The Effect of Visual Angle on Slot Machine Gambling in Virtual Reality

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Abstract

Gambling has proliferated into virtual reality (VR). Increasing gambling and VR popularity prompts the blending of the two. Affective arousal can influence decision-making, an intrinsic aspect of gambling. The somatic marker hypothesis and other theories of affective valuation posit that affective arousal is beneficial for decision-making. Changing the size of a stimulus, or the visual angle (VA), can alter affective arousal. Researchers investigating how VA influences gambling have employed flawed methods like the Iowa Gambling Task (IGT) that rely heavily on cognitive reliance and do not apply to an affective arousal framework. In the current study, a VR slot machine muted cognitive reliance. Forty-six participants gambled with a VR slot machine in 20° and 60° VA conditions. We examined post-reinforcement pauses and gambling persistence. Participants did not differ across the experimental conditions on our dependent measures. Further work investigating other VR properties will inform virtual casino regulation.

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The Effect of Visual Angle on Slot Machine Gambling in Virtual Reality

Over the past decade, there has been increased use of virtual reality (VR) head-mounted displays (HMDs). Consumers have transferred their video game or television experiences from a static screen to an immersive environment. More recently, new HMDs, like the *Apple Vision Pro* (Haslam & Cross, 2024), allow users to integrate their VR experience into the office or subway station via pass-through technology. As Apple and other major technology companies introduce VR HMDs to the mainstream market, and as HMDs become more advanced, these technologies will become integral to everyday life.

Of late, there has also been a marked rise in several types of gambling. A report from Juniper Research in 2016 predicted that gambling wagers in VR would grow by 800% by 2021 (Kharpal, 2016). Juniper Research has also projected $20 billion in revenue from video game gambling by 2025 (Juniper, 2021). Further, single-game sports betting was legalized in Canada in 2021 (Evans, 2021), leading to more than $17 billion wagered after the market opened (McMillan, 2024). Researchers have discovered that, over the length of a typical sports game, over 21% of the coverage has a reference to gambling (Wheaton et al., 2024). Due to increases in popularity, blending VR and gambling is an obvious next step. Online gambling companies like *SlotsMillion* have introduced their games into the VR landscape, allowing users to play over forty casino games with a customized avatar (Griffiths, 2017). Further, the already popular *PokerStars.net* has adapted so players can enjoy their casino experience in *PokerStars VR.*

Descriptive Accounts of Decision-Making

Gambling inherently involves making decisions. The decision-making literature has seen shifts in the models used to assess human decision-making. Rottenstreich and Shu (2008) discuss how decision researchers have primarily been interested in *normative* accounts of decision-making. That is, how people *ought* to behave. In contrast, *descriptive* theories factor in various phenomena that influence decisions, typically those overlooked by normative accounts. For example, normative theories do not consider other components in the decision-making process, such as *affect*.

In this domain, earlier research suggests that the mood one is in can influence decisions. For example, research shows that, when gambling in a positive mood, gamblers place larger values on losses than controls (Isen et al., 1988). Further, by having participants focus on affective, hedonic properties rather than cognitive, utilitarian properties when making a choice, participants become loss-averse (Dhar & Wertenbroch, 2000). These results show that decision-making is not simply a cold, rational cognitive process. Instead, affective components inform decisions.

These results align with an equally interesting paradigm in descriptive accounts, *dichotomic valuation* (Frederick, 2002). Earlier research suggests that people value outcomes differently when information influencing their subjective judgments varies. For example, one faces many choices when looking for a new home (Rottenstreich & Shu, 2008). A new, large, expensive home may include a long commute with updated amenities. Another smaller, cheaper property might have a shorter commute with average appliances. Since both options have properties that result in only marginally distinct levels of value, a choice like this might induce a *deliberate* valuation method. One might need more time to think this choice through. However, imagine a decision where subjective value is clear – you enter a home which is just what you have been looking for. Here, one might rely on an *automatic* valuation method. The *automatic* method is typically experienced through strong affect inducement (Finucane et al., 2000). When one experiences greater affect, they make quicker decisions but are more cautious than if in a neutral affective state.

Further, earlier work shows that other aspects of cognition, such as working memory, can alter decisions. In a classic study, researchers told participants to remember a two-digit or a seven-digit number string (Shiv & Fedorikhin, 1999). Participants then left their original location and navigated to a different room to “report” this number to another researcher. A confederate interrupted the participants, offering them a snack – either chocolate cake or fruit salad. The authors argue that chocolate cake has favourable feelings (via taste) but unfavourable cognitions (unhealthy). In contrast, fruit salad has fewer favourable feelings (not as tasty) but more favourable cognitions (healthy). The researchers thought that higher working memory loads in the seven-digit condition would bias participants to choose the chocolate cake since they would rely on automatic valuations with a reduced capacity for deliberative valuations (Shiv & Fedorikhin, 1999). They found that participants chose chocolate cake more often in the seven-digit versus two-digit condition. Overall, this study emphasizes the importance of these valuation styles in decision-making and their susceptibility to external stimuli. Simply enhancing working memory load can override deliberative valuation styles, biasing people toward a hedonistic choice.

The Somatic Marker Hypothesis

Other theories, like the somatic marker hypothesis (SMH) (Damasio, 1996), posit that affect is beneficial and necessary to decision-making. The SMH draws on research involving neuropsychiatric patients with bilateral ventromedial prefrontal cortex (VMPFC) damage. Although these patients have intact intellect and language abilities, they make abnormal social and economic decisions. For example, Bechara et al. (1999) examined how individuals with

VMPFC and amygdala damage performed on the Iowa Gambling Task (IGT) compared to control subjects. Those with damage preferred the disadvantageous deck versus control subjects that increasingly drew cards from the advantageous deck. The researchers also measured skin conductance responses (SCRs) in response to reward and punishment and before drawing a card, which were indicative of considering a decision. Compared to controls, patients with amygdala and VMPFC damage did not generate responses before choosing a card, and those with amygdala damage did not produce an SCR to either reward or punishment. Since the brain damage occurred in areas crucial to affective arousal, Damasio et al. (1994) submitted that affect is necessary for decision-making and that a lack of affect contributes to abnormal decisions.

