Think Twice: The Influence of Immersion on Decision Making during Gambling in Virtual Reality

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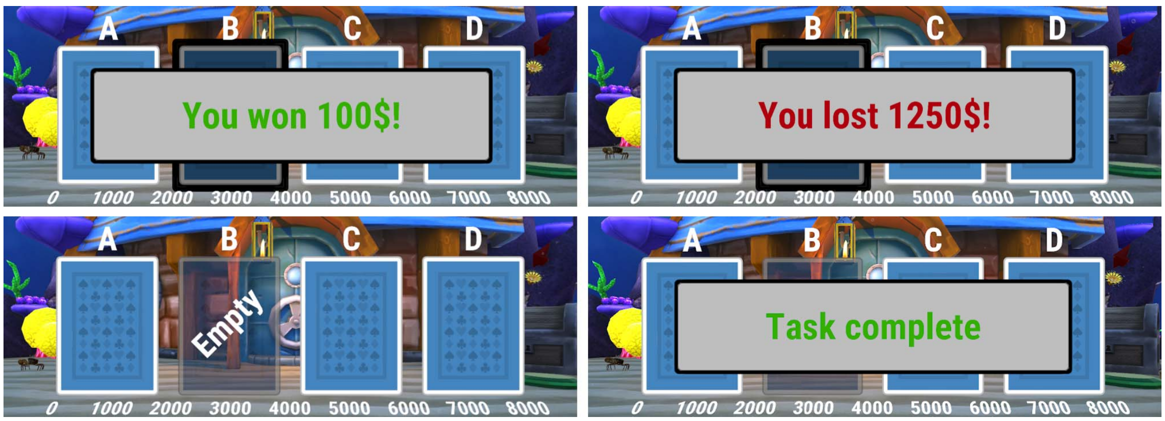

Figure 1: Our virtual IGT informs users about the current state of the simulation. Top left: The player's win is displayed for 2 seconds. Top right: The loss is shown for 2 seconds. Bottom left: A player drew all cards from a deck. Bottom right: The player drew 100 cards and finished the task.

ABSTRACT

Immersive Virtual Reality (VR) is increasingly being explored as an alternative medium for gambling games to attract players. Typically, gambling games try to impair a player's decision making, usually for the disadvantage of the players' financial outcome. An impaired decision making results in the inability to differentiate between advantageous and disadvantageous options. We investigated if and how immersion impacts decision making using a VR-based realization of the Iowa Gambling Task (IGT) to pinpoint potential risks and effects of gambling in VR. During the IGT, subjects are challenged to draw cards from four different decks of which two are advantageous. The selections made serve as a measure of a participant's decision making during the task. In a novel user study, we compared the effects of immersion on decision making between a low-immersive desktop-3D-based IGT realization and a high immersive VR version. Our results revealed significantly more disadvantageous decisions when playing the immersive VR version. This indicates an impairing effect of immersion on simulated real life decision making and provides empirical evidence for a high risk potential of gambling games targeting immersive VR.

Index Terms: Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods; Human-centered computing—Human computer interaction (HCI)—Empirical studies in HCI; Human-centered computing—Interaction paradigms—Virtual Reality;

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1 INTRODUCTION

In the *International Statistical Classification of Diseases and Related Health Problems* and the *Diagnostic and Statistical Manual of Mental Disorders*, gambling disorder is classified with substance-related and addictive disorders [3, 79]. Millions of people suffer from this disorder that leads to a patient's deterioration of social, professional, material, family values, and commitments [18, 78]. Despite causing these drastic consequences, the gambling industry continuously invests in new technologies to increase the attractiveness of gambling, e.g., providing gambling in *immersive Virtual Reality (VR)* to target young individuals [32]. At the same time, these new technologies might additionally increase the overall risk potential [2]. A higher risk potential results in a higher chance to cause gambling related harm, e.g., evoking an addiction in a player. One method to assess and compare the overall risk potential is measuring harm-inducing factors evoked by a gambling game [34]. Measuring these factors, it was shown that immersion increases the risk potential of a gambling game [34].

Decision making plays a central role in gambling. An effective manipulation of players' decision making capabilities by specific gambling-related game mechanics certainly affects and increases many harm-inducing factors of gambling. As in the real world, decision making situations with respect to gambling are often complex because they are associated with uncertainties related to punishment and reward [16]. Commonly, decisions relate to the choice of the game, the size of the bets, and whether or not to continue playing. Gambling games are designed to influence and lead players to make more disadvantageous decisions [5, 69]. An impaired decision making results in a player's inability to differentiate between options that are either advantageous or disadvantageous for them. In such a situation, players purposefully make a decision that seems beneficial to them despite clearly being disadvantageous, e.g., trying to make up for a substantial loss by making even more risky decisions in their next moves [30].

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For more than 20 years, decision making is *measured* and *analyzed* using the *Iowa Gambling Task (IGT)* [5, 16]. It simulates real life decision making featuring uncertainties with respect to assumptions and outcomes. The task requires participants to draw cards from four different decks of which two are advantageous and two are disadvantageous. The number of disadvantageous cards drawn commonly determines a subject's decision making in this task.

Determining the impact of immersion on human factors of VR systems, e.g., on emotion and cognition [75], has a long tradition. Immersion, *"the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant"* [67] is a significant characteristic of VR. For example, recent work identified that the degree of immersion significantly increases the body ownership, agency, as well as the feeling of presence [76]. Given (1) the recent trend of gambling using immersive VR, (2) the high dependency of gambling on decision making, and (3) knowing about the various effects of immersion, specifically on risk potentials of gambling games, it seems important to investigate whether immersion has an effect on players' decision making as a central target of gambling-related game mechanics [37].

