these stimuli are strengthened. As a result, these strengthened associations may weaken the existing associations that lead individuals to approach these stimuli. Moreover, this form of retraining is especially effective if training situations are highly similar to consumption situations (van den Akker *et al.*, 2018), for example, with regard to the level of craving elicited by cues. In the context of addiction, a reduction in approach bias after computer-based training that uses the AAT has been detected for substances such as nicotine (Machulska *et al.*, 2016) and alcohol (Wiers *et al.*, 2010, 2013). Likewise, in the context of eating high-calorie food, research on chocolate bias has shown that training individuals to push away chocolate images can decrease chocolate bias (Dickson *et al.*, 2016; Becker *et al.*, 2015) and even chocolate consumption (Schumacher *et al.*, 2016). However, some studies could not find a decrease in chocolate consumption (Dickson *et al.*, 2016; Becker *et al.*, 2015), even though they found a decrease in approach bias. In contrast, some studies showed a decrease in chocolate consumption without a decrease in approach bias (Schumacher *et al.*, 2016). Thus, it is still unclear whether AAT training is actually effective in changing health-related outcomes. Given that these studies were all conducted with slightly different operationalisations regarding image content, their inconsistent results emphasise that it is still unclear what role specific stimuli design elements might play in the AAT. Moreover, recent work has shown that AAT training can be successfully transferred to IVR and partly enhance health-related behaviour without affecting several measures of the impulsive system, including approach bias (Machulska *et al.*, 2021). Against this background, in the next section, we draw on theories of telepresence and object presence to develop a theoretical understanding of the effects of AAT design in IVR to gain more insights into the role that design elements in IVR training aimed at training the impulsive system can play in health-related outcomes.

2.2 Telepresence and object presence

The sense of being able to act in a virtual space is of great importance to computer-mediated environments (Schultze, 2010, 2014; Schultze and Orlikowski, 2010; Altschuller and Benbunan-Fich, 2013) as well as health-related IVR applications (Tal and Wansink, 2011). Several definitions of telepresence exist, but in a general sense, it can be defined as the "illusion of being in a distant place, that is, being there" (Schultze, 2010, p. 438). The function of the cognitive processes that lead to this illusion is to identify possibilities for acting in the environment (Triberti and Riva, 2016). As such, presence is a subjective experience (Witmer and Singer, 1998) that is influenced by how the technology addresses users' sensory modalities to recreate reality (Slater and Wilbur, 1997) and cognitive and affective factors (Gorini *et al.*, 2011; Hoffman *et al.*, 1998). For instance, the illusion of "being there" can refer to the user's sense of actually driving a car by interacting with the throttle or brake, even though he or she is sitting at a computer in an experimental setting. Previous research has shown that telepresence can lead to a range of positive outcomes, including enjoyment (Sylaiou *et al.*, 2010; Nah *et al.*, 2011).

Acknowledging that virtual and real environments are composed of objects, the definition of telepresence can be rephrased as "the subjective experience of being *colocated with a set of objects*, even when one is physically *not in such a situation*" (Stevens and Jerrams-Smith, 2000, p. 195). Object presence is described as the sense of being able to touch and manipulate a virtual object (Reiner and Hecht, 2009). In line with this definition, recent definitions of telepresence offer a more agentic perspective by emphasising that presence arises if individuals can engage in behaviour based on high-level conscious intentions in the form of distal future-directed intentions (D-intentions) and proximal present-directed intentions (P-intentions) or automatic motor intentions (M-intentions) in an environment (Riva, 2009; Pacherie and Nicod, 2007). In relation to dual-process theory (Strack and Deutsch, 2004), the reflective system is represented by D- and P-intentions, whereas the impulsive system is represented by M-intentions. Considering these definitions, we define object presence as an individual's subjective experience that a particular object exists in his or her environment that enables him or her to behave on the basis of impulsive or reflective processes. Keeping with the example of the illusion of driving a car, high object presence leads to an individual feeling able to take hold of the (virtual) steering wheel and adjust its height. Object presence in this context is much greater than that when the individual is presented with a photograph in virtual reality that shows a steering wheel, even though neither object actually exists. Although the physical picture is experienced as a "real" object, the content of the picture is perceived as an object only if the individual engages in a high degree of mental simulation. Clearly, although object presence has been researched mainly in actual reality with augmented reality devices (Stevens and Jerrams-Smith, 2000; Sugano *et al.*, 2003), it is becoming an increasingly relevant concept for explaining such effects in IVR. Consequently, when creating a task such as the AAT in IVR, the question of how object presence should be addressed arises, especially against a background in which the explanations of the effects of IVR on health-related and eating behaviours are still at an early stage (Tal and Wansink, 2011).

3. Hypothesis development

Until now, different designs of the AAT have scarcely been considered. Most studies have conducted the AAT by using arm movement to initiate approach and avoidance. Arm movements can be implemented by pressing buttons (Roelofs *et al.*, 2009), enacting pull and push movements with a joystick (Machulska *et al.*, 2016; Chen and Bargh, 1999; Wiers *et al.*, 2013) or pushing and pulling a table upward or downward (Förster *et al.*, 2001). However, arm movements can be ambiguous, as they make it unclear whether the stimuli are being pushed away or if the arm is being moved closer to the stimuli. To successfully implement the AAT, it is therefore necessary to use an additional indicator that resolves this ambiguity (Krieglmeyer and Deutsch, 2010), which is usually done by giving visual feedback that is congruent with arm movements. Thus, for push movements, the size of the stimuli decreases, and for pull movements, the size increases. Alternatively, visual feedback can be designed for pull movements in which the distance between the stimuli and a manikin decreases, whereas push movements lead to an increased distance.

From a design perspective, a few new outstanding versions have been recently developed. A version in which the participant is more involved in the task was developed by Stins *et al.* (2011), who used full-body movements (stepping forward or backward) instead of arm movements to allow individuals to approach or avoid the stimuli. Regarding design elements that vary the presence of the stimulus material, Kim and Lee (2015) developed a virtual reality task for alcohol dependence in which participants were shown videos of social situations as stimuli. Additionally, in the area of spider-anxious individuals, a conflict version of the AAT has been developed for measurement and training in approaching spiders (Mühlberger *et al.*, 2008; Dibbets, 2015). Recently, an IVR training with the AAT has been developed for smoking (Machulska *et al.*, 2021). Additionally, a first version of an IVR AAT training can enhance motivational outcomes and reduce errors during training (Kakoschke *et al.*, 2021). However, the above study did not investigate learning performance. Thus, an evaluation of both the motivational and learning outcomes of an AAT training version in the eating domain, which is designed to take advantage of the opportunities offered by IVR, is still lacking, although initial evidence suggests that individuals show faster approach reactions to food stimuli than to neutral stimuli (Schroeder *et al.*, 2016). Therefore, we aim to investigate how the design of cues with regard to object presence (i.e. 3D objects vs 2D images) affects health-related outcomes and compare this approach with the traditional approach vs avoid condition of the AAT usually conducted on a desktop computer. The hypothesised effects are explained in the following sections on the basis of the previously introduced theories. An overview of the hypotheses is given in Figure 2.

