An Approach to Investigate an Influence of Visual Angle Size on Emotional Activation During a Decision-Making Task

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Abstract. Decision-making is an important ability in our daily lives. Decision-making can be influenced by emotions. A virtual environment and objects in it might follow an emotional design, thus potentially influencing the mood of a user. A higher visual angle on a particular stimulus can lead to a higher emotional response to it. The use of immersive virtual reality (VR) surrounds a user visually with a virtual environment, as opposed to the partial immersion of using a normal computer screen. This higher immersion may result in a greater visual angle on a particular stimulus and thus a stronger emotional response to it. In a between-subjects user study, we compare the results of a decision-making task in VR presented in three different visual angles. We used the Iowa Gambling Task (IGT) as task and to detect potential differences in decision-making. The IGT was displayed in one of three dimensions, thus yielding visual angles of 20°, 35°, and 50°. Our results indicate no difference between the three conditions with respect to decision-making. Thus, our results possibly imply that a higher visual angle has no influence on a task that is influenced by emotions but is otherwise cognitive.

Keywords: Virtual Reality · Decision-Making · Emotions · Iowa Gambling Task.

1 Introduction

Decision-making is an important ability in our daily lives. While most daily decisions rarely have strong impacts, some decisions can cause severe consequences in the long run, such as financial ruin and life-threatening events. In these situations, people often must deal with uncertainties with regards to reward and punishment [6]. A good decision-making ability generally keeps people from consciously making disadvantageous decision. However, when the decision-making ability is impaired, disadvantageous decisions might seem beneficial. A strong impairing influence can be emotions [2].

Fig. 1: Our virtual IGT is presented on the deck of a forest cabin.

Decision-making situations can also take place when using immersive media, such as during training [22] as well as gaming [30] in immersive Virtual Reality (VR), and Augmented-Reality-based collaborative work [27]. With an increase in immersion, the visual angle on a particular stimulus can also be increased. Immersion is "*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*" [41]. The visual angle defines the total amount of available visual information. A higher visual angle can lead to a higher emotional response to audiovisual stimuli [12]. While this can lead to a stronger emotional response to emotionally designed Virtual Environments (VEs) [19, 42] in general, it could also cause a stronger emotional activation in a decision-making situation.

As VR is not only used for entertainment [1] but also for learning [35], therapy [24], and scientific analyses [21], it is important to investigate whether a higher immersion and respective VR-factors impair a user's decision-making abilities. This research direction receives even a higher importance considering the fact that gambling games can be played in VR [13]. Research shows higher risk potential when playing a slot machine in VR instead of on a regular computer screen [14]. The required research should evaluate whether different visual angles influence a user's performance in a decision-making task.

Contribution

In this paper, we measure the influence of three different visual angles on a decision-making task in VR. We use the Iowa Gambling Task (IGT) as decision-making task [3] and present it in visual angles of 20°, 35°, and 50°. The design of the surrounding VE intends to evoke positive emotions in users. In particular, we designed a sunny forest environment allowing users to enjoy lush greenery from the deck of a wooden cabin as displayed in Figure 1. In a between-subjects study, we measured IGT decision-making as well as positive and negative affect. Our results did not show a statistical difference between the three conditions with respect to affect and decision-making. While not ruling out an emotional influence of a higher visual angle on a stimulus, our results may suggest that visual angle sizes have no effect on a repetitive decision task that may be influenced by emotion but is otherwise cognitive.

2 Theoretical Background

Our research visualizes the IGT in three different visual dimensions in VR to investigate whether a higher visual angle causes a higher emotional activation and hence an influence on IGT decision-making. Research demonstrates that IGT decision-making potentially is impaired when completing the task in VR instead of on a regular computer screen [29]. However, research found no differences when the IGT was presented in the same visual angle size in a real laboratory environment using a computer screen and in a virtual replicate of the laboratory as well as in a virtual forest using a Head-Mounted Display (HMD) [28].