Bechara and Damasio (2005) discuss the SMH using several bioregulatory processes that ultimately change the decisions and behaviours one makes. First, an *emotionally competent stimulus* (ECS) must be presented to the participant to evoke heightened affect. The closely related responses to the ECS are called primary and secondary inducers (PI/SI). A PI is a response that automatically evokes a somatic state. Somatic states are physiological alterations that occur in the body. SIs are generated through thoughts or memories of an event, creating somatic states. According to Bechara and Damasio (2005), the amygdala and ventromedial cortex (VMC) are *trigger structures* for PIs and SIs, respectively, as they help create somatic states after stimulus presentation. PIs and SIs are typically evoked simultaneously by a single ECS (Bechara et al., 2003). SIs play a critical role in determining the subsequent decision one makes, as they bias participants to make a choice.

From here, researchers suggest a “body loop” is generated, providing physiological support for the influence affect has on decision-making (Damasio, 1996). The amygdala and VMC create somatic states which transfer to the body via structures like the hypothalamus, brainstem nuclei, and periaqueductal gray (PGA) (Bechara & Damasio, 2005). The somatic state is felt in the body and relayed to cortical structures through sensory and neurotransmitter nuclei and the vagus nerve (Bechara, 2004). Once the somatic state has rerouted to the brain, areas like the insula influence activity in regions important for working memory (e.g., DLPFC). This influence on working memory helps manage SIs when considering a decision. These transferred somatic states to the brain can bias subjects and moderate regions associated with behavioural actions (e.g., supplementary motor area). The SMH has been assessed using various paradigms (IGT, risk tasks, delayed discounting tasks) (Bickel et al., 1995; Rogers, 1999) and is still referenced often in recent decision-making studies in VR (Oberdörfer et al. 2020; 2021a; 2021b; 2023).

Virtual Reality Presence

A factor in the use of VR is *presence*, defined as the feeling of being in the virtual environment (Witmer & Singer, 1998). Higher levels of presence can have varying effects on human performance. Researchers have found that sensory task performance increases with a higher level of presence and that presence increases in a multisensory environment (Marucci et al., 2021). The kind of virtual environment (VE) one is in can modulate their affective states. Presence can also influence the affect one experiences in VR (Riva et al., 2007). Higher levels of presence typically invoke more intense affective states. Inversely, greater affect can also lead to higher presence in VR (Jicol et al., 2021). With knowledge of the SMH and this apparent reinforcement loop between affect and presence, stimuli in VR can strongly impact emotion and behaviour.

Presence has been manipulated to increase affect, ultimately leading to altered decision-making. Commonly, the VE changes while researchers observe differences in decision-making.

For example, Oberdörfer et al. (2021a) analyzed how participants respond to the IGT in a welcoming forest environment compared to a duller virtual replication of their laboratory. Researchers have also examined how a virtual avatar that follows the movements of the participant influences the prevalence of harm-inducing factors related to gambling (Oberdörfer et al., 2022). Interestingly, a less explored area of emotional induction in VR gambling pertains to the visual angle of the task (Oberdörfer et al., 2023).

Visual Angle

The visual angle makes up the information available in our field of view. The visual angle is a lower-level component independent of properties such as colour and brightness (Junghöfer et al., 2001). A higher visual angle typically means the stimulus perceived is large. The size of a stimulus is an important feature that determines salience and even threat detection. For example, past work found that as an aversive stimulus was perceived to come closer, participants' brain activity resembled a state of apprehension, most common when participants anticipated pain (Mobbs et al., 2007). Previous work found that, compared to a small and medium screen (2- and 13-inches, respectively), a large (56-inch) screen elicited the highest level of heart rate deceleration, a marker of the orienting response (Reeves et al., 1999). The larger screen also led to higher SCRs than the smaller screens. Interestingly, past research has also found that participants feel more aroused when only *imagining* a negative scene travelling towards them versus away from them (Davis et al., 2011). Taken together, the size of a stimulus changes the affective states one experiences.

Previous studies have used photorealistic stimuli when manipulating the visual angle, which can confound the stimulus (e.g., Codispoti & De Cesarei, 2007). Earlier research states that two fundamental aspects of visual angle are confounded when using photorealistic stimuli (perceived distance and stimulus discrimination) (Gall & Latoschik, 2020). Consistent with their recommendations, using 2D, non-photorealistic figures with high and low visual angle conditions, researchers found that higher visual angles increase affective arousal in audiovisual contexts, independent of object recognition (Gall & Latoschik, 2020). These results suggest that using a higher visual angle will enhance affective states and, drawing on the SMH, assist decision-making.

Previous work (Oberdörfer et al., 2023) has built on this finding concerning visual angle in VR. Researchers manipulated the visual angle of the IGT in VR to 20-, 35-, and 50-degree conditions. A shortcoming of this study was its use of the IGT as its decision paradigm. Despite the seemingly emotional aspects of the IGT, the task has inherent properties that make it mainly *cognitive*. The IGT contains various phases where participants learn about the task and develop "hunches" about which decks of cards are advantageous. The limitation of this task is that participants do not rely on their affective states, which is a crucial part of descriptive decision-making accounts, and the framework the researchers used. The researchers state that participants were not responding emotionally even at the stages of the task influenced by a participant's mood (de Vries et al., 2008). They suggest using an affective task to assess the effects of visual angles on decision-making. This study used a virtual slot machine, a non-cognitive, purely affective task. Since slot machines run on fixed schedules and have determined outcomes, participants cannot progressively learn about the task. Even if participants had hunches, acting on these beliefs did not influence the outcome.

Further reinforcing the affective components of a virtual slot machine, previous work found that participants are more persistent gamblers when in a sad affective state induced through a movie clip, compared to a control group (Devos et al., 2018). Interestingly, this finding would appear to violate the automatic valuation framework, wherein participants are effectively less loss averse (marked by increased gambling) despite a strong affective experience (sadness). However, research shows that negative feelings (i.e., sadness) work in the opposite direction (Johnson & Tversky, 1983). That is, negative feelings increase judgments about the likelihood of undesirable future events. Participants may not have been as risk-averse (and therefore persistent) because their affective arousal biased them to expect future outcomes as losses, further driving an attempt to "make up" their losses.