One reason for the low effectiveness of training in the area of substance dependency is the low engagement of individuals with the training, which is related to treatment participation – a

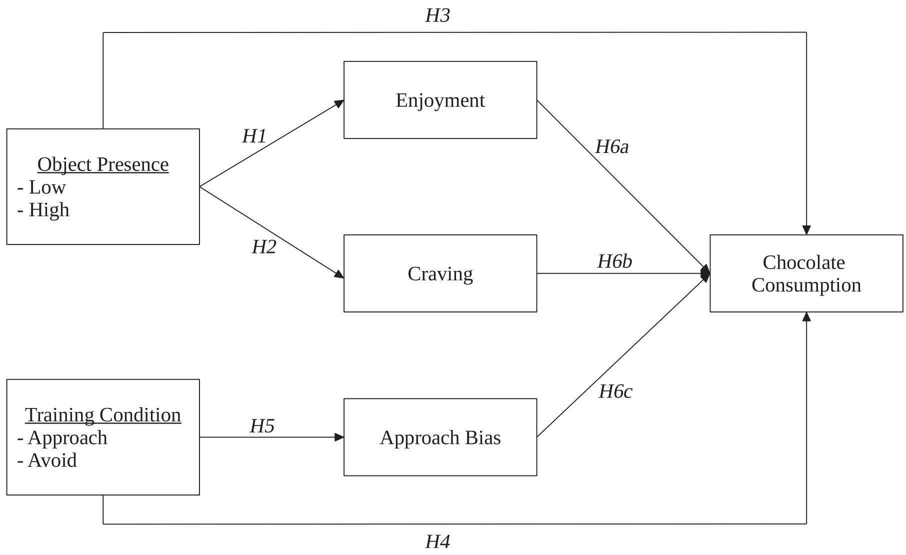


Figure 2.
Research model

prerequisite for positive outcomes (Simpson and Joe, 2004). As it is essential for IS research to investigate both learning performance outcomes and motivation-related outcomes in other domains to avoid overlooking negative effects on acceptance (Liu *et al.*, 2017), we decide to use an indicator of motivation in the system in the form of enjoyment. Enjoyment is a relevant indicator with which to assess engagement with training (Dingle *et al.*, 2008). For telepresence, research has quite consistently shown that telepresence is positively related to enjoyment (Sylaiou *et al.*, 2010; Nah *et al.*, 2011). The reason for this relationship is the higher degree of control and interest provided by environments with high telepresence (Nah *et al.*, 2011). We argue that even when telepresence with regard to the environment is held constant, changing merely the presence of the objects with which the user interacts results in increased enjoyment because the control and interest are still higher for objects that are high in object presence. Specifically, the increased affordance to interact with objects in the form of D-, P-, and M-intentions provide a higher perception of control and interest. Therefore, we hypothesise that object presence can increase the perceived enjoyment of AAT training.

H1. Individuals in the high-object-presence condition experience higher enjoyment than do those in the low-object-presence condition.

Previous research on the AAT has indicated that repeated interaction with cues can increase cravings (Dickson *et al.*, 2016) and that this effect can be enhanced by designing the AAT in a way that makes the cues more salient (Meule *et al.*, 2019). From a learning viewpoint, providing a training with a high degree of cravings is beneficial for providing a higher degree of similarity to actual consumption situations. If users experience a high level of cravings during training without eating chocolate, then it is easier for them to refrain from chocolate in an encounter with actual chocolate where the level of cravings is high and chocolate can be eaten. AAT versions for IVR in the eating domain have yet to be investigated in the area of cue exposure therapy, but several IVR studies that have not applied AAT training are related to food consumption and food cues.

In IVR, cravings can be increased for different types of cues, e.g. for smoking (García-Rodríguez *et al.*, 2013) or high-calorie foods (Ferrer-García *et al.*, 2015). One study that compared 3D food objects in IVR with both 2D food images on a computer screen and real food provided evidence that 3D objects in IVR and real food elicit similar emotional reactions in users with anorexia and bulimia nervosa compared with 2D images (Gorini *et al.*, 2010). However, the virtual environment in which the 3D objects in IVR were displayed was a restaurant, which might have confounded the effects of object presence and contextual stimuli, and neither craving level nor food consumption was measured. Further results have indicated that displaying 3D objects on a 3D computer screen leads to a comparable level of cravings as that when displaying 3D objects in IVR (Gutiérrez-Maldonado *et al.*, 2016), but in the former, these 3D objects are not compared to 2D images. Therefore, we want to test the effect of object presence alone, as we propose that it is sufficient to elicit a higher craving level if the stimuli are similar to those encountered by individuals in reality. We thus hypothesise that when object presence is high, food cravings should be higher than when object presence is low.

H2. Individuals who train with stimuli that elicit high object presence experience higher craving levels than do individuals who train with stimuli that elicit low object presence.

Drawing on classical learning theories (van den Akker *et al.*, 2018), extinction due to cue exposure should be more effective if the training situations are similar to real consumption situations. From this perspective, interactions with high-object-presence stimuli should be more effective than those with low-object-presence stimuli because the former provide affordances to interact with objects that are similar to real objects. As a result, 3D objects should be more strongly perceived as objects that can actually be eaten. Because of these affordances, the high-object-presence stimuli activate behavioural schemata from the impulsive (M-intentions) and reflective (D- and P-intentions) systems more strongly than do the stimuli in the low-object-presence condition. In contrast, 2D pictures cannot activate these schemata to the same degree because they do not appear as 3D objects and thus provide much lower affordances to interact with the object (i.e. although a participant may want to eat the object in a picture, he or she usually tries to grab not the object in the picture but rather the picture itself). In line with this reasoning, previous research has shown that experiencing 3D food objects compared with 2D food pictures increases the emotional responses to these stimuli after exposure in IVR (Gorini *et al.*, 2010). To illustrate this, individuals training with high object presence may have experiences (e.g. high craving levels) similar to those in situations in which they actually have the opportunity to eat food, thus activating behavioural schemata. Since individuals train not to engage in unhealthy behaviour (e.g. not to eat high-calorie food) when they have these experiences (e.g. high craving), these training effects are more likely to transfer to a situation in which individuals can actually eat food and are confronted with these experiences (e.g. high craving) again. In contrast, when individuals train with low-object-presence stimuli for which the training and actual recall situation experiences are not as similar, training effects are less likely to occur. Therefore, it is important to note that H2 and H3 do not contradict one another even though, at first glance, they may appear to do so. We thus hypothesise that repeated interaction with high-object-presence stimuli without the ability to engage in unhealthy behaviour with the object (eating it) acts as a form of extinction by strengthening the associations with healthy (non-eating) behaviour. As a consequence, chocolate consumption should be reduced for users who use the AAT with high-object-presence stimuli.

H3. Individuals who train with high object presence show less chocolate consumption than do individuals who train with low object presence.

In the investigation of new design elements in the area of health training, it is important to assess how these elements affect the existing training. To achieve this in the case of the AAT, the avoidance training version can be compared to a version in which half or more stimuli are approached instead of avoided. This version should be less effective than the avoidance training version.