Contribution

This article reports–to the best of our knowledge–novel findings of the effects of immersion on decision making in VR gambling. Thus, our contribution is twofold: (1) We describe the design and core concepts of a digital version of the IGT (see Fig. 1) which supports a variable degree of immersion for low and high immersive VR (*IGT VR*). (2) In a novel user study, the effects of immersion on decision making are measured by comparing the results of IGT VR to its desktop 3D counterpart. The study's results indicate a *significant impact* of immersive VR on the measured real life decision making simulated by the IGT. Participants of the VR group drew *significantly more* disadvantageous cards than the control group.

Our results have implications for the VR community in general. Immersive VR reduces external, non-task relevant stimuli and achieves an undisturbed focus on a decision process. This potentially affects a user's decision making, e.g., leading to more risky choices, thus requiring the provision of additional assistance for decision making processes.

2 Related Work

Gambling is a player's calculated risk-taking to improve the own financial situation [48]. However, the return to player, i.e., the percentage of the stake being paid back to a player, of commercial gambling games is below 100% [31]. As a result, a player looses money in the long run. Pathological gambling is classified by the *International Statistical Classification of Diseases and Related Health Problems* and the *Diagnostic and Statistical Manual of Mental Disorders* as a disorder which formalizes the similar characteristics of addictive behaviors and substance use [3, 79].

2.1 Decision Making and Game Mechanics

Real life decision making situations are complex. People have to deal with uncertainties in the context of punishment and reward with choices being advantageous in the short-term becoming disadvantageous in the long run and vice versa [16]. Gambling games create artificial decision making situations, e.g., selecting the bet size when playing a slot machine. By incorporating harm-inducing game mechanics, probably acquired using psychological literature [54], gambling games deliberately try to manipulate the decision making of the players.

Game mechanics are the integral elements of a computer game. They encode a game's underlying rules, processes, and data [1]. Game mechanics either create the virtual environment as well as a game's challenges or are executed by players to interact with the virtual environment [52]. This interaction creates the gameplay. Normally, computer games clearly communicate a game mechanic's underlying principles to a player either via a tutorial or by providing further descriptions. Gambling games, however, use game mechanics to either allow a player to place their bets and to start a game round or to evoke and exploit erroneous beliefs [34, 69]. These erroneous beliefs affect a player's overall risk assessment [25, 26]. While this is intended by the gambling industry to make profit, it can lead to substantial financial losses on the side of the players. An impaired decision making further increases the chances for bad decisions and high risk taking. Current assessment methods, like the *AsTERiG* tool [55], determine the risk potential of gambling games by analyzing the realization of specific game mechanics, e.g., the event frequency or the size of a jackpot.

A *stop button* game mechanic creates the illusion of having the ability to influence the outcome of a game round [25], i.e., it evokes an *illusion of control* [39]. Internally, this game mechanic only gives players the opportunity to decide when a game round ends. The results of this round are already determined based on the game's algorithm. Inducing an illusion of control is one of the main incentives for maintaining a player's gambling activity [2]. For instance, if players are allowed to throw the ball in roulette themselves, they make higher bets because they believe they have a higher probability of winning due to their abilities [38, 39]. Therefore, inducing an illusion of control with game mechanics, such as providing a stop button or throwing a dice, potentially impairs a player's decision making and causes more otherwise unintended bets.

The *existence of a jackpot* game mechanic, commonly found in lotteries, similarly affects decision making. Here, a player's assessment of the overall risk changes with the potential payout. Although *not affecting* the overall chances to win a game, larger jackpot sizes provoke a higher risk taking [43]. This also applies to jackpots with an unknown size. The mere existence of a jackpot increases a player's gambling intensity and risk taking [26]. Hence, providing jackpots potentially impairs a player's risk assessment and leads to bad decisions, e.g., placing higher or more bets than initially wanted.

2.2 Iowa Gambling Task

The IGT is a popular experimental paradigm that simulates *real life* decision making in a laboratory setting, commonly referred to as *IGT decision making* [5, 11]. The IGT has been used for more than 20 years as an experimental platform in multiple fields of research aiming at the analysis of decision making [22]. Aside from determining a subject's decision making, the IGT was used to measure differences with respect to this quality between clinical populations, e.g., cocaine users [74] and pathological players [16, 17], and control groups. The task is commonly administered to investigate the often underestimated influence of emotions on decision making [4]. According to the *Somatic Marker Hypothesis* [4, 23], emotions can interfere with decision making and *cause* a person to make unfavorable decisions. This hypothesis was frequently tested using the IGT and has a high potential to explain IGT decision making behavior [16]. Aside from emotions and clinical conditions, other factors also influence the results of the IGT. Induced time pressure [24], excitement [49, 56], gender [72], and age [20] showed an influence on IGT decision making.

The IGT is a repeated task in which subjects draw 100 cards from four different decks [5], commonly denoted as deck *A*, *B*, *C*, and *D*. Each deck consists of 40 cards. Following a fixed win and loss schedule as displayed in Table 1, each card has a fixed payout, i.e., \$100 for deck A and B as well as \$50 for deck C and D, but also a chance for a loss of money. The schedule results in deck A and B being advantageous in the short-term but *disadvantageous* in the long run and deck C and D being disadvantageous in the short-term but *advantageous* in the long run. Drawing all cards

Table 1: Overview of the decks and their win and loss schedule.