The Current Study

In the current study, we hypothesized that exposure to a high visual angle (HVA) when completing a VR gambling task will lead to better decisions versus exposure to a low visual angle (LVA). We predict that, due to the affect-inducing components of visual angle, presence will increase, and participants will become more affectively aroused, making better decisions, as stated in the SMH. Through an automatic valuation framework, the HVA condition will heighten autonomic arousal, biasing participants toward automatic, not deliberative, valuations. Since past work shows that automatic valuations increase loss aversion (Dhar & Wertenbroch, 2000; Isen et al., 1988), participants will show reduced gambling persistence and longer post-reinforcement pauses (PRPs). We believe participants will have shorter PRPs between trials in the LVA condition, a marker of poor decision-making (Dixon et al., 2013). Participants will also show more gambling persistence in the LVA since the lack of affective arousal will hinder their decisions and place them in a deliberative, non-loss-averse method of valuation.

Method

Participants

We recruited 46 (33 female; $M_{age} = 20.67$) undergraduate students from Wilfrid Laurier University. Students were eligible to participate in the study if they were at least 18 years old and enrolled in a psychology class. We advertised the study in Wilfrid Laurier University's participant recruitment database. We compensated participants with course credit upon completion.

Materials

Questionnaires

Participants completed a demographic questionnaire requesting their age, gender identity, and visual acuity, among other information. These components helped determine participation eligibility and ability to complete the decision-making task. In addition, we asked participants if they suffered from severe motion sickness since VR presents adverse effects for some users (Chattha et al., 2020; Munafo et al., 2017). If they did suffer from motion sickness, researchers remained vigilant during participation and were prepared to cease the experiment upon request.

Further, we administered the Problem Gambling Severity Index (PGSI). The PGSI is a part of the Canadian Problem Gambling Index introduced by Wynne (2002) as part of a three-year study on gambling severity and problems in Canadian populations. This measure differs from the South Oaks Gambling Screen (Lesieur & Blume, 1987) as it is non-clinical. Further, the PGSI aims to assess problem gambling, and recent confirmatory factor analyses have found that the PGSI measures a single factor and is highly reliable (Cooper & Markmurek, 2023; Holtgraves, 2009; Miller et al., 2013). The PGSI includes nine items (e.g., Thinking about the past 12 months, how often have you felt that you might have a problem with gambling?) that are scored on a 4-point Likert scale ranging from 1 (“Never”) to 4 (“Almost always”), with higher scores representing higher problem gambling. Maintaining highly conservative exclusion criteria, participants who scored higher than zero on the PGSI were ineligible to participate in the study.

We used the Positive and Negative Affect Schedule (PANAS) to measure participant affect (Watson & Clark, 1988). Researchers administer PANAS to evaluate self-reported affect. Recent confirmatory factor and reliability analyses have found that PANAS accurately assesses two factors, as theoretically desired, and is highly reliable (Brdar, 2022; Crawford & Henry, 2004; Tuccitto et al., 2010). This measure consists of 20 items, split into positive affect (PA) and negative affect (NA) categories. Each category has ten items (e.g., Indicate to what extent you feel hostile right now.) measured on a 5-point Likert scale ranging from 1 (“Not at all”) to 5 (“Extremely”), where higher PA scores indicate high affective arousal and high NA scores indicate unpleasurable engagement. We administered the PANAS at the beginning and end of the study.

This study used the Presence Questionnaire (PQ) version 3.0 to measure participant’s immersion in VR (Witmer et al., 2005). The PQ is the main questionnaire used in VR and VE research to assess presence (Grassini & Laumann, 2020). The PQ is a highly reliable and internally consistent measure modified to accurately include four crucial factors for evaluating presence (Witmer et al., 2005). The PQ consists of 19 items (e.g., How compelling was your sense of objects moving through space?) scored on a 7-point semantic differential scale with opposing anchors of “not compelling” to “very compelling” along with a midpoint anchor of "moderately compelling." Higher scores indicated higher levels of presence. This measure was administered immediately after the completion of each condition.

Slot Machine Design

We designed the VR slot machine with the VR engine *Unity*. We customized and modified the *Retro VR Slot Machine* asset (DiMichele, 2019) purchased from the *Unity Store*. We customized programming scripts to augment the gambling persistence variable and collect participants' gambling persistence data. We also tracked PRPs by retrieving system-generated files tracking millisecond engagement with the slot machine. To interact with the slot machine, participants used a *Meta Quest 3* HMD, and a single VR controller suited to their handedness.

The slot machine was fully interactive, including "bet" and "spin" buttons, a functional slot machine lever, sounds, and engaging reels. The slot machine was in a virtual casino that participants could navigate using a teleportation feature. The casino had three grey walls, a black ceiling, and a single wall with an image of the entrance of a real-life casino. Participants faced a grey wall when using the machine. Images of the stimuli from the current study are in Figure 1.

Figure 1

Experimental Stimuli

Note. (A) the low visual angle stimulus (20°). (B) the high visual angle stimulus (60°).

Slot Machine Payout Schedules

Our slot machine payout schedule differs from previous work. Past research has highlighted the typical schedules used in physical and virtual slot machines ranging from 70-99% return-to-player (RTP) rates, respectively (Oberdörfer et al. 2022). The RTP rate denotes the probability a player will receive their placed bets returned as winnings. In commercial settings, this rate is always under 100%. Work in laboratory settings, however, has used RTP rates higher than 100% to increase persistence in gambling tasks where participants always finish gambling with a net gain (e.g., Devos et al. 2018).

Our slot machine's predetermined payout schedule followed a 25-trial *mandatory* phase and an (up to) 50-trial *persistence* phase. The mandatory phase is a sequence of slot machine spins that must be completed during the experiment. The persistence phases allowed us to assess if participants continually gamble past a gambling quota. The number of trials past the mandatory phase constituted, *gambling persistence,* one of our dependent variables. During the persistence phase, participants decide when they would like to stop gambling. Prolonged gambling during the persistence phase was a marker of poor inhibitory control and poor decision-making (Devos et al., 2015).