Research in the area of actual health-promoting behaviour, which is a result of an interaction between the impulsive and reflective systems according to dual-process theory Strack and Deutsch (2004), has shown that health-related behaviour can be improved by AAT avoidance training. Studies on cigarettes and alcohol have shown that AAT avoidance training is effective in reducing consumption compared to control training (Machulska *et al.*, 2016; Wiers *et al.*, 2010). Likewise, in the area of food, AAT avoidance training with chocolate images can successfully reduce the consumption of, e.g. a chocolate muffin compared to AAT approach training (Schumacher *et al.*, 2016). However, other studies have shown that food consumption in the context of chocolate cannot be reduced through AAT avoidance training compared to approach training (Dickson *et al.*, 2016; Becker *et al.*, 2015). These results indicate that an IVR version of the AAT should also investigate how the AAT performs compared with an approach training version. Given the strong theoretical background of dual-process models, we hypothesise that avoidance training leads to less unhealthy behaviour in the form of chocolate consumption than does approach training.

H4. Individuals who train to avoid unhealthy objects show less chocolate consumption than do individuals who train to approach unhealthy objects.

Regarding the impulsive system in relation to the AAT, approach bias is an excellent indicator of the impulsive system because it is directly related to the AAT by using the same basic procedures for measurement as the training version of the AAT. Therefore, approach bias can directly measure whether the specific aspects of the impulsive system that have been trained have actually changed. The results regarding approach bias show that in the context of the traditional desktop version, a reduction in chocolate approach bias after AAT avoidance training is found, despite the absence of a significant training effect on alternative snack approach bias after AAT training (Dickson *et al.*, 2016) or in line with a decrease in alternative snack approach bias after alternative snack AAT approach training (Schumacher *et al.*, 2016). Moreover, the results of one study did not indicate changes in the chocolate approach while revealing an increase in stationary object approach bias (Becker *et al.*, 2015). These mixed results demonstrate the need for additional research in this area. Therefore, we want to test the assumption of the dual-process model (Hofmann *et al.*, 2008, 2009; Strack and Deutsch, 2004) and hypothesise that training to avoid stimuli with an IVR version of AAT training decreases approach bias.

H5. Approach bias (a) decreases after AAT avoidance training and (b) increases after AAT approach training.

Finally, dual-process theory proposes that changing the impulsive system in a beneficial way during and after training can lead to increased learning performance (Hofmann *et al.*, 2008, 2009; Kakoschke *et al.*, 2021). Moreover, a central aspect of the research on presence is that it facilitates enjoyment, which can also increase learning performance (Kakoschke *et al.*, 2021; Lowry *et al.*, 2013; Nah *et al.*, 2011). Therefore, we hypothesise that enjoyment, craving, and approach bias serve as mediators of the effects of object presence and the training condition on health-related behaviour.

H6. The effects of object presence on chocolate consumption are mediated by (a) enjoyment and (b) cravings. The effects of the training condition on chocolate consumption are mediated by (c) approach bias.

4. Method

4.1 Participants and design

After recruiting online, over the radio, through newspaper articles and with a physical flyer, 83 participants agreed to participate in the laboratory IVR experiment. In line with previous research in the area of cravings and chocolate consumption (Schumacher *et al.*, 2016; Ledoux *et al.*, 2013), we recruited only female participants because previous studies have indicated that women have higher food cravings (Weingarten and Elston, 1991; Lafay *et al.*, 2001) and tend to overeat more than do men (Burton *et al.*, 2007). Additionally, because previous research has shown that hunger can influence approach bias scores (Seibt *et al.*, 2007), we instructed participants not to drink or eat anything other than water in the two hours prior to the experiment. The final requirement was that participants had to like chocolate. Participants were, on average, 27.11 years old (SD = 9.68), 68.67% of which were students. Participants, on average, consumed 0.90 chocolate bars per week ($SD = 0.84$) and had a body mass index (BMI) of 23.57 ($SD = 4.17$).

We used a 2 (training condition: approach vs avoid) x 2 (object presence: high vs low) between-subjects design in a laboratory experiment. To assess the adequacy of the sample size, a power analysis was conducted by using G*Power (Faul *et al.*, 2007). Previous research that assessed reactions to 3D versus 2D cues in IVR (Gorini *et al.*, 2010) have suggested an average effect size of $f = 0.325$. Moreover, research that used an IVR version of the AAT in the food domain was not yet available before conducting the study, but developing an IVR application is highly resource intensive. Therefore, we also used the medium effect size of $f = 0.325$ as an estimator for approach vs avoidance conditions, given that the increased effort required to develop an IVR application would be justified by at least a medium effect size. The results of the power analysis with $\alpha = 0.05$ and a power of 80% showed that 80 participants were necessary for a 2×2 between-subjects analysis of variance (ANOVA). We recruited three additional participants to avoid low power if other participants had to be excluded. The groups did not differ significantly in terms of their age, their chocolate cravings before the AAT training, the number of chocolate bars consumed per week or BMI (all ps > 0.15).

4.2 Materials and measurements

4.2.1 Immersive virtual reality. For the AAT training, we used an HTC Vive head-mounted display with a resolution of 2,160 × 1,200, a refresh rate of 90 Hz, and a field of view of 110°. When participants put on the head-mounted display, they saw a room in which they could push and pull either objects (high-object-presence condition) or pictures (low-object-presence condition) by using the Vive controllers. The interaction was implemented by first grabbing the object with the trigger button and then throwing it away or pulling it towards themselves with an arm motion. We used robot hands as the embodiment of the hands, as previous research has shown that they have high presence and likeability and low eeriness ratings (Schwind *et al.*, 2017).

4.2.2 Approach bias measurement. Since the correct measurement of approach bias is highly dependent on correct RT measurements, it was conducted on a desktop computer with a joystick, a procedure that has been successfully applied in previous research (Machulska *et al.*, 2016). In this measurement, AAT version, participants had to repeatedly pull or push pictures with a joystick. If the picture was rotated to the right, then participants had to push it away, and if the picture was rotated to the left, then participants had to pull it. As the picture was pulled, it became larger, and as it was pushed, it became smaller.

The measurement AAT version consisted of three parts, namely, a practice version aimed at increasing participants' familiarity with the AAT, a premeasure that took place before the IVR training and a post-measure that occurred after the IVR training. The pre- and post-measures were necessary because the differences among participants' approach bias scores could be considered by calculating difference scores. For the practice version, participants were presented with 10 neutral images that were rotated to the left or right for the premeasure (2 practice images were presented for the post-measure). For the pre- and post-measures of the AAT, participants had to push and pull a set of 10 chocolate and 10 fruit images. Each picture was presented 4 times in total for each version so that participants pulled and pushed images 80 times for one bias measurement. Participants were instructed to complete the task as quickly as possible while making as few errors as possible. Approach bias scores were then calculated by subtracting the RT for pulling an image of a specific category (e.g. chocolate images) from that for pushing an image of the same category. Therefore, higher scores indicated higher approach bias for this category.

4.2.3 Chocolate consumption. We measured chocolate consumption during a chocolate tasting. Participants were provided with two bowls of 100 grams of chocolate (1 bowl of white chocolate and 1 bowl of whole milk chocolate) and given ten minutes for chocolate tasting. After the tasting, both flavours of the remaining chocolate were weighed. The weight was then subtracted from 100 grams to obtain the amount of chocolate that was eaten.