Card	A (+100)	B (+100)	C (+50)	D (+50)
1	0	0	0	0
2	0	0	0	0
3	-150	0	-50	0
4	0	0	0	0
5	-300	0	-50	0
6	0	0	0	0
7	-200	0	-50	0
8	0	0	0	0
9	-250	-1250	-50	0
10	-350	0	-50	-250
11	0	0	0	0
12	-350	0	-25	0
13	0	0	-75	0
14	-250	-1250	0	0
15	-200	0	0	0
16	0	0	0	0
17	-300	0	-25	0
18	-150	0	-75	0
19	0	0	0	0
20	0	0	-50	-250
21	0	-1250	0	0
22	-300	0	0	0
23	0	0	0	0
24	-350	0	-50	0
25	0	0	-25	0
26	-200	0	-50	0
27	-250	0	0	0
28	-150	0	0	0
29	0	0	-75	-250
30	0	0	-50	0
31	-350	0	0	0
32	-200	-1250	0	0
33	-250	0	0	0
34	0	0	-25	0
35	0	0	-25	-250
36	0	0	0	0
37	-150	0	-75	0
38	-300	0	0	0
39	0	0	-50	0
40	0	0	-75	0
Overall win	4000	4000	2000	2000
Overall loss	-5000	-5000	-1000	-1000
Combined	-1000	-1000	1000	1000

of a deck, both advantageous decks would lead to the same total profit and both disadvantageous decks would lead to the same total loss. Before starting with the IGT, participants receive a virtual loan of $2000 and are instructed to maximize their virtual money by drawing cards. They receive no further information concerning the task itself, e.g., number of cards to be drawn, or the underlying principles, e.g., the fixed schedule of win and loss. As a result, the IGT simulates decision making featuring an uncertainty in the context of punishment and reward [16].

Unimpaired subjects develop a particular knowledge about the IGT throughout the task's completion. The typical sequence of IGT card selection patterns goes through four periods [8]. At the beginning, subjects do have no knowledge about the distribution of advantageous and disadvantageous decks [7]. During this *pre-punishment* period, they usually prefer decks A and B. The first period typically ends by game round 10 when participants experienced a few losses. Subjects then enter the *pre-hunch* period. During this second period, subjects still do not know which decks are advantageous or disadvantageous, but start to develop a first hunch. Around the 50th game round, users start to express minimal knowledge about the distribution of good and bad decks, i.e., they enter the *hunch* period. The hunch period leads to a more pronounced decline in the number of disadvantageous cards drawn. By game round 80, subjects with an unimpaired decision making enter the *conceptual* period being associated with the development of knowledge about the underlying principles. Once having reached this period, subjects express knowledge about the effects of drawing cards from the individual decks in the long, i.e., they identified the advantageous and disadvantageous of the four decks.

For evaluating the IGT, the total number of advantageous and disadvantageous selections determines a subject's decision making on this task [6, 27, 29]. Splitting the results in segments of 20 draws each further allows for an analysis of a subject's selection patterns [9, 14, 73]. The more advantageous cards a participant drew, the better their decision making is. However, the structure of the fixed schedule of win and loss can lead to the so-called *prominent deck B* phenomenon [21]. While deck A and C feature a high frequency of small losses, deck B and D feature substantial losses at a low frequency. Subjects may come to the assumption of deck B being beneficial, thus drawing several cards from it. As good IGT decision making bases on drawing a high number of advantageous cards, the prominent deck B phenomenon leads to skewed measurements.

The IGT has not been administered in immersive VR, yet. Due to its popularity and its potential to compare decision making between various influencing conditions, designing an immersive VR version is an important contribution. While the original IGT implemented physical cards, digital versions of it were developed and validated [10,14]. For IGT VR, this is an important finding. It implies that the IGT is transferrable to another medium and that the measurements are not influenced by using a virtual currency. Also, the tested versions of the digital IGT can act as a guideline for implementing our two IGT realizations.

2.3 Immersive VR

Immersion depends on objective system properties achieving a reduction of real world sensory inputs and a simultaneously replacement by providing digital information [67], e.g., by using a head-mound display. The degree of immersion affects the experience of presence [65, 76]. *Presence*, telepresence, or place illusion describes the subject sensation of being in a real place, e.g., accepting the virtual environment as the *real* environment, despite being physically located in a different place [64]. In contrast, *plausibility illusion* describes the subjective illusion of perceiving events inside a virtual environment as real events [64]. Evoking and maintaining presence requires a continuous stream of stimuli and experience [77] and a support of sensorimotor contingencies, e.g., allowing users to move their heads or to walk [64]. Aiming for a high degree of presence can be a central goal, e.g., for VR storytelling [63] or computer games [15]. Also, presence affects a user's intrinsic motivation for learning [46], enhances the overall performance in a training scenario [68] especially when a high visual fidelity is provided [57], and increases the emotions experienced in a virtual environment [59]. As emotions interfere with decision making, a higher intensity of emotions could result in gambling-related game mechanics that aim at an impairment of decision making to be more effective and hence more dangerous.

Providing other VR specific factors positively increases presence. The provision of an avatar as a proxy for a user's body [36] leads to an illusion of virtual body ownership [66]. This illusion increases presence [76]. In this way, measuring presence can confirm an effect of an increased immersion as long as no other VR specific factors are added to the simulation.

It was shown that immersive VR increases the overall risk potential of gambling games [34]. In this study, significantly higher harm-inducing factors, i.e., dissociation, urge to gamble and dark

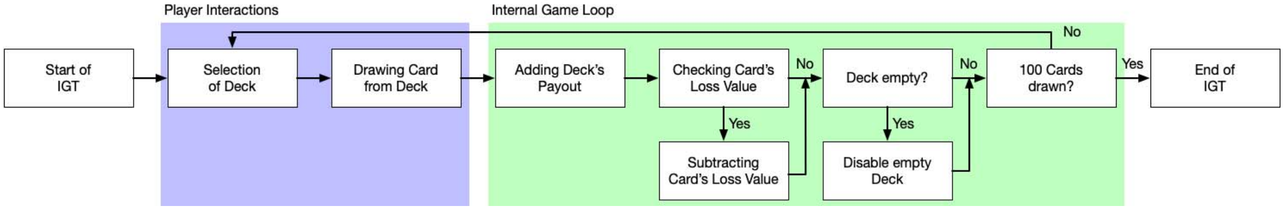

Figure 2: Visualization of the IGT game loop. After selecting a deck, players can draw a card. The IGT checks the player's selection, executes the payout process and checks if the deck is empty as well as if the IGT is complete.