In the current study, to maintain participant engagement, we incentivized participants by informing them that multiple entries to a real-life $100 draw were contingent on their gambling performance. Initially, we planned to let participants expect to receive more than one ballot if their gambling results called for it. We planned to inform them that since our slot machine operates on a predetermined schedule, they would only receive one ballot. However, we experienced an ethical constraint wherein our payout schedule had to make it impossible for participants to exceed the one ballot range, so they did not experience undue psychological harm when informed of the study's deception. Restraining the slot machine's RTP ratio within the range seen in previous work was difficult.

Also, to ensure that participants were not simply gambling in the persistence phase until they fell out of the one-ballot territory, then subsequently ending the experiment because they lacked incentives, we had to make the slot machine pay out a large excess so users stayed well above the one-ballot cut-off. Therefore, our mandatory phase RTPs ranged between 660% and 684%. Further, hit frequencies, the number of trials resulting in a win, ranged between 48% and 52%. Despite these large payouts, earlier work has found that ending the mandatory phase with a net gain increases gambling persistence and induces a sense of positive expectancy (Devos et al., 2015). Emphasizing that gambling during the persistence phase was a poor gambling decision, wins were less frequent and lower in amplitude in the persistence phase. We modified the slot machine like this since generating a negative relationship between trials played and profits in the persistence phase ensures that participants eventually stop gambling (Devos et al., 2015). The RTP rate in the persistence phase ranged from 110% to 127%, and the HF in the persistence phase for both schedules was 32%.

There was variability in RTP and HF rates because we used two varied payout schedules to control for order effects. Since the experiment used a within-group design, we wanted to ensure participants did not notice the parallel slot machine behaviour between conditions. Therefore, we moderately changed the schedules to create an illusion of randomness.

EmotiBit

Finally, to ensure participants experienced a change in their autonomic arousal in each condition (LVA and HVA), we implemented a physiological device called *EmotiBit*. This device is scientifically validated (Montgomery et al., 2024) and measures various physiological data. In this study, the *EmotiBit* was attached to a participant's finger on the hand without a VR controller. The participant had this device attached to their finger during each experimental condition. We used this device to evaluate changes in autonomic arousal by using electrodermal activity (EA), heartbeats per minute (BPM), heart rate variability (HRV), skin conductance response (SCR) amplitude and duration, and photoplethysmogram (PPG), which are all markers for changes in affective arousal, attention, or the orienting response (Egger et al., 2019; Kim et al., 2010; Nardelli et al., 2015; Reeves et al., 1999; Wascher, 2021). This study benefitted from the *EmotiBit* since it allowed for direct analysis of physiological change, not merely self-report or behavioural inferences. This device allowed for several exploratory hypotheses and informed earlier work on how autonomic arousal changes when visual angle differs.

Procedure

Before arriving for the study, participants completed an informed consent form, filled out the demographic questionnaire, and finished the PGSI online. Once participants were deemed eligible and completed the pre-experiment measures, they entered the laboratory. Participants were seated at a desk with a MacBook Pro and completed the first administration of the PANAS questionnaire.

Afterwards, we exposed participants to both the LVA and HVA conditions. We counterbalanced the conditions to control for order effects. LVA was denoted by the VR slot machine having a 20° visual angle. The HVA condition had the VR slot machine situated at a 60° visual angle. Participants completed the task in identical VEs, no matter their condition.

The researcher introduced participants to the study and the HMD. Researchers informed participants of the gambling task. The researcher also introduced the participant to the *EmotiBit*.

Participants performed an orientation task after adjusting the HMD to their heads. After becoming comfortable with the HMD, participants were seated in a chair where the experiment occurred. Researchers explained that participants will start with 10 credits, aiming to maximize their profits. Researchers informed participants that for every 100 credits they make in profit, they will receive one ballot for a $100 gift card raffle. Using a real-life monetary expectancy based on performance helps increase engagement in the gambling task and improves ecological validity (Ladouceur et al., 2003). As mentioned, this component included deception since the slot machine ran on a predetermined payout schedule, and each participant only received a single ballot for the draw.

Building off the design from Devos et al. (2018), researchers informed participants that, for each condition, they must initiate 25 slot machine spins (*mandatory* phase). After that, participants could quit whenever they wanted (*persistence* phase). To initiate a trial, participants used the HMD's controller to pull a virtual lever or push virtual buttons, spinning three icons, resulting in an outcome. Researchers closely examined gambling behaviours through the experiment, and when 25 spins were complete, researchers told participants that they were free to stop or to continue gambling if they would like. The persistence phase included a maximum of 50 trials with reduced payout frequency and amplitude. Based on the payout schedule, participants always ended the mandatory phase with 165-171 credits. After introducing the experiment, the researcher told participants to begin the gambling task.

After the first condition, the researcher recommended that participants remove the HMD and remain seated until they feel they have adapted to their real-world environment. Once adjusted, the researcher presented the participant with the MacBook Pro. The researcher then administered the PQ. At this time, and outside the participant's view, the researcher also adjusted the slot machine's visual angle to match the counterbalanced requirements. Once the participant completed the PQ, the researcher helped the participant put on the HMD to complete the second condition. The second condition mimicked the first condition, with the visual angle of the slot machine and a slightly varied payout schedule to control for order effects being the only differences. Upon completion, the researcher administered the PQ again, and the participant completed the second PANAS administration.

After final questionnaire completion, the researcher debriefed the participant. The researcher explained that the participant would only receive one entry for the $100 gift card since each participant's VR slot machine followed the same payout, meaning there was no opportunity for varying earnings. Following the debriefing, the participant was free to exit the laboratory.

Independent and Dependent Variables

The independent variable was the visual angle. We exposed participants to the HVA (60°) and LVA (20°) conditions. We counterbalanced the conditions for this within-group design. The dependent variables were gambling persistence and post-reinforcement pauses (PRPs). Increased trials during the persistence phase marked gambling persistence, indicating poorer gambling decisions (Devos et al., 2018). PRPs denote the time between the end of a trial and the initiation of the next. Shorter pauses are typically associated with worse gambling decisions (Dixon et al., 2013).