4.2.4 Questionnaire measurements. The scales used in this study are displayed in Table 1. The reflective construct of chocolate cravings was measured before and after the AAT was conducted by using the chocolate craving experience questionnaire (CEQ), which is a validated theory-based measure with three subscales – intensity, intrusiveness and imagery (May *et al.*, 2014). For the manipulation check for object presence, two self-developed items were used. Additionally, a manipulation check for telepresence was used to ensure that only object presence and not telepresence was manipulated, and we assessed the buying intention for light and dark chocolate with two items each ("I would buy this product" and "I would recommend this product to a friend if they asked me for advice regarding chocolate") as control variables for the reflective system by using a seven-point Likert scale (1 – strongly disagree to 7 – strongly agree).

4.3 Design elements

4.3.1 Object presence. The design elements of the cues presented to participants are displayed in Figure 3. Participants in the high-object-presence condition interacted with stimuli that were similar to real objects while standing in front of a table on which the objects were placed. Participants had to throw objects with a red border into a trash bin that was placed behind the table (avoid condition) and had to put objects with a blue border into a box that was set directly in front of them (approach condition).

Participants in the low-object-presence condition stood a few metres away from a striped wall. The stimuli appeared as pictures presented in front of participants, who then had to pull pictures that were rotated to the left and push pictures that were rotated to the right.

The basic interaction of the AAT task worked identically in both conditions. New stimuli appeared when participants pressed the track pad with their thumb, and stimuli could be moved by moving the controllers towards the stimuli and pressing the trigger to grab them.

4.3.2 Training condition. The participants in the approach condition had to push all fruit stimuli (objects or pictures, depending on the object presence condition) away, whereas they pulled all chocolate stimuli towards themselves. In the avoid condition, they had to push away all chocolate stimuli and pull all fruit stimuli towards themselves.

4.4 Procedure

When participants entered the laboratory, they were told that the experiment was about the effects of virtual reality on taste experiences and provided their informed consent. Afterwards, the experimenter brought them to a desktop computer, where they completed measurements of hunger, noted the time that they had last eaten and drank something other than water, and the CEQ. Next, the experimenter explained how the premeasure of the AAT on the desktop computer worked and how to use the joystick. After participants had completed the AAT, they were led to another room to conduct the IVR training, which was randomly selected for them.

Enjoyment, adapted from Nah *et al.* (2011), α = 0.92, (1 = "strongly disagree", 7 = "strongly agree")	
I found doing the cognitive task in virtual reality . . .	
. . . enjoyable	
. . . interesting	
. . . boring	
. . . fun	
Craving Experience Questionnaire – Strength, adapted from May *et al.* (2014), α = 0.87 (pre), α = 0.89 (post) (1 = "not at all", 7 = "extreme")	
Right now . . .	
. . . how much do you want chocolate?	*Intensity, α = 0.87 (pre), α = 0.92 (post)*
. . . how much do you need chocolate?	
. . . how strong is the urge to have chocolate?	
. . . how hard are you trying not to think about chocolate?	*Intrusiveness, α = 0.77 (pre), α = 0.86 (post)*
. . . how intrusive are your thoughts?	
. . . how hard is/was it to think about anything else?	
Right now, how vividly do you . . .	
. . . picture chocolate?	*Imagery, α = 0.88 (pre), α = 0.92 (post)*
. . . imagine the taste of chocolate?	
. . . imagine the smell of chocolate?	
. . . imagine what chocolate would feel like in your mouth or throat?	
Object Presence Manipulation Check, two items, self-developed, α = 0.66	
How natural was the interaction (gripping, pulling, pushing) with the objects?" (1 = "not natural at all", 7 = "very natural")	
How strong was your impression that the virtual objects you pushed or pulled were actually in front of you? (1 = "not at all", 7 = "very strong")	
Telepresence Manipulation Check, four items adapted from Nah *et al.* (2011), α = 0.62 (1 = "strongly disagree" to 7 = "strongly agree")	
I could forget the real world around me, as I was moved in the virtual world	
When I took off the VR glasses, I felt like I came back to the real world after a journey	
During the exercise in virtual reality, I forgot that I was in the middle of an experiment	
The virtual world seemed to me "somewhere I visited" rather than "something I saw."	

Table 1. Items with Cronbach's α values

In the next part of the experiment, participants completed the presence and enjoyment questionnaires. In the next step, they completed the chocolate tasting including the subjective likeability and purchase intention measures and the AAT post-measure at the desktop computer in randomised order. Finally, they completed the post-craving measure and were thanked and debriefed.

5. Results

We used 2 × 2 ANOVAs with the training condition and object presence as between-subject factors to check whether the object presence manipulation was successful and to assess the hypotheses related to enjoyment and consumption. Additionally, we used 2 × 2 × 2 mixed ANOVAs with the training condition and object presence as between-subjects factors and time as a within-subject factor to assess the hypotheses with approach bias as the dependent variable and to gain more insights into the craving effect. The means and standard deviations

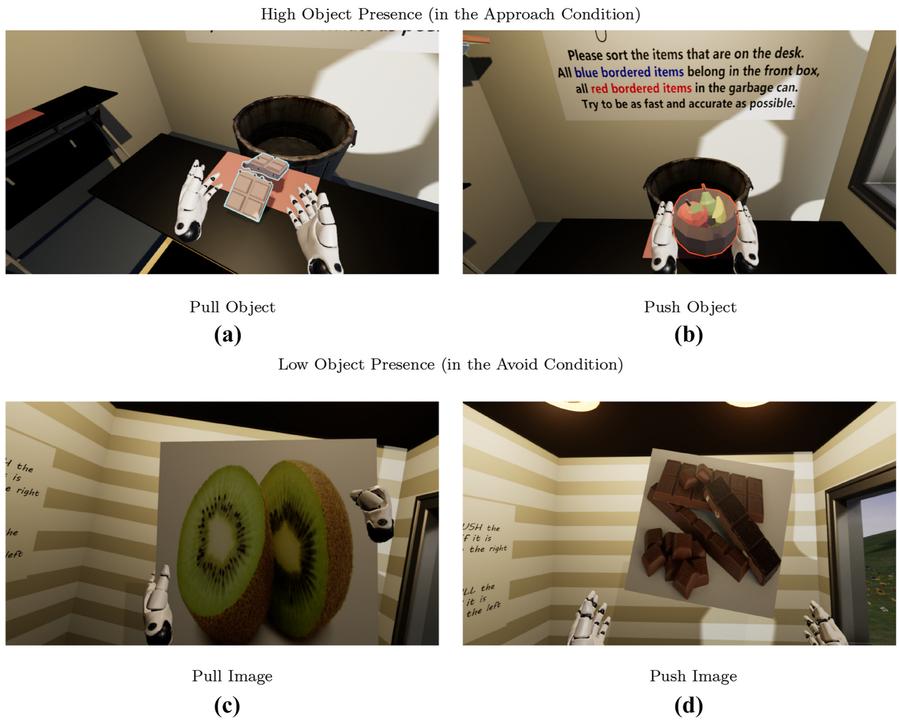


Figure 3.
Design elements for high and low object presence

of the measured constructs are displayed in Table 2. The use of 2 × 2 × 2 mixed ANOVAs, instead of a 2 × 2 between-subjects ANOVA, on the difference scores enabled us to assess whether there was a main effect (e.g. Did the bias change from pre- to post-measure?) in addition to the hypothesised interaction effects with time (e.g. Did the bias change from pre- to post-measure differently in the approach and avoid conditions?). Thus, this approach provided more information than would an ANOVA on the change scores, facilitating future research on these main effects.