Figure 3: We compare the effects of immersion on decision making by realizing a VR (top) and a desktop (bottom) version of the IGT. In both versions, players use an HTC Vive controller as input device.

flow, were measured when using an immersive VR instead of a desktop-3D realization of a slot machine. The two versions of the slot machine were identical with respect to game mechanics and interaction patterns. They only differed in the medium used. However, the effects of immersion on decision making are still *unclear*. Several immersive VR gambling games have been released showing the importance of this research. For instance, Gonzo's Quest VR [51] realizes a virtual slot machine and PokerStars VR [44] provides an embodied and visually exaggerated virtual environment for socially playing poker with other players. In this way, PokerStars VR not only represents a high immersion gambling game, but also combines it with additional prominent VR factors, thus potentially increasing the risk potential even further.

2.4 Summary

Specific gambling-related game mechanics aim at the evocation of erroneous beliefs, illusions and emotions in the player. Aside from causing several harm-inducing factors, the emotions evoked are intended to interfere with a player's decision making. Immersive VR leads to higher harm-inducing factors in comparison to a low-immersive desktop-3D environment. A higher immersion also leads to a higher presence and thus in a higher intensity of the experienced emotions. This could result in the impairing effects of gambling game mechanics on decision making to be more effective and hence dangerous.

3 System Description

For analyzing the effects of immersive VR on decision making, a *desktop*, i.e., low immersion, and a *VR* version, i.e., high immersion, was developed for the IGT. Basing on the original version of the IGT [5], our implementation requires the realization of two core interactions: (1) *selection* of a deck and (2) *drawing* a card from the selected deck (see Fig. 2). To ensure for a comparability of the medium's effects, the interactions and the user interface (UI) need be the *same* for both versions of the IGT. As the HTC Vive Pro [35] was selected as the output device for the VR version, we implemented a *single* HTC Vive game controller as the main input device for both versions. Our IGT allows a user to select a deck and to draw a card by using the touchpad. Touching it on its left or right side selects a deck and pressing it draws a card. The controller is physically and visually present when playing the desktop version. Therefore, we implemented it as a diegetic UI element in the VR version by using its 3D model as Fig. 3 displays [41]. Following the design of a validated desktop-based IGT realization [10, 14], the IGT also needs UI elements for the four decks, the player's current balance and initial loan as well as the indication of a player's win and loss per card drawn (see Fig. 1 and Fig. 3). For visualizing a deck, the backside of a playing card is used. The decks are labeled with characters, i.e., *A* and *B* denote disadvantageous decks and *C* and *D* mark advantageous decks. Two bars on a grid represent the loan, i.e., an orange bar, and the player's balance, i.e., a green bar. For supporting an experience of presence in both conditions, we decided to embed the gameplay into a virtual environment featuring a high visual fidelity, i.e., an underwater scenario [47].

Internally, the deck game mechanic encodes the IGT's fixed schedule of win and loss for each card (see Table 1). Each deck encodes an ordered list consisting of 40 entries, i.e., cards. An entry contains the value that a player looses when drawing the respective card. Drawing a card adds the deck's payout to a player's balance and subsequently subtracts the card's loss value as well as removes the entry from the list (see Fig. 2). Following the IGT's original design, each card of deck A and B rewards a player with \$100, whereas each card of deck C and D results in a payout of \$50. A player starts with a loan of \$2000. Our IGT system always displays the payout after a card is drawn, but only shows losses when they occur (see Fig. 1). Each information is displayed for two seconds. During this time, the virtual IGT adjusts the length of a player's balance bar according to the displayed value. The player cannot draw a new card until the payout phase is over. When a deck is empty, the IGT system displays a notification and prohibits a player to draw further cards from this deck. After 100 cards are drawn, our virtual IGT informs the player about the completion of the task.

Our IGT versions[1] are developed with Unity 2018.2.5f1 [70] using the SteamVR plugin version 1.2.2 [71]. We implemented the underwater scenario using the 3D asset *Aquarium* [58].

[1] https://downloads.hci.informatik.uni-wuerzburg.de/igt-vr.zip

4 METHOD

Based on our theoretical considerations in Sect. 2 and the design of the two IGT versions described in Sect. 3, we assume the following hypothesis:

Immersion Impairs Decision Making. A higher immersion increases the experienced presence which then increases the intensity of the experienced emotions. The Somatic Marker Hypothesis suggests that emotions interfere with IGT decision making. Thus, we expect an impaired decision making when using IGT VR.

For testing our hypothesis, we compared the two realizations of the IGT in a user study with respect to presence and decision making in this task. An unimpaired decision making leads to the development of an understanding for the structure of the IGT over the course of the experiment [7,8]. As a result, participants would no longer deal with uncertainties when repeatedly completing the IGT. Therefore, we chose an *in-between subjects* experimental design. Participants were randomly assigned to either one of the two IGT versions, i.e., *VR condition* and *desktop condition*. As described in Sect. 3, both representations only differ in the medium used. Thus, the *independent variable* was the degree of immersion, i.e., low immersion in the desktop condition and high immersion in the VR condition. We only used young and healthy subjects, i.e., participants with no signs of a gambling addition. They are the primary target group for gambling in immersive VR [32].

Our study was approved by the Human-Computer-Media institutional ethics review board of the University of Würzburg.

4.1 Apparatus

The experimental setup consisted of a desk, three chairs, a computer (CPU: Intel Xeon E31230v5, RAM: 16GB, GPU: NVIDIA GeForce GTX 980 Ti), two screens (resolution: 1920x1080), an HTC Vive Pro Head-Mounted Display (2160x1200 resolution per eye), a single HTC Vive controller, a mouse, and a keyboard. As Fig. 4 displays, we provided three stations for the individual phases of the experiment, i.e., a questionnaire station, an IGT desktop station and an IGT VR station. Depending on a participant's condition, they were seated at the respective playing station and played the IGT using the single HTC Vive controller (see Fig. 3). The gameplay of IGT VR was rendered to the HTC Vive Pro HMD and the gameplay of IGT desktop was rendered to a 24" screen. For achieving comparability between the two IGT versions, the chair of the desktop station was position at the specific distance to the screen that yielded the same apparent size of the IGT desktop-3D UI elements to the IGT VR UI elements. For filling in the questionnaire, participants sat at the questionnaire station.