2.1 Iowa Gambling Task

The IGT has been used for more than 20 years in research to measure decision-making [6] and emotion-based learning [8]. The task simulates real-life decision-making and features uncertainties in regards to assumptions and outcomes. The task requires participants to win as much money as possible by drawing 100 cards from four card decks. Each card deck contains 40 cards. Following a fixed win and loss schedule, each card can result in an overall win or loss of money as shown in Table 1. The schedule results in two card decks making a profit and two card decks making a loss in the long run as shown in Table 2. Throughout the task, healthy participants cognitively develop an understanding for the underlying structure of the win and loss schedule [2]. The total number of advantageous minus disadvantageous selections determines a participant's IGT decision-making. A higher number of advantageous cards drawn indicates a better IGT decision-making. Splitting the results in blocks of 20 draws each allows for a more detailed analysis of the selection patterns [4]. The IGT proved robust to certain changes in its parameters, such as use in the original manual version with 40 cards [3], the computerized version with 60 cards [5], and the computerized version with a higher contrast value [23].

Researchers used the IGT to investigate the often underestimated effect of emotions on decision-making [2]. For example, induced arousal showed an influence on measurements [26, 33]. Researchers also used the IGT to investigate the influence of emotion and mood induced by movie sequences on decision-making [9, 17]. It was shown that a positive mood can lead to better IGT decision-making in the second block of the task lasting from game round 21 to 40 [9]. Moreover, subjects who were in an emotional state associated with certainty performed

Table 1: Overview of the win and loss schedule. Values are in $.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Card Deck A										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	0	0	-150	0	-300	0	-200	0	-250	-350
Card Deck B										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	0	0	0	0	0	0	0	0	-1250	0
Card Deck C										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	-50	0	-50	0	-50	0	-50	-50
Card Deck D										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	0	0	0	0	0	0	-250
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Card Deck A										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	0	-350	0	-250	-200	0	-300	-150	0	0
Card Deck B										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	0	0	0	-1250	0	0	0	0	0	0
Card Deck C										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	-25	-75	0	0	0	-25	-75	0	-50
Card Deck D										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	0	0	0	0	0	0	-250
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Card Deck A										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	0	-300	0	-350	0	-200	-250	-150	0	0
Card Deck B										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	-1250	0	0	0	0	0	0	0	0	0
Card Deck C										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	-50	-25	-50	0	0	-75	-50
Card Deck D										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	0	0	0	0	0	-250	0
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Card Deck A										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	-350	-200	-250	0	0	0	-150	-300	0	0
Card Deck B										
Win:	+100	+100	+100	+100	+100	+100	+100	+100	+100	+100
Loss:	-1250	0	0	0	0	0	0	0	0	0
Card Deck C										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	-25	-25	0	-75	0	-50	-75
Card Deck D										
Win:	+50	+50	+50	+50	+50	+50	+50	+50	+50	+50
Loss:	0	0	0	0	-250	0	0	0	0	0

better than those who were in an emotional state associated with uncertainty [17]. Although not fully applicable, research showed an impact on IGT decision-making of subjects suffering from anxiety when anxiety-relevant stimuli were displayed on either the favorable or the unfavorable card deck [32].

In contrast to examining the effects of emotions on decision-making, several studies have also shown that the IGT can be completed with the development

Table 2: Overall win and loss for each IGT card deck. Values are in $.

	Card Deck A	Card Deck B	Card Deck C	Card Deck D
Win	4000	4000	2000	2000
Loss	-5000	-5000	-1000	-1000
Combined	-1000	-1000	1000	1000

of, as well as access to, explicit knowledge and thus cognitive processes [25, 10]. Typically, a participant goes through four phases: pre-punishment phase, pre-hunch phase, hunch phase, and conceptual phase [2]. During the *pre-punishment phase*, which lasts until about the 10th card, subjects have no knowledge about the distribution of the card decks. Until around the 50th card is drawn, subjects are in the *pre-hunch* phase and begin to develop a first hunch about the existence of good and bad card decks. Subsequently, in the *hunch* phase, which lasts until about the 80th card, they begin to show initial knowledge of the distribution of the card decks. Finally, for the remainder of the task, subjects develop a more detailed knowledge of the underlying principles in the *conceptual* phase. This is consistent with the observation that decision time decreases strongly during the first two blocks [8]. However, besides a cognitive development of knowledge, research has further shown that healthy participants with higher risk attitudes intentionally draw cards from riskier card decks [37].

Taken together, this results in a dichotomy of cognition and emotion in IGT decision-making [36, 20]. While emotions have been shown to constantly influence IGT decision-making [15], they are not the only factor contributing to a person's behavior in the task [10].