Table 2.
Means and standard deviations of the dependent variables and manipulation checks

	High		Low	
Construct	Approach	Avoid	Approach	Avoid
1. Enjoyment	5.25 (0.54)	5.08 (0.57)	5.00 (0.35)	4.52 (0.81)
2. CEQ-S (Pre)	3.52 (1.07)	3.41 (1.12)	3.45 (1.14)	3.61 (1.39)
3. CEQ-S (Post)	3.39 (1.38)	3.7 (1.35)	3.04 (1.11)	3.07 (1.24)
4. Chocolate consumption	15.03 (8.65)	16.01 (12.71)	18.33 (10.69)	20.32 (11.30)
5. Chocolate bias (Pre)	−46.47 (216.57)	−83.03 (145.58)	−84.8 (114.22)	−63.55 (99.55)
6. Chocolate bias (Post)	−9.76 (178.17)	−75.95 (104.19)	−67.42 (145.84)	−76.5 (73.63)
7. Fruit bias (Pre)	−73.03 (143.97)	−76.65 (121.32)	−62.75 (104.57)	−123.73 (179.50)
8. Fruit bias (Post)	−20.93 (112.69)	−40.42 (129.64)	−81.80 (125.24)	−18.80 (76.73)
9. Object presence	5.54 (1.05)	5.55 (0.78)	5.02 (1.38)	4.5 (1.78)
10. Telepresence	5.41 (0.81)	4.6 (1.20)	5.12 (0.87)	4.71 (1.21)

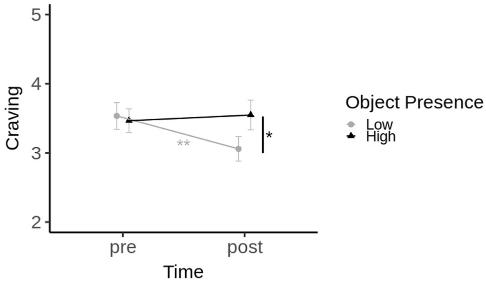
Note(s): The mean values are outside the parentheses, and the standard deviations are inside the parentheses

5.1 Experimental results

5.1.1 Manipulation checks. We used telepresence and object presence as manipulation checks for our conditions. Since both scales refer to a similar construct, we conducted a confirmatory factor analysis with both scales. The results with all items and both scales modelled as separate factors revealed sufficient discriminant and convergent validity according to the Fornell–Larcker criterion. Specifically, the square root of the average variance extracted (AVE) was 0.60 for telepresence and 0.79 for object presence, whereas the two constructs correlated with a strength of 0.59. However, in terms of the factor loadings, item 3 of the telepresence measurement showed only a mediocre loading of 0.213, whereas all other items showed values above 0.50. We retained the abovementioned item because its content represented an important aspect of telepresence (individuals forgetting that they are part of an experiment), it is part of a scale validated in previous studies, and the significant effect reported below increased after item removal. Therefore, removing the item for purely statistical reasons could lead to reduced construct validity and an overestimation of significance. Nevertheless, we report the results for both the full and reduced telepresence scales below. First, we assessed whether the manipulation of object presence was successful. The ANOVA on perceived object presence showed a significant main effect of object presence ($F(1, 78) = 9.36, p = 0.014, \eta^2_G = 0.07$), with higher values for objects than for pictures, indicating that participants who used 3D objects perceived higher object presence (M = 5.50, SD = 0.92) than did those who used 2D pictures (M = 4.76, SD = 1.60). Neither the main effect for the training condition ($F(1, 78) = 0.52, p = 0.474, \eta^2_G = 0.007$) nor the interaction effect for object presence and the training condition ($F(2, 78) = 1.14, p = 0.287, \eta^2_G = 0.013$) was significant. We further assessed whether the use of 2D pictures or 3D objects changed the perceptions of telepresence. The ANOVA revealed no main effect for the object presence condition (full scale: $F(1, 67) = 0.13, p = 0.726, \eta^2_G = 0.002$, reduced scale: $F(1, 67) = 0.16, p = 0.069, \eta^2_G = 0.097$). Unexpectedly, a significant main effect for the training condition was found (full scale: $F(1, 67) = 6.19, p = 0.015, \eta^2_G = 0.081$, reduced scale: $F(1, 67) = 6.19, p = 0.009, \eta^2_G = 0.097$), which reflected that participants in the approach condition (full scale: M = 5.27, SD = 0.84, reduced scale: M = 5.59, SD = 0.92) experienced a higher level of telepresence than did those in the avoid condition (full scale: M = 4.66, SD = 1.19, reduced scale: M = 4.87, SD = 1.29). Overall, these results indicate that the object presence manipulation was successful.

5.1.2 Enjoyment. The ANOVA revealed a significant main effect for object presence ($F(1, 79) = 9.36, p = 0.003, \eta^2_G = 0.107$), with high object presence leading to higher enjoyment (M = 5.16, SD = 0.56) than low object presence (M = 4.76, SD = 0.67), which supports H1. Additionally, there was a significant main effect for the training condition ($F(1, 79) = 6.19, p = 0.015, \eta^2_G = 0.075$), which reflected higher enjoyment for approaching (M = 5.12, SD = 0.47) than for avoiding (M = 4.79, SD = 0.75) chocolate. The interaction effect was not significant ($F(2, 79) = 1.32, p = 0.252, \eta^2_G = 0.017$).

5.1.3 Cravings. For cravings, an analysis of covariance (ANCOVA) on the postscore for the CEQ as a dependent variable and the prescore as a covariate revealed a significant main effect of object presence ($F(1, 79) = 5.80, p = 0.018, \eta^2_G = 0.044$) and a significant positive effect of the prescore ($F(1, 79) = 47.44, p < 0.001, \eta^2_G = 0.361$). Therefore, the postscores in the high-object-presence condition were higher than those in the low-object-presence condition, over and above the effect that individuals with higher craving prescores showed higher post-craving scores. Thus, H2 was supported. To further explore whether this difference arose from an increase or decrease in craving over time, we used a mixed $2 \times 2 \times 2$ ANOVA. The ANOVA revealed a significant time x object presence interaction effect ($F(1, 79) = 5.50, p = 0.022, \eta^2_G = 0.013$), which is displayed in Figure 4. No other main or interaction effects were significant (all ps > 0.102). Separate ANOVAs for high and low object presence revealed



Note(s): *$p < 0.05$, **$p < 0.01$

Figure 4.
Interaction effect for cravings

that this interaction was due to a main effect of time, which reflected that individuals in the low-object-presence condition experienced lower craving levels after the training ($M = 3.06$, SD $= 1.16$) than before the training ($M = 3.53, 1.26, F(1, 41) = 8.40, p = 0.006, \eta^2_G = 0.038$). The other main and interaction effects for low and high object presence did not reveal significant differences (all ps > 0.225).