Since the presence of an observer can lead to a less risky gambling behavior, the experimenter could have confounded the study [50,60]. For safety reasons, the experimenter, however, had to remain in the room. Thus, to limit this potential confounding effect, participants were told that the experimenter was *working* in a corner of the room during the session. The experimenter's desk was positioned out of a participant's line of sight and facing away from the center of the room to further reduce a potential feeling of being observed.

4.2 Measures

We assessed a participant's demographical data, experienced presence and IGT decision making. The demography questionnaire and the orally communicated mid-immersion question were presented in the common language of the study's location.

4.2.1 Pre-Questionnaire

For demographical data, we assessed a participant's *age* (in years), *gender*, *video game experience* (hours per week), *VR experience* (hours total), *visual impairments*, and the *level of correction* of their visual impairments. As an additional control variable, the pre-questionnaire included the *Immersive Tendency Questionnaire* (ITQ) [77] to assess a participant's immersive tendency, their current alertness as well as fitness, and their ability to focus.

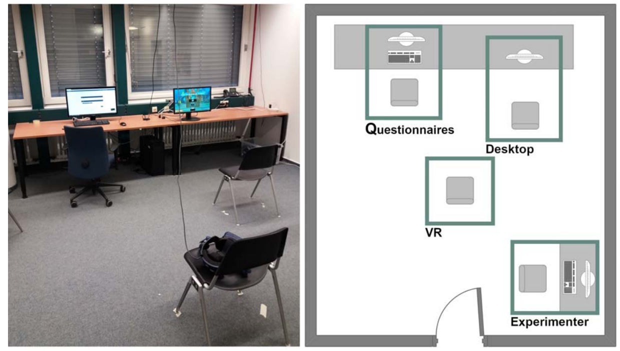

Figure 4: Overview of the experimental setup. Participants were sitting in front of the left screen to fill in the questionnaires (questionnaire station). For playing the IGT, they either sat in front of the right screen (IGT desktop station) or on the chair in the center of the room (IGT VR station). The experimenter sat in a corner of the room and pretended to work during a session.

4.2.2 Mid Immersion Presence Questionnaire

For measuring presence, we implemented the single-item *Mid Immersion Presence Questionnaire* (MIPQ) [12, 13]. After having drawn the first 50 cards, the participants answered to the following question out loud: *To what extent do you feel present in the virtual environment right now?* The MIPQ uses a 0 (not at all) to 10 (totally) Likert scale. We explained this question and the concept of presence to the participants before starting with the IGT.

4.2.3 Iowa Gambling Task

We used our two IGT realizations to measure the decision making. As described in Sect. 2.2, the IGT requires subjects to draw 100 cards from four decks which are either advantageous or disadvantageous. The number of disadvantageous cards drawn determines a subject's decision making [6, 27, 29], i.e., a higher number of advantageous cards drawn indicates a better decision making.

4.3 Procedure

Before the start of the study, each participant had to fill in the Problem Gambling Severity Index (PGSI) [19] as a safety measurement to protect them against gambling related harm. This 9-item questionnaire measures the severity of a gambling addiction by considering a person's gambling behavior over the past year [28]. Only healthy participants, i.e., they scored 0 on the PGSI, were allowed to take part in the experiment (see Sect. 4). The participants signed a consent form and were seated at the questionnaire station to fill in the pre-questionnaire. Subsequently, the participants were seated at the station relevant for their condition. The experimenter gave an introduction about the IGT gameplay and explained the MIPQ before the participants started with the IGT. In the case of the VR condition, we also informed them about the functionality of the head-mounted display and the symptoms of cybersickness. After having finished the IGT, i.e., they drew 100 cards, we explained the goal of the experiment as well as the IGT's fixed schedule of win and loss, showed a short educational video about problem gambling, and handed them some additional educational material concerning the risks of gambling. Finally, we thanked the participants and, in the case of the VR condition, reminded them of the effects of cybersickness. Fig. 5 provides an overview of our procedure.

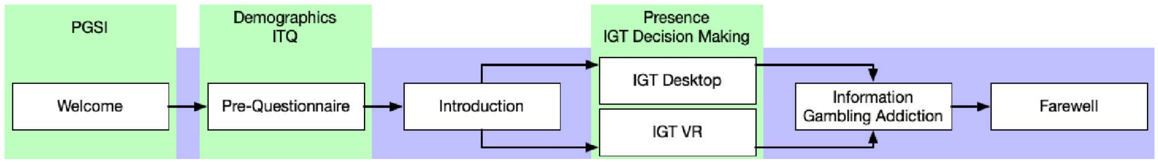

Figure 5: Overview of the experimental procedure. The figure combines the individual steps with the measurements used.

Table 2: Demographical data. Values are either $M(SD)$ or $n(\%)$.