Data Analysis

For our main analyses, we conducted a paired t-test for PRPs and a Wilcoxon signed-rank test for gambling persistence. We compared how participant means differ in each condition compared to themselves. Since participants occasionally made errors when interacting with the slot machine (e.g., pressing the "spin" button twice), we removed any PRP values 1.5 times beyond the interquartile range from the third and first quartiles. Since gambling persistence and *EmotiBit* data were not as vulnerable to user or technological error, we did not remove these outliers. To investigate order effects, we used a 2x2 mixed-model ANOVA for PRPs and a permutation-based ANOVA (Frossard & Renaud, 2021) for gambling persistence. Where there was evidence of an order effect, we reorganized the PRP data for between-subjects t-tests and reorganized gambling persistence data for Wilcoxon ranked-sum tests. Exploratorily, we conducted paired t-tests and Wilcoxon signed-rank tests to examine changes in physiological arousal on various measurements, such as SCR amplitude and duration, BPM, HRV, EA, and PPG, when manipulating the visual angle. Again, to control for order effects, we conducted 2x2 mixed-model ANOVAs or permutation-based ANOVAs for *EmotiBit* data. If ANOVA results demanded it, we conducted between-subjects t-tests or Wilcoxon rank-sum tests. Exploratorily, we also conducted a paired t-test to examine how participants' PANAS and PQ scores differed before and after the experiment and after each condition. We obtained Cohen's *d* for parametric data with two groups and Cliff's Delta (δ) for non-parametric data with two groups (Torchiano, 2020). For parametric ANOVAs, we obtained partial eta-squared (η_p^2) to report effect size. For non-parametric ANOVAs, we use general eta-squared (η^2_G), an effect size appropriate for mixed-model non-parametric designs (Olejnik & Algina, 2003). We completed all statistical analyses in the statistical software *R* (version 4.4.3) (R Core Team, 2025) and *JASP* (JASP Team, 2024).

Results

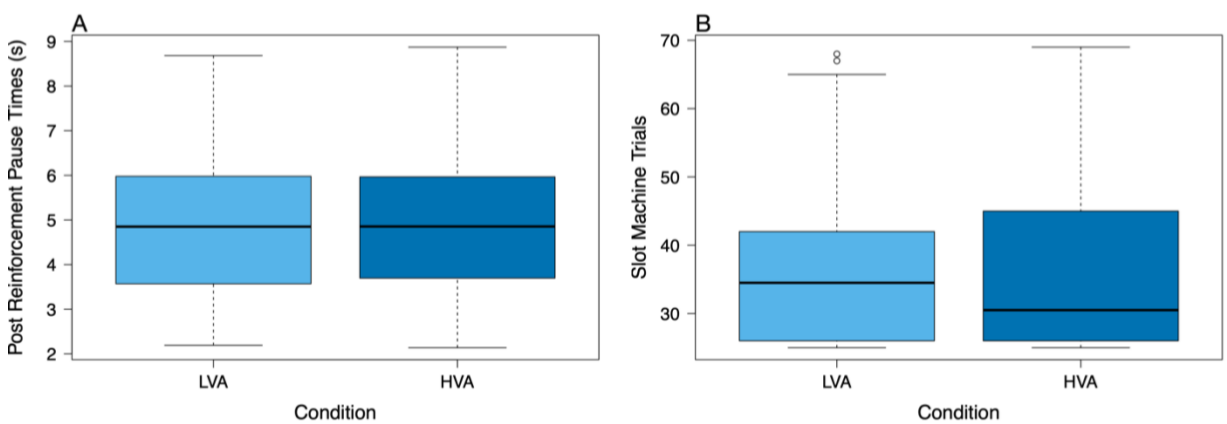
Gambling Persistence and PRP Analyses

To assess the distribution of our data, we first used the Shapiro-Wilk test of normality. For the PRP variable, the data were normally distributed. For the gambling persistence variable, these data were non-normal. We applied square root and logarithmic transformations, but the data remained non-normal. Since we primarily used within-group statistical tests, we conducted variance tests when the statistical test demanded it. For PRPs, we used parametric statistical tests, and for gambling persistence scores, we used non-parametric tests.

The results of a Wilcoxon signed-rank test showed no significant differences in gambling persistence between LVA and HVA conditions, $V = 307.5$, $p = .69$, $\delta = .007$, 95% CI [-.22, .24]. Further, the results of a paired t-test revealed no statistically significant differences between LVA and HVA conditions on PRPs, $t(45) = .04$, $p = .97$, $d = .007$, 95% CI [-.41, .42]. These results suggest that visual angle does not increase gambling trials or shorten the period between trials. See Figure 2 for graphical displays of these findings.

Figure 2

Gambling Persistence and PRP Results



Note. (A) the effect of visual angle on post-reinforcement pauses (PRPs). (B) the effect of visual angle on gambling persistence. Boxplots depict the differences in PRPs (in seconds) and gambling persistence when comparing participants to themselves across conditions. Boxes stand for the middle 50% of the data. The midline indicates the median. The whiskers extend to the greatest non-outlier minimum and maximum values. Circles represent outlier values 1.5 times greater than the interquartile range. LVA = low visual angle, HVA = high visual angle.

EmotiBit Analyses

Next, we conducted a series of paired t-tests to examine changes in various physiological dependent variables across conditions. First, we evaluated normality assumptions using Shapiro-Wilk tests for each dependent variable. PPG, BPM, and HRV were normally distributed, while SCR duration, SCR amplitude, and EA were not. We applied square root and logarithmic transformations, but these data remained non-normal. We used parametric and non-parametric tests accordingly.