5.1.4 Chocolate consumption. Since the assumption of normality was violated, we used a logarithmic transformation on the chocolate consumption scores, similar to the previous research of Schumacher *et al.* (2016). The ANOVA for chocolate consumption revealed a significant main effect for object presence ($F = 4.00, p = 0.049, eta^2_G = 0.048$), which showed that participants in the low-object-presence condition ($M = 19.35$ *g*, SD $= 10.93$) ate more chocolate than did those in the high-object-presence ($M = 15.52$ *g*, SD $= 10.74$) condition. All other main and interaction effects revealed no statistical significance. The results indicate support for H3 but not for H4.

5.1.5 Approach bias. RTs were recorded from the time that the picture appeared until the time that it disappeared. We excluded error trials (participants pushed or pulled in the wrong direction, 5.7% of all trials) for the approach bias analysis. For the remaining trials, we subtracted the median RTs by using the formula $RT_{Push} - RT_{Pull}$ to calculate approach bias scores (Rinck and Becker, 2007). We calculated the medians instead of the means because they are less sensitive to outliers (Wiers *et al.*, 2010). Thus, positive values for approach bias scores mean that individuals pulled images faster than they pushed them away, whereas negative values indicate faster pushing than pulling.

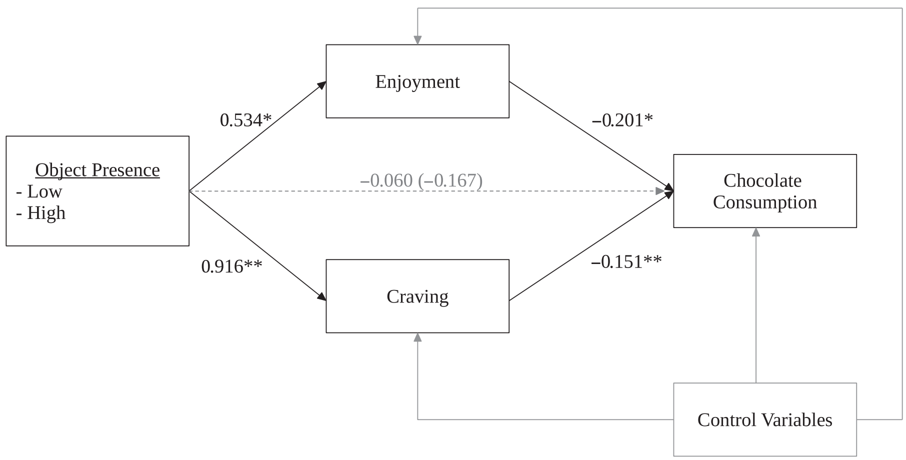
For chocolate bias, there was neither a main effect nor an interaction (all ps > 0.297). To investigate fruit approach bias, we had to exclude one participant whose RT in the post-measure was more than five times the mean, which created an artificial interaction effect. After this exclusion, only the main effect for time was significant ($F(1, 78) = 5.80$, $p = 0.018, \eta^2_G = 0.027$), which indicated that the fruit approach bias scores were higher after training ($M = -39.96$, SD $= 113.01$) than before training ($M = -85.01$, SD $= 140.77$), regardless of the condition. Therefore, participants learned to show less avoidance for fruit stimuli, and H5 was not supported.

5.2 Mediation analyses

We further tested whether enjoyment and chocolate cravings served as mediators of the effect of the experimental variables on chocolate consumption (H6). The experimental variables were dummy coded (object presence: 0 for low object presence, 1 for high object presence; training condition 0 for approach; 1 for avoid). Since chocolate and fruit approach biases were not significantly affected by our experimental variables, we did not include them in the mediation analysis, as the assumption that the independent variable needed to be significantly related to the mediator was violated (implying no support for H6c). Furthermore, overall craving levels did not reach significance in a regression on chocolate consumption ($p = 0.513$). Therefore, we looked at the intensity, intrusiveness and imagery subscales of the questionnaire, for which only intensity revealed a significant effect on chocolate consumption in a regression ($b = -0.131$, SE $= 0.055$, $t(79) = -2.38$, $p = 0.020$, all other ps > 0.152). Thus, the results below refer to the intensity subscale for craving. Additionally, we used age and BMI as covariates for all analyses and intention to buy white and whole milk chocolate for the regressions on chocolate consumption. A mediation analysis was conducted with the mediation package (Tingley *et al.*, 2014) in R by using nonparametric bootstrapping with 2,000 simulations each. The results of the mediation analysis are displayed in Figure 5.

Enjoyment: A regression on enjoyment showed a significant effect of object presence ($b = 0.534$, SE $= 0.210$, $t(72) = 2.55$, $p = 0.013$), whereas no significant effect emerged for the training condition ($p = 0.084$). A subsequent regression on chocolate consumption revealed a significant effect of enjoyment ($b = -0.201$, SE $= 0.085$, $t(68) = -2.35$, $p = 0.022$), whereas the effect of object presence did not reach significance ($b = -0.060$, SE $= 0.169$, $t(68) = -0.35$, $p = 0.724$). In addition, there were significant effects of white chocolate purchase intention ($b = 0.142$, SE $= 0.048$, $t(68) = 2.98$, $p = 0.004$) and craving intensity ($b = -0.151$, SE $= 0.056$, $t(68) = -2.69$, $p = 0.009$) on chocolate consumption. The average causal mediation effect (ACME) was significant after bootstrapping, and the confidence interval did not include zero ($b = -0.107$, *CI*[-0.23; -0.02], $p = 0.02$), whereas neither the average direct effect nor the total effect reached significance (all ps > 0.29). Thus, H6a is supported.

Craving: The regression on cravings revealed a significant effect of object presence ($b = 0.916$, SE $= 0.319$, $t(72) = 2.87$, $p = 0.005$, all other ps > 0.278). Additionally, cravings revealed a significant effect ($b = -0.151$, SE $= 0.056$, $t(68) = -2.69$, $p = 0.009$) in a regression on chocolate consumption, whereas object presence did not reach significance ($b = -0.060$, SE $= 0.169$, $t(68) = -0.35$, $p = 0.724$). The ACME was significant after bootstrapping, and the confidence interval did not include zero ($b = -0.138$, *CI*[-0.28; -0.02], $p = 0.009$). Thus, H6b is supported.



Note(s): *$p < 0.05$, and **$p < 0.01$.The dotted line indicates a nonsignificant relationship of the direct effect (outside parentheses) and total effect (inside parentheses)

Figure 5. Results of the mediation analysis with enjoyment and the intensity subscale of cravings as mediators

6. Discussion

Regarding enjoyment, our results show that participants enjoyed the AAT version with high object presence more than they did that with low object presence, which supports H1. Unexpectedly, individuals also experienced higher enjoyment for the approach than for the avoidance training. In support of H2, the results for cravings indicated that although the chocolate craving scores remained stable for high object presence, participants experienced fewer cravings after using the low-object-presence AAT version. In line with H3, the high-object-presence version of the AAT also led to increased health-promoting behaviour compared to the low-object-presence version, which indicates that training with high object presence is more effective because of the higher similarity (e.g. with regard to cravings) to real situations in which the learned behaviour has to be recalled. Surprisingly, we found no support that the AAT could reduce chocolate consumption (H4) or bias scores (H5). The theoretical and practical implications of these results are explained below.