	VR $n = 25$	Desktop $n = 25$	Total $n = 50$
Age	20.44 (1.71)	21.80 (6.59)	21.12 (4.81)
Male	8 (32%)	10 (40%)	18 (36%)
Female	17 (68%)	15 (60%)	32 (64%)
VR Exp.	15 (60%)	0 (0%)	15 (30%)
Gaming Exp.	14 (56%)	16 (64%)	30 (60%)
ITQ	4.35 (0.61)	4.46 (0.68)	4.40 (0.64)

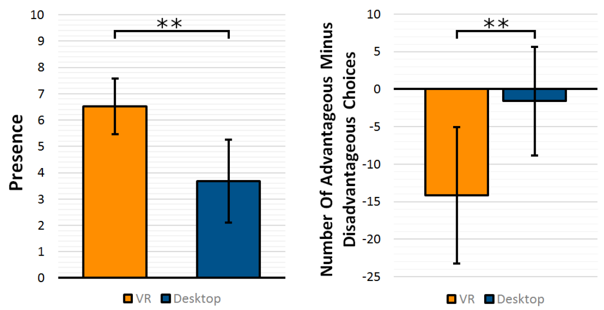

Figure 6: Left: Comparison of the mean presence ratings. Right: Comparison of the mean IGT decision making results. The error bars denote the standard deviations. *$p < .05$, **$p <= .01$

4.4 Participants

We recruited the participants from the undergraduate students who were enrolled at the University of Würzburg using an online participant recruitment system. The participant were rewarded with credits mandatory for obtaining their program of study's degrees. In total, 54 participants took part in the study but four of them had to be removed from the sample due to technical problems. None of the remaining 50 participant had an uncorrected visual impairment. Table 2 provides an overview about the participants' demographical data. 15 participants reported a previous VR experience ($M = 6.31h$, $SD = 8.04h$) and 30 participants reported to play video games for $M = 7.19h$ per week ($SD = 7.15h$). None of them had completed the IGT before. We randomly assigned them to either one of the two conditions.

5 Results

For comparing the results, we computed either an *independent t-test* for datasets with an equal variance or a *Welch's t-test* for datasets with an unequal variance. We analyzed a dataset's variance by using an *F-test*. Effect sizes were determined by computing *Cohen's d* and were described as suggested by Sawilowsky [62]. We used *Pearson's r* to check for correlations.

5.1 Presence

For analyzing the presence ratings, we computed a Welch's t-test due to unequal variances ($F(24,24) = 0.46$, $p = 0.03$, $n = 50$). Presence

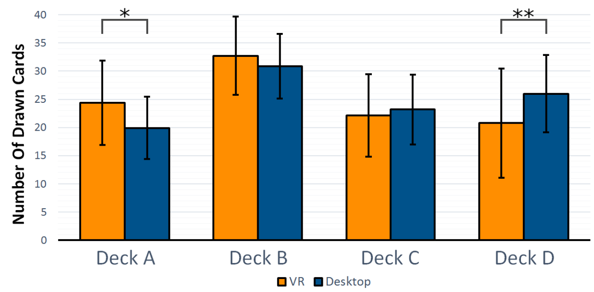

Figure 7: Comparison of the mean number of cards drawn per deck. The error bars denote the standard deviations. *$p < .05$, **$p <= .01$

was rated significantly higher for IGT VR ($M = 6.52$, $SD = 1.06$) than for IGT desktop ($M = 3.68$, $SD = 1.57$) with a strong effect size ($t(42) = 4.76$, $p < 0.01$, $d = 2.16$; see Fig. 6 left). Computing a Pearson's r test, no correlation was found between presence and decision making ($r(48) = 0.19$, $p = 0.18$).

5.2 Decision Making

The IGT results' variances were unequal ($F(24,24) = 2.98$, $p < 0.01$, $n = 50$) and hence we computed a Welch's t-test. In contrast to the desktop condition ($M = 50.80$, $SD = 6.27$), the VR condition ($M = 57.08$, $SD = 10.82$) drew significantly more cards from the disadvantageous decks A and B with a medium effect size ($t(38) = 2.46$, $p = 0.02$, $d = 0.74$; see Fig. 6 right). As the results showed an equal variance ($F(24,24) = 1.82$, $p = 0.07$, $n = 50$), a detailed analysis using a t-test of the cards drawn per deck revealed that the VR condition drew significantly more cards from the disadvantageous deck A with a medium effect size ($t(48) = 2.36$, $p = 0.02$, $d = 0.69$; see Fig. 7). Computing a Welch's t-test ($F(24,24) = 2.00$, $p = 0.048$, $n = 50$), the desktop condition drew significantly more cards from the advantageous deck D with a medium effect size ($t(43) = -2.17$, $p = 0.04$, $d = 0.63$). As Fig. 8 displays, the number of disadvantageous cards drawn over time declined in the desktop condition while the VR condition showed a slight incline. We further compared the selection patterns by splitting the results in segments of 20 draws each [9, 14, 73]. The desktop condition drew significantly less disadvantageous cards in the period from game round 41 to 60 with a medium effect size ($t(48) = 2.39$, $p = 0.02$, $d = 0.68$) using a t-test ($F(24,24) = 1.13$, $p = 0.39$, $n = 50$) and from game round 81 to 100 with a large effect size ($t(48) = 3.68$, $p < 0.01$, $d = 1.04$) using a t-test ($F(24,24) = 0.89$, $p = 0.39$, $n = 50$).

For the VR condition, we found a significant correlation between the IGT results and gender using a Pearson's r test ($r = 0.42$, $p = 0.03$; see Table 3). A t-test ($F(7,16) = 1.50$, $p = 0.24$, $n = 25$) revealed that women ($n = 17$, $M = 53.94$, $SD = 9.23$) drew significantly less disadvantageous cards in the VR condition than men ($n = 8$, $M = 63,75$, $SD = 10.92$) with a very small effect size ($t(23) = 2.24$, $p = 0.02$, $d = 0.09$). In the desktop condition, a Welch's t-test ($F(9,14) = 2.95$, $p = 0.03$, $n = 25$) revealed no significant difference between women ($n = 15$, $M = 49.87$, $SD = 4.67$) and men ($n = 10$, $M = 52.20$, $SD = 7.88$) with respect to the number

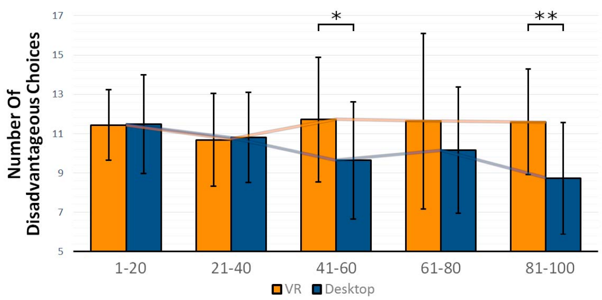

Figure 8: Comparison of the mean number of disadvantageous cards drawn per 20 draws. The error bars denote the standard deviations. $^*p < .05$, $^{**}p <= .01$

Table 3: Correlation between decision making and the control variables (Pearson's r).