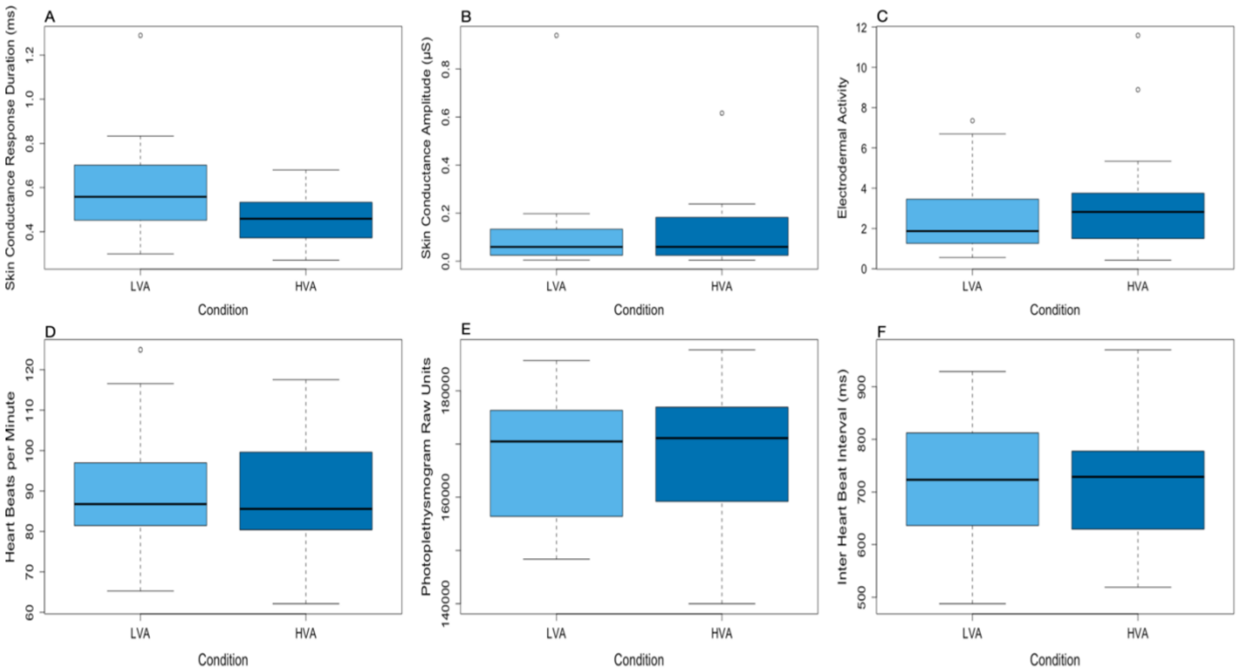
First, we performed a Wilcoxon signed-rank test to assess SCR duration mean differences across LVA and HVA conditions. We found a significant difference between these conditions, $V = 143$, $p = .01$, $\delta = .43$, 95% CI [.03, .70]. Second, we performed a Wilcoxon signed-rank test for SCR amplitude and found no significant differences between conditions, $V = 74$, $p = .64$, $\delta = -.05$, 95% CI [-.42, .33]. Third, we examined EA using a Wilcoxon signed-rank test and found no statistically significant differences between conditions, $V = 74$, $p = .16$, $\delta = .13$, 95 CI [-.89, .36]. These results suggest that EA and SCR amplitudes do not differ when the visual angle of a virtual slot machine differs. However, those in the LVA condition tend to have longer SCR responses.

Further, we performed a paired t-test for PPG values and found no significant differences across conditions, $t(23) = .19$, $p = .85$, $d = -.03$, 95% CI [-.61, .55]. A paired t-test examining differences in BPM across conditions revealed no significant differences, $t(23) = .10$, $p = .92$, $d = .008$, 95% CI [-.57, .59]. Finally, we conducted a paired t-test for HRV and found no significant differences across conditions $t(23) = -.06$, $p = .95$, $d = -.06$, 95% CI [-.59, .58].

Overall, these findings suggest that there were few physiological changes when the visual angle of a virtual slot machine differed. Graphical displays of each test are in Figure 3.

Figure 3

EmotiBit Results



Note. The effect of visual angle on: (A) skin conductance response (SCR) duration (milliseconds). (B) SCR amplitude (microsiemens). (C) electrodermal activity (arbitrary units). (D) heart rate (beats/min). (E) photoplethysmogram (arbitrary units). (F) heart rate variability (milliseconds). Boxes stand for the middle 50% of the data. The midline indicates the median. The whiskers extend to the greatest non-outlier minimum and maximum values. Circles represent outlier values 1.5 times greater than the interquartile range. LVA = low visual angle, HVA = high visual angle.

Order Effects Analyses

We conducted a permutation-based ANOVA (*visual angle*; LVA, HVA) x (*block*; LVA First, HVA First) to examine order effects for gambling persistence. We employed this test as a non-parametric alternative to a 2x2 mixed-model ANOVA. Permutation-based ANOVAs are useful for non-normal data (Kherad-Pajouh & Renaud, 2014). First, there was no main effect of *visual angle*, collapsing across *block*, $F(1, 44) = .13$, $p = .73$, $\eta^2_G = .001$. There was no main effect of *block*, collapsing across *visual angle*, $F(1, 44) = .47$, $p = .49$, $\eta^2_G = .01$. Further, there was no significant *visual angle* x *block* interaction, $F(1, 44) = 1.69$, $p = .20$, $\eta^2_G = .006$. We did not conduct further between-subjects analyses.

For PRPs, we conducted a 2 (*visual angle;* LVA, HVA) x 2 (*block;* LVA First, HVA First) mixed-model ANOVA to evaluate order effects. There was no main effect of *visual angle*, collapsing across *block*, $F(1,44) = .002$, $p = .96$, $\eta_p^2 < .001$. There was also no main effect of *block*, collapsing across *visual angle*, $F(1,44) = 1.48$, $p = .23$, $\eta_p^2 = .03$. However, there was a significant *visual angle* x *block* interaction, $F(1,44) = 28.84$, $p < .001$, $\eta_p^2 = .40$, suggesting that the effect of visual angle on PRPs may depend on the order of the conditions.

We further investigated this order effect by conducting a between-subjects t-test. We categorized participants into *LVA First* and *HVA First* groups, where we only examined their first-condition average PRP score. We found no significant differences between these groups on the PRP dependent variable, $t(43) = .87$, $p = .39$, $d = .30$, 95% CI [-.85, .33]. This result suggests that an order effect was likely not the driving factor behind the nonsignificant paired t-test results. Our findings show the visual angle does not play a role in altering gambling persistence or PRP times.