6.1 Theoretical implications

Our study is a first step towards building a theory that explains learning in IVR. Previous studies in psychology have considered IVR as a means through which to achieve a desirable outcome (Ferrer-García *et al.*, 2015, 2019), whereas our study emphasises the need to investigate specific design elements in IVR to explain why it has beneficial learning effects. Furthermore, in contrast to previous IS research that investigated the effects of 3D objects in virtual environments on a desktop computer (Nah *et al.*, 2011), our study shows that the ability of IVR to create possibilities for acting that closely resemble reality can unravel the related effects in a way that is not possible with traditional technologies. IS research can benefit from the further investigation of object presence and additional building blocks of IVR to identify the specific working mechanisms and boundary conditions in which learning within and outside the health domain occurs in IVR. We discuss below specific contributions to the literature on presence, dual-process theory, and the identification of design elements in an AAT version for health and learning.

First, the present study contributes to the research on presence by identifying the relevance of object presence for health-related experiential and behavioural outcomes. Thus, even though previous research has argued that the construct of object presence holds an "apparent lack of relevance to IS research" (Schultze, 2010, p. 437), our results show the opposite. The result that cues with high object presence elicited higher enjoyment (H1) strengthens and refines previous theories in presence research. Although telepresence has been shown to be associated with enjoyment in previous research using desktop computers (Nah *et al.*, 2011), our study provides the first evidence that increasing object presence by using 3D objects can be sufficient to increase enjoyment, even when telepresence is held constant. Related to the research on motivation for therapy and against the background of technology acceptance models with enjoyment as an antecedent of acceptance (van der Heijden, 2004; Lowry *et al.*, 2013), this finding provides initial evidence that object presence can be a relevant design element with which to increase motivation and use intentions among patients. Moreover, the finding that enjoyment serves as a mediator of the effect of object presence on health-promoting behaviour (H6a) extends these implications for actual learning performance. In line with this conclusion, the finding that stimuli with high object presence elicited higher chocolate craving levels after the IVR experience than did stimuli with low object presence (H2), which led to health-promoting behaviour (H6b), further strengthened the proposition that object presence suffices to influence experiential outcomes and shows that this hypothesis can even be generalised to health-related experiential outcomes. This result further clarifies the observed effects of the study of Gorini *et al.* (2010) by showing that 3D stimuli in IVR do not necessarily need an environment with additional environmental cues to affect health-related experiential outcomes. Furthermore, our study generalises their results for cravings in a nonclinical sample. Finally, the finding that object presence can reduce chocolate consumption (H3) may even extend these findings to actual behaviour. However, future research must still investigate whether the effect of object presence for stimuli persists when individuals are present in an environment that provides environmental cues (e.g. a restaurant).

Interestingly, in contrast to previous research on the AAT on a desktop computer (Dickson *et al.*, 2016), we did not find an increase in the chocolate craving scores from pre- to post-measurement. The level of craving in the high-object-presence condition remained stable, whereas that in the low-object-presence condition was reduced. This occurred even though both our study and the study of Dickson *et al.* (2016) measured chocolate craving levels after chocolate tasting. An explanation for this finding could be that IVR AAT training is associated with a higher level of physical activity than is traditional AAT training conducted on a desktop computer. Users of the traditional AAT move a joystick while sitting in front of a computer, whereas the participants in our IVR AAT training had to conduct the AAT training while standing and moving their arm to a much larger degree to fulfil the task. Thus, this form of physical exercise could have had diminishing effects on chocolate cravings similar to those of other forms of physical exercise, such as a short walk (Ledochowski *et al.*, 2015).

Second, our study contributes to dual-process theory by evaluating and comparing the effect of object presence and AAT training on questionnaire and behavioural measurements. The finding that object presence reduced chocolate consumption indicates that the association between the sight of chocolate and eating chocolate was successfully extinguished and implies that new responses became associated with this cue. Importantly, this result that chocolate consumption was reduced while craving remained high (a) contributes to the existing literature that indicates that chocolate consumption and craving levels reflect independent processes in the impulsive system (Dickson *et al.*, 2016), (b) suggests that learning in a situation with high craving levels helps provide a certain immunity to the cue, and (c) provides support for the assumption of classical conditioning (van den Akker *et al.*, 2018) that learning in a context with a higher similarity to the situation in which the learned content is recalled facilitates learning effects. Furthermore, as we measured cravings by using a questionnaire, it is possible that reflective processes had an additional impact on the craving measure. Thus, whereas individuals might have reflectively come to the conclusion that they want and need chocolate, training the eating-related impulsive system multiple times in the AAT training could have prevented them from enacting behaviour on behalf of the reflective system.

Regarding the specific effects of the AAT, the questions of why the AAT did not consistently change approach bias (H5 and H6c) and why we could not find evidence for a reduction in chocolate consumption after the AAT avoidance training (H4) arise. In contrast to our hypothesis, chocolate consumption increased in the avoidance training conditions of high and low object presence, even though this result did not reach statistical significance. Thus, considering that previous studies of the AAT have revealed mixed results with regard to training effectiveness, one explanation for our results could be that the AAT is not suited for changing food consumption. Additionally, we cannot rule out the possibility that training to avoid high-calorie foods in the AAT increased chocolate consumption in the form of a behavioural rebound effect, as indicated by study 3 in Becker *et al.* (2015). In contrast, it might be that neither AAT design in IVR was suitable for affecting chocolate consumption with sufficient strength. Whether the problem lies in the specific design of the stimuli in our study or in the exclusion of relevant design elements in IVR is still unclear. Thus, our study emphasises the need for future research to investigate different stimuli and additional design elements in IVR, such as the inclusion of environmental cues (e.g. a TV screen with a couch or a laser scan of the room in which food tasting takes place) in the training. Additionally, these findings demonstrate the need for IS research to investigate (a) how the different components (e.g. craving and approach bias) of the impulsive system can be measured by using different forms of technology such as IVR, (b) what differential effects design elements have on the impulsive and reflective systems, and (c) how impulsive processes can be measured in real time with NeuroIS methods (vom Brocke *et al.*, 2020) to design adaptive systems that can improve health-promoting behaviour.

For the AAT in the eating domain, our study is the first to investigate the design elements of the AAT in IVR. Although object presence could decrease chocolate consumption, AAT avoidance training failed to reveal a significant effect. Considering the specific design variants of the AAT, this finding could suggest that the specific design for approach and avoidance were still ambiguous for participants. In the traditional AAT version on a desktop computer, visual feedback (i.e. decreasing/increasing the picture size when pushing/pulling the picture) is necessary to reduce the ambiguity of arm movements; thus, the increased complexity of the task in IVR could lead to additional ambiguity. On the one hand, participants must reach towards the object and grasp it before they can push or pull it; therefore, both reactions could be interpreted as an approach. This ambiguity could be reduced by avoiding grabbing when interacting with the stimuli (Schroeder *et al.*, 2016) or by implementing a full-body interaction in which participants stepped away or towards a stimulus after seeing it (Stins *et al.*, 2011). On the other hand, the repeated interaction with 3D objects (pictures in the case of low object presence and chocolate/fruit objects in the case of high object presence) is closer to reality than is the interaction with 2D pictures in the traditional AAT version. Thus, this interaction could be more easily interpreted as avoidance in both the approach and avoid conditions because in both conditions, the stimuli were neither virtually consumed nor permanently stored in direct proximity to the body, even though the IVR environment would allow for such a scenario.