Factor	VR $r(23)$	p	Desktop $r(23)$	p
Age	0.00	0.98	0.13	0.52
Gender	0.42	0.04	0.18	0.38
Gaming Exp.	0.00	0.96	0.31	0.12
VR Exp.	0.33	0.10	–	–
ITQ	0.10	0.63	−0.04	0.87

of disadvantageous cards drawn ($t(13) = 0.80$, $p = 0.22$, $d = 0.05$). We found no further significant correlation between the IGT results and the demographical data of the participants in any of the conditions (see Table 3).

The random assignment of the participants led to all participants with prior VR experience being assigned to the VR condition by chance (see Table 2). To analyze the effects of prior VR experience, we split the VR condition into two groups, i.e., *prior-VR* ($n = 15$, $M = 56.67$, $SD = 11.42$) and *no-VR* ($n = 10$, $M = 57.70$, $SD = 11.02$). Computing a t-test ($F(9,14) = 1.08$, $p = 0.47$, $n = 25$) to compare these two groups revealed no significant difference with respect to prior VR experience on the IGT results ($t(23) = -0.22$, $p = 0.82$). Also, we compared IGT decision making of new VR users only. After excluding all participants with prior VR experience from the VR condition ($n = 10$, $M = 57.70$, $SD = 10.45$), we computed a Welch's t-test ($F(9,24) = 2.97$, $p = 0.02$, $n = 35$) confirming the significant difference in the number of disadvantageous cards drawn ($t(12) = 1.86$, $p = 0.04$, $d = 0.09$) between the VR conditions and the desktop condition.

6 Discussion

In the present user study, we analyzed the effects of immersion on IGT decision making. For measuring this quality, we implemented the IGT for desktop-3D and immersive VR.

Presence was significantly higher when using IGT VR, thus validating our design. Presence depends on objective system properties, i.e., the immersion of a user, as discussed in Sect. 2.3.

6.1 Immersion Affects Decision Making

Our study revealed that the VR condition drew significantly more disadvantageous cards. In particular, the VR condition drew significantly more disadvantageous cards from deck A while the desktop group drew significantly more advantageous cards from deck D. In contrast to the VR condition, the desktop condition showed a decline in the number of disadvantageous cards drawn over time. The difference between the number of bad cards drawn over time was significant for the period from game round 41 to 60 and from game round 81 to 100 of the IGT. Previous VR experience showed no significant effect on the results in the VR condition. This is a critical outcome as it indicates that decision making was not dominated by a sensation of novelty when experiencing immersive VR for the first time. Therefore, as both IGT versions only differed in the medium used, our results show an *impairing effect of immersion on decision making* in this task. Overall, our results are not only critical for assessing the risk potential of gambling in immersive VR, but also important for researchers and designers of immersive VR applications in general.

Immersion Impairs Decision Making: We found a significantly higher number of disadvantageous cards drawn in the VR condition. Our results show an impairing effect of immersion on simulated real life decision making. Thus, our hypothesis is *supported*.

As discussed in Sect. 2.2, the *Somatic Marker Hypothesis* is a potential explanation for our measurements [4, 21]. A higher immersion leads to a higher presence as shown with our MIPQ measurements. As a higher sensation of presence can increase the intensity of emotions experienced, participants of the VR condition might have been more emotionally involved in the IGT's gameplay [59]. The stronger emotions potentially dominated the participants' decision making in this task. Thus, as a higher immersion leads to a higher presence, the study's results indicate that immersion causes an impairing effect on IGT decision making. Simultaneously, our results contribute to the ongoing research of decision making and provide further evidence for the Somatic Marker Hypothesis being an explanation for IGT decision making.

Presence not only depends on the degree of immersion, but is also affected by other prominent VR factors. The simulation and the evoked presence could be altered by providing an embodiment [36,45,66]. The experience of an illusion of virtual body ownership increases presence and hence might affect IGT decision making [76]. Embodiment further can evoke the *Proteus* effect [80]. This effect could, depending on the avatar appearance [40,61], lead to differences in IGT decision making. Decision making in immersive VR potentially is also affected by these factors as they increase presence and hence the intensity of the experienced emotions.

Fig. 8 reflects the typical sequence of card selection of an unimpaired decision making [8] as discussed in Sect. 2.2. Participants of the desktop group started to show a decline in the number of cards drawn in the second phase, i.e., round 21 to 40, which increased in the third phase, i.e., game round 41 to 60. For the majority of these two phases, subjects were in the *pre-hunch* period and did not know which decks are advantageous or disadvantageous, but started to develop a first hunch. By reaching the 50th game round, users entered the *hunch* period. The development of this first hunch led to a more pronounced decline in the number of disadvantageous cards drawn as shown in our results. By game round 80, subjects with an unimpaired decision making typically enter the *conceptual* period. Our results reflect this conceptual period with a further decline in the number of bad cards drawn. This development was not present in the VR condition. Instead of indicating the establishment of a hunch, the VR condition even showed a slight incline in the number of cards drawn from bad decks. This *supports* our assumption of an impairing effect of immersion on IGT decision making.

The study's results also reflect the so-called *prominent deck B* phenomenon, thus supporting behavioral decision making [21]. Both conditions drew most of their cards from deck B as Fig. 7 displays. Due to the low frequency of the substantial losses in deck B, users might fail to recognize the long-term outcomes of drawing from this disadvantageous deck. This leads to the false assumption of deck B being beneficial for the overall goal of maximizing the own money.