2.2 Immersion and Emotion

Immersion evokes and directly affects presence [40, 45]. *Presence* describes the subjective illusion of being in a real place even though one is physically in a different place [39]. Thus, presence refers to the perceived realness of a virtual experience [38]. Maintaining presence requires support from sensorimotor contingencies [39] and a continuous stream of stimuli and experiences [48]. The experience of presence is the precondition for emotional influence through the design of a VE [34]. Vice versa, higher emotional intensity of a predominant emotion in a VE can increase presence [19].

Research suggests that VR may serve as an ideal expressive medium for emotional challenge [31]. A recent publication discusses the influence of VE design on the emotional perception of VEs and provides design recommendations for joyful and fearful VEs [42]. Emotional positive VEs are characterized primarily by natural aspects such as lush vegetation, access to water, sunshine, and overall wide, colorful, and open spaces. In contrast, emotional negative VEs are designed to enclose the user in dark places with unbalanced light, harsh and dirty elements, and even signs of past violence.

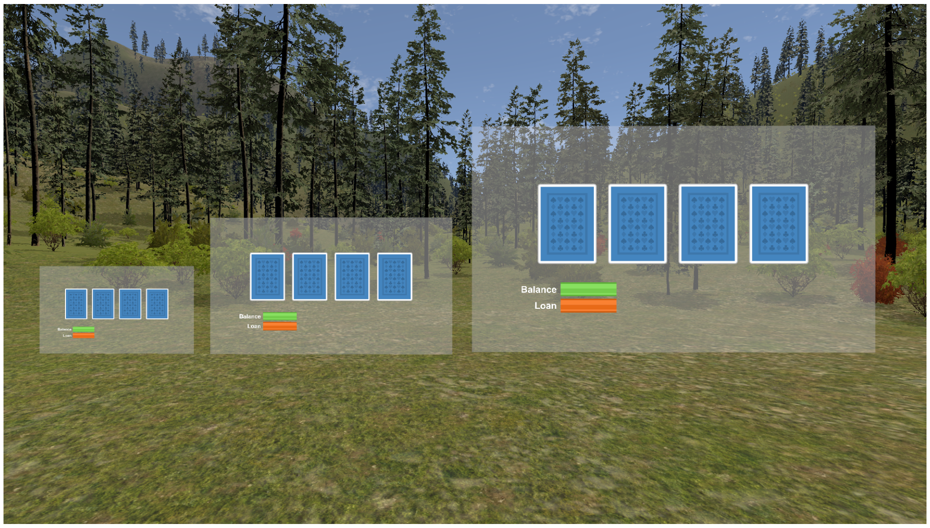


Fig. 2: Comparison of the three conditions: Visual angle of 20°, 35°, and 50°.

2.3 Summary

The dichotomy of cognition and emotion makes the IGT ideal for our research. The sensitivity to emotions of this otherwise cognitive task allows for an investigation whether potential changes in emotional activation caused by different visual angles influence IGT decision-making. The results of this investigation provide first insights into the effects of visual angle size on emotional activation and decision-making in a cognitive task.

3 System Design

We embedded the IGT in a VE following recommendations for an emotional positive design [42]. The VE consists of a sunny forest environment featuring lush greenery and colorful flowers. The VE further features a wooden and cozy cabin as depicted in Figure 1. Facing away from the cabin and towards the trees, we displayed the IGT on a semi-transparent white background as displayed in Figure 2. The participants were positioned at the same distance to the IGT and the IGT was displayed in one of three dimensions thus yielding visual angles of 20°, 35°, and 50°.

3.1 Virtual IGT

Our implementation of the virtual IGT is based on the fixed schedule of win and loss of the original IGT version [3]. The VR application displays the four card decks with cards lying face down. Our virtual IGT provides two interactions:

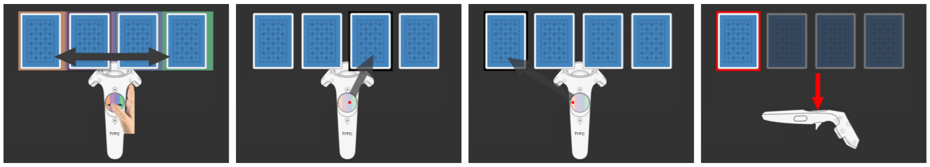


Fig. 3: Visualization of our IGT interaction techniques.