Finally, the unexpected result that the approach bias scores did not change as hypothesised could be explained by the difference between the training conditions, which took place in IVR, and the bias measurement, which took place on a desktop computer, implying that even the approach-avoidance-related part of the impulsive system is composed of different, possibly unrelated subconstructs that need to be measured under conditions with high similarity to the training environment. Previous research has applied mainly AAT training that uses the same technology for training and measurement (Dickson *et al.*, 2016; Schumacher *et al.*, 2016), whereas we used IVR for training and a desktop computer version of the AAT for measurement. Thus, regarding the implications for dual-process theory, it might be the case that the AAT is more sensitive than previously assumed, which would imply that different approach biases that could be measured through different means are likely to exist. This is theoretically plausible given that it is a pattern already shown for different bias measurements, for example, for approach bias compared with the implicit association test (Wiers *et al.*, 2016). Specifically, whether approach is measured or trained through different means, for example, (a) on a desktop computer, (b) in IVR with interaction through controllers, (c) in IVR with interaction through virtual hands, or (d) in IVR with full-body interaction, may make a difference. As a consequence, future research would benefit from comparing different interaction types when measuring and training approach biases. Moreover, this unexpected result represents a basis for IS research, especially NeuroIS research, to further investigate the components of the impulsive system, the design elements necessary to measure them, and the specific design elements necessary to change them. Overall, our findings inform design research by helping identify additional ways to increase effectiveness in IVR. Against the background of the mixed results of the approach bias scores, a first step for future research could be to test whether high-object-presence AAT training can change approach bias scores if measurement and training take place with the same IVR AAT version.

6.2 Practical implications

Our study has several implications for practice. First, our study notes that IVR can be successfully used to facilitate health behaviour. In this area, the use of 3D stimuli for cue exposure provides an opportunity for training effects that may not be provided by traditional technologies, such as desktop computers, which cannot display 3D objects with sufficient object presence. Therefore, distributing IVR training online that aims to improve health-related outcomes may provide an additional positive effect compared to the effect of traditional training. In particular, the combination of smartphones with IVR to display 3D objects (e.g. with smartphone headsets) can be an easily accessible technology for most consumers. Moreover, whether displaying 3D objects on a smartphone elicits the same positive effects on health-related behaviour is still an open question that can be further investigated. In this regard, the individualisation of cues by the user by photogrammetry through a smartphone can be another fruitful road on which designers can create cues for which users have a high craving. Second, by showing that the use of 3D objects instead of 2D objects increases training effectiveness, we can conclude that augmented reality and holographic devices can be sufficient in place of IVR. This can provide opportunities for individuals who cannot use IVR because of motion sickness or because they are too young. Thus, once such devices have become available as consumer technologies, providing online training designed for them may be another promising opportunity. Third, our study showed that using 3D objects increased the enjoyment of AAT training over that experienced with 2D images. This finding indicates that an IVR version of the AAT or cue exposure treatment can facilitate long-term engagement compared to using devices in which it is possible to display only 2D images. This is especially relevant for online training, in which motivation can be of greater importance than it can in offline learning settings. Fourth, the result concerning whether participants had trained to approach or avoid cues seemed to be irrelevant to health behaviour suggests that pushing away objects by touching them is too ambiguous because it may be seen as training an initial approach. Therefore, designers should be careful to design avoidance in a way that reduces such ambiguity, which could be done by a full-body approach and avoidance (e.g. stepping forward/backward after a cue appears) or by hand movements that touch the cues for approach but increase the physical distance between the cues and the hand for avoidance.

6.3 Limitations and future outlooks

As with all research, our study has some limitations. First, with 83 female participants, our sample size could have been larger. It cannot be ruled out that we missed some effects due to low power in relation to H4 and H5, and we cannot yet test whether our effects can be generalised to all genders. Given that we have included effect sizes in all our analyses, future research can use them to conduct studies with higher power. Additionally, it would be interesting to investigate whether gender effects may arise. Apart from possible gender effects in relation to enjoyment, this angle could especially be interesting in relation to the question of whether specific design elements have similar effects on health-related behaviour for all genders. Furthermore, it would have been preferable to measure approach bias directly in IVR with the same task as the training, but this was not possible for technical reasons. Third, we assessed chocolate consumption directly after one AAT training session, but the results could have been different from those of a longitudinal study that included more training sessions. Additionally, our conditions differed slightly regarding the virtual room in which participants were trained (e.g. striped wall in the low-object-presence condition and the presence of a table on which the objects were placed) and the size of the objects. This was done to have an optimal design for both conditions: if the pictures would have been presented to be as small as the objects, then the content of the pictures could have easily been overlooked.

Moreover, although it was possible to design the low-object-presence condition similar to the AAT versions used on a desktop computer (that is, tilting the pictures to the left or right as an approach/avoidance cue) by using a striped background, this was not possible for high object presence because a rotation of realistically sized 3D food objects could be easily overlooked in an IVR environment. Therefore, a red and blue border was chosen as the cue for approach and avoidance, respectively. However, it is unlikely that the differences in the room had any effect because we did not find a significant difference in the telepresence measures in our manipulation checks. Nevertheless, future research should investigate what role the presence of cues that are not directly learning relevant (e.g. the trash bin) or the interaction mechanism may play. Finally, we decided to measure craving levels after chocolate tasting instead of directly after the IVR experience to avoid the contamination of the tasting with the craving measurement. Nevertheless, as our study provides initial insights into AAT design related to object presence in IVR, our results provide a foundation for the further development of IVR AAT tasks. Specifically, future research can investigate the role that the size of objects in the AAT plays, the other forms of interactions that can lead to higher AAT effectiveness, and how different biases of impulsive system can be measured inside and outside of the IVR.

6.4 Conclusions

The objective of this study was to investigate the effects of the design elements of immersive AAT training that can be distributed online on experiential and behavioural health-related outcomes. From the perspectives of dual-process theory, the literature on classical conditioning and presence, we investigated object presence as a relevant factor that influences enjoyment, craving and consumption. The results show that the increased object presence induced by 3D pictures in IVR increases enjoyment and craving, whereas chocolate consumption is reduced. Therefore, this study contributes to the current IS research on presence by proposing the development of a learning theory in IVR considering different types of design elements. In line with this, the study shows that accounting for object presence in the theoretical explanations of the effectiveness of IVR, especially in cases in which traditionally nonimmersive tasks are transferred to IVR, helps transfer learning effects into reality. Furthermore, this study strengthens the incorporation of dual-process perspectives into the research on online learning systems.

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