We investigated the *EmotiBit* analyses for possible order effects since our prior analyses were prone to this confound. Analogous to earlier analyses, we performed permutation-based ANOVAs (*visual angle;* LVA, HVA) x 2 (*block;* LVA First, HVA First) for non-parametric variables. For SCR duration, we found a significant main effect of *visual angle*, $F(1,19) = 11.68$, $p = .003$, $\eta^2_G = .38$. Among the remaining non-parametric tests, we found no evidence for main effects of *visual angle*, *block*, or *visual angle* x *block* interactions. Since each ANOVA yielded null results regarding order effects, we did not perform between-subjects analyses. Concerning the above main effect, we conclude that the main effect of visual angle does not provide evidence for an order effect. We considered this finding as further evidence that the LVA condition elicited longer SCRs versus the HVA condition.

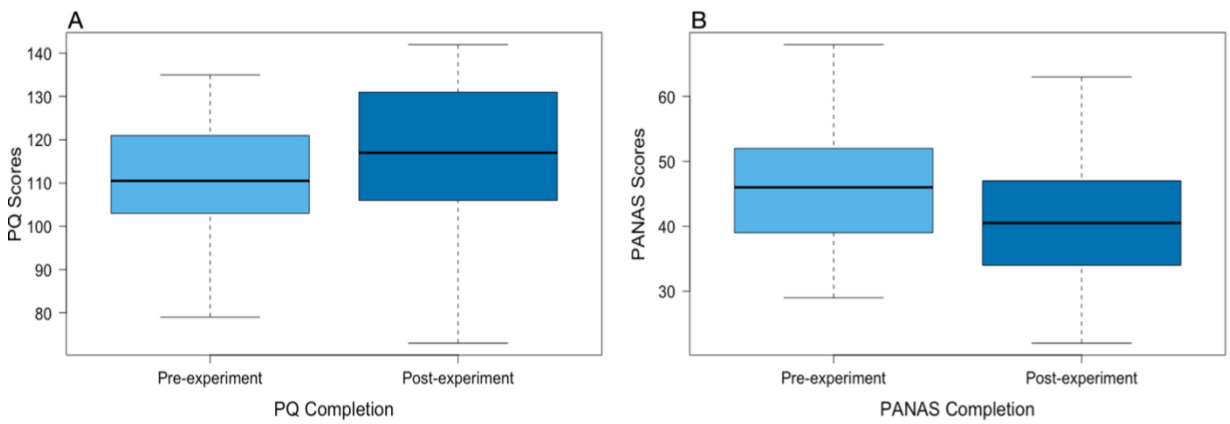
For our parametric *EmotiBit* variables, we performed 2 (*visual angle*; LVA, HVA) x 2 (*block*; LVA first; HVA first) mixed-model ANOVAs for each EmotiBit measure. The results yielded no statistically significant main effects of *visual angle*, or *block*, and no statistically significant *visual angle* x *block* interactions. We conducted no between-subjects analyses. Overall, we conclude that order effects did not influence our findings.

PQ and PANAS Analyses

Lastly, we were interested in the mean differences between the PANAS and PQ. Data for both questionnaires were normally distributed, according to Shapiro-Wilk tests. A paired t-test for PQ scores showed that participants scored higher when completing the PQ after the second condition vs. after the first condition, such that participants scored higher on the PQ after increased VR exposure, $t(45) = 2.60$, $p = .01$, $d = .35$, 95% CI [.06, .77]. For the PANAS, we conducted a paired t-test to examine participants' scores pre- and post-experiment. This test revealed significant differences, such that participants reported more intense affect before the experiment compared to after the experiment, $t(45) = 4.12$, $p < .001$, $d = .51$, 95% CI [.09, .93]. These results show that participants experience affective decreases after the experiment finishes while experiencing increased presence as they gain more familiarity with VR. See Figure 4 for graphical displays of these data.

Figure 4

PQ and PANAS Results



Note. (A) the effect of VR exposure on Presence Questionnaire (PQ) scores. (B) the effect of experiment completion on Positive and Negative Affect Schedule scores (PANAS). Boxes stand for the middle 50% of the data. The midline indicates the median. The whiskers extend to the greatest non-outlier minimum and maximum values. Circles represent outlier values 1.5 times greater than the interquartile range.

Discussion

Main Findings

The current study sought to examine how changing the visual angle of a slot machine in VR modified gambling behaviours. Building off past research, we hypothesized that increasing visual angle would increase affective arousal (Gall & Latoschik, 2020), thereby assisting gamblers in making better gambling decisions. Increases in affect are implicated in rational economic decision-making (Damasio, 1996) and automatic modes of valuation that increase loss aversion (Dhar & Wertenbroch, 2000; Isen et al., 1988). We did not find support for this hypothesis, evidenced by similar averages across conditions for gambling persistence and PRPs. Further, we did not find support for the notion that modifying the size of a virtual slot machine changes affective arousal, evidenced by similar mean scores for most physiological measures. Finally, we did find evidence that self-reported affect and VR presence changed across conditions. Users felt different before and after the experiment and felt increasingly present in the VR environment after increased VR exposure. However, as is discussed below, the implications of the PANAS data are rather dubious due to questionnaire administration. We discuss alignment with the broader literature, critiques of past theoretical conceptions of decision-making, explanations for ineffective experimental manipulations, and real-world applications.

Alignment with the Literature

First, the current study aligns with some past work examining how VR environments change user behaviours. For example, past work examined how participants completed the IGT in VR in a forest environment, a virtual laboratory, or a desktop computer (Oberdörfer et al., 2021). They found no significant differences between conditions, such that the virtual environment had no impact on decision-making. This finding doubly aligns with the current study since the researchers found a significant difference in levels of presence in each VR condition, yet no significantly different behavioural measures (Oberdörfer et al., 2021). Similarly to the current work, researchers have examined how changing the visual angle of the IGT in VR alters gambling decisions (Oberdörfer et al., 2023). The IGT can be problematic in descriptive decision-making accounts because users rely primarily on cognition rather than affective states. Like our results, the researchers found no significant differences across various experimental conditions on the IGT when manipulating visual angles (Oberdörfer et al., 2023). The current work sought to build on this study by using a non-cognitive gambling mechanism to isolate the effect of affective arousal on decision-making. As shown above, our study also rendered null results, showing that visual angle does not alter gambling decisions in VR, even when relying on affect. Our findings suggest that the apparatus used to study the effect of visual angle on VR gambling may not be foci of future research but rather another VR component, given the lack of evidence that the visual angle modifies gambling decisions.