For IGT VR, our results show a significant correlation between the participants' gender and their measured IGT decision making. Interestingly, in contrast to previous research [72], female participants performed better than male participants. Also, we found no significant correlation between the gender and IGT decision making in the desktop condition. However, our sample size is relatively small which could account for these results. Furthermore, we could not confirm a correlation between age and IGT decision making [20]. This is explainable with our experimental design. We focussed on young individuals and thus only tested a single age group.

6.2 Implications

As discussed in Sect. 2, gambling games implement certain game mechanics to evoke erroneous beliefs in players and to hide the game's underlying principles. During the gameplay, the game mechanics influence a player's decisions concerning the continuation of playing and the size of the bets. The impairing effect of immersion on decision making potentially increases these effects. As a result, gambling in immersive VR has a higher risk potential than gambling in a low immersion environment, e.g., a desktop application, when the same game mechanics are provided.

Aside from the gambling context, our results are also of high importance for the VR community. An impaired decision making might have implications for other areas of application of immersive VR, e.g., learning [53] and therapy [33]. Users of an immersive VR learning environment could need a longer time to solve given assignments or even fail to make correct decisions in a virtual safety training [42]. For instance, our results *provide an explanation* for the results of two studies comparing the effectiveness of immersive VR and powerpoint for safety training [42]. Here, participants of the VR condition made more risky choices than participants of the powerpoint conditions. This could be a result of the impairing effect of immersion on decision making. Developers and educators need to provide additional feedback or assistance during the learning process to compensate for the impairing effect of immersion.

6.3 Limitations

Although we took special care to only manipulate the immersion, following Slater's definition [67] of immersion as *"the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant"*, immersion actually combines four different aspects [67]: **Inclusive (I)** indicates the extent to which physical reality is shut out. **Extensive (E)** indicates the range of sensory modalities accommodated. **Surrounding (S)** indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field. **Vivid (V)** indicates the resolution, fidelity, and variety of energy simulated within a particular modality.

Our approach certainly manipulated (S) and tried to match (V) and (E) as good as possible between the two conditions. However, the inclusiveness (I) might play a central role in this design. Our immersive VR IGT blocked-out any additional environmental distractors. The virtual environment of IGT VR in which the user is visually immersed using a head-mounted display only provides the *Aquarium* 3D assets aside from the task itself. By looking around, the user remains in this virtual environment and potentially never gets distracted from the IGT. In contrast, our desktop-3D version is played on a computer screen inside of a lab. Despite having positioned the participants at a specific distance to the computer screen to achieve the same apparent size of the IGT UI elements, the user still receives stimuli from the real world and from the virtual environment, simultaneously. When turning their head, the user can observe other real world objects and might even loose sensory inputs from the virtual environment, entirely.

As a result, IGT desktop-3D is *closer* to the original physical card game setup than IGT VR. Ultimately, these distracting variables could potentially evoke additional analytical thoughts in the subject resulting in an in-depth reflection of the gameplay and thus in a better IGT decision making. Therefore, a follow-up experiment needs to remodel the IGT desktop-3D gameplay in immersive VR, i.e., the user completes the IGT on a virtual computer screen in a virtual version of the lab. For this experiment, we hypothesize IGT decision making in immersive VR to not significantly differ from IGT decision making using the desktop-3D version. Validating this hypothesis would not only indicate the importance of accurately remodeling training situations, but also the high risk potential of gambling in immersive VR as it would benefit from the reduction of external stimuli.

As it happened, the random assignment resulted in all participants with prior VR experience being assigned to the IGT VR condition by chance. Hence, we statistically analyzed whether prior VR experienced caused an effect on the measurements. We found no significant difference in IGT decision making in the VR condition with respect to previous VR experience. In addition, we compared the two conditions with regard to IGT decision making after having excluded all participants with prior VR experience. This comparison confirmed the statistical difference between the two conditions, i.e., an impairing effect of immersion on IGT decision making. Despite these efforts, there might potentially still be an effect of prior VR experience that could not be detected due to the sample's size. Also, all participants were young and healthy. As a result, our study cannot provide insights on the effects of immersion on IGT decision making with respect to age or other clinical conditions. Considering these limitations, it is important to replicate our experiment with a more heterogeneous sample and to counterbalance the conditions.

7 Conclusion

This article reported novel findings on IGT decision making in immersive VR. Our contributions are twofold. We (1) developed–to our best knowledge–the first implementation of the IGT for VR and (2) compared its results to a desktop-3D counterpart in a novel study.

7.1 Findings

The study's results indicate a *significant impact* of immersion on the measured real life decision making simulated by the IGT. Participants of the VR group drew *significantly more* disadvantageous cards than the control group. This result is notable. As we only used healthy and young participants, i.e., the primary target group of the game industry for gambling in VR [32], our findings support previous research indicating the high risk potential of VR-based gambling. The results further indicate to have implications on other applications of immersive VR. Here, the reduction of external, non-task relevant stimuli, could result in an impairing effect on decision making, e.g., more risky choices or false actions. This is an important insight for researchers and developers. It indicates the need to provide further assistance or information allowing users to reflect on the simulated decision making situation.

7.2 Future Work

Future work needs to be aimed at a large-scale analysis of IGT VR to verify our findings and to check for already known effects, e.g., differences in gender and age, by using a more heterogeneous group of participants. A second future direction would be the investigation of the effects of presence on decision making by implementing a high and a low presence version of IGT VR, e.g., by providing an embodiment [36,45,66] or by adjusting the simulation's audiovisual fidelity [47]. This would allow for a detailed analysis of the individual impairing effects of presence and immersion. Also, it would provide insights whether and to what extent other VR factors, e.g., using an embodied virtual environment, and their degree, e.g., avatar appearance, have an impact on IGT decision making in immersive VR. Finally, to evaluate the effects of a distracting environment on IGT decision making, the setting of playing IGT on a computer screen has to be remodeled in immersive VR. This allows for an analysis whether the visual immersion in the virtual environment of the IGT has an effect on a user's decision making.

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