Theoretical Misconceptions in the Literature

The decision-making literature has seen various paradigm shifts over the last few decades, and this has come with varied interpretations of classic theories. For instance, earlier work suggests that presence and affective arousal work in a feedback loop where increased presence drives affect, which should help participants make economically rational decisions (Marucci et al., 2021). Other work broadly states that affect independently benefits rational economic decision-making (Damasio, 1996). The current study conceptualized affect in this “positive” way, suggesting that its effects help gamblers make adaptive decisions. However, other work suggests that immersion (and subsequent affect) *interferes with* gambling decisions (Oberdörfer et al., 2021a). These researchers consider previous work from their laboratory where those gambling in VR conditions made worse decisions on the IGT compared to a desktop computer group. They posit that this increased immersion and affect through VR acts as a decision hindrance (Oberdörfer et al., 2020). The authors postulate that, according to the SMH, affect impairs decision-making, rendering choices more difficult because the relative weight of each option is similar (Oberdörfer et al., 2020). This theory runs counter to the basic conclusions of the SMH, such that affective arousal is *necessary and beneficial* for rational economic decisions (Damasio, 1996). Researchers argue that affect can boost cognitive processes like attention and working memory while inhibiting undesirable responses (Damasio, 1996). Further, somatic markers are needed to manage decisions, disposing the decision-making realm to cost-benefit analyses for efficient decision-making (Damasio, 1996). Earlier work also argues that increased arousal leads to advantageous, quick decision-making (Bechara & Damasio, 2005). These mixed theoretical interpretations make interpreting the decision-making literature more difficult. While the current study cannot provide evidence for either interpretation since our experimental manipulation was not effective and had no downstream behavioural effects, we outline previous debates in the literature so future work can elucidate these differences.

Experimental Manipulation Challenges

The current study did not align with previous work suggesting that visual angle or stimulus-size manipulations alter affect (e.g., Gall & Latoschik, 2020; Mobbs et al., 2007). Even with our significant findings that those in the LVA condition experienced longer SCR responses, this finding does not imply they also experienced heightened autonomic arousal because the SCR amplitude was the same across conditions. The lack of observed affective changes could initially be explained by how an object's visual angle is inversely correlated with the object's distance from the observer (Todorovic, 2016). That is, visual angle is a function of physical size and distance. In the current study, participants interacted with the slot machine at a fixed distance while the size of the VR slot machine was altered. Our slot machine required that participants interact with it directly, so users were limited in moving away from the stimulus since it would eventually be out of their reach. Therefore, manipulating only the VR slot machine size may not have effectively changed the visual angle. Keeping slot machine size fixed means that perceived stimulus size may have been the primary property altered in this study. Future work interested in visual angle using VR slot machines should ensure observer distance and physical size are both altered. This is a delicate balance because placing participants too far from the machine requires other methods for initiating slot machine spins. Placing users near the machine increases ecological validity as participants can directly interact with the apparatus.

Further, as Gall and Latoschik (2020) state, past research does not adequately isolate visual angles because perceived proximity and spatial information density often confound the stimulus. Spatial information density likely confounded the visual angle because the LVA condition constituted the same amount of information, simply on a smaller stimulus. Another possible confound is that, compared to a desktop computer, the visual angle in VR is by default larger because the apparatus takes up the entire visual field (Oberdörfer et al., 2021a). Therefore, since LVA and HVA conditions occurred in VR, the slot machine size difference was not salient enough between conditions to evoke an autonomic response. These two confounds and the potential for boredom throughout the experiment, shown by decreased affect on the PANAS before and after the experiment, are evidence for the lack of autonomic arousal differences in the LVA and HVA conditions.

However, our results theoretically align with the predictions of somatic markers on decision-making. Since there were no significant differences between conditions on physiological measures, we should expect participants to score similarly on dependent measures. Further, our data suggest that those in the LVA conditions had marginally higher gambling persistence mean scores. This finding aligns with our hypothesis that those in the LVA condition would gamble more.

Limitations

In the context of loss aversion, there is potential that the payout schedule in the current study did not evoke great fears of losses. Since the payout schedule produced ample gains and participants could only lose a maximum of one credit per trial, users may never have considered the implications of losing their gained credits. Therefore, the loss-averse states seen in automatic valuation methods were negated. The choice to continue gambling was obvious, based on the earlier pattern of wins. This lack of aversion to losses could have contributed to the nonsignificant findings on our behavioural measures.

Finally, the current study found significant differences in PANAS measures pre- and post-experiment. This result indicates that there were changes in affect throughout the experiment. However, we draw limited conclusions from this data because of how we administered the questionnaires in the experiment. Since participants completed the PANAS before and after the experiment, we cannot know which condition altered their affective changes. While we administered the PQ after the LVA and HVA completion, we did not administer the PANAS the same. Therefore, we can conclude that, based on the lack of affective arousal at the end of the experiment, participants likely became disengaged with the experiment as it progressed. Despite earlier work suggesting that a real-life monetary expectancy can maintain participant engagement (Ladouceur et al., 2003), the repetitiveness of the gambling task did not keep participants interested. To gauge the manipulations' effects, future work should ensure the questionnaires are placed shortly after completing an experimental manipulation.

Conclusion

Overall, the current study provides future insights into research regarding VR gambling. Future work may not focus on visual angle as a factor contributing to modified gambling behaviours in virtual casinos since the current study and previous work (Oberdörfer et al., 2023) have not found differences between how people gamble when visual angle is modified. This subset of the VR literature has examined the effect of visual angle on both slot machine gambling and IGT gambling, yielding no meaningful findings. Therefore, researchers should investigate VE design components like mimicry, auditory stimuli, and even the presence of other VR gamblers in a VR casino. Research in this domain can meaningfully examine how factors in VR casinos alter the behaviours of already vulnerable populations, such as problem gamblers. Further research efforts can inform impactful policy decisions aimed at regulating VR casinos.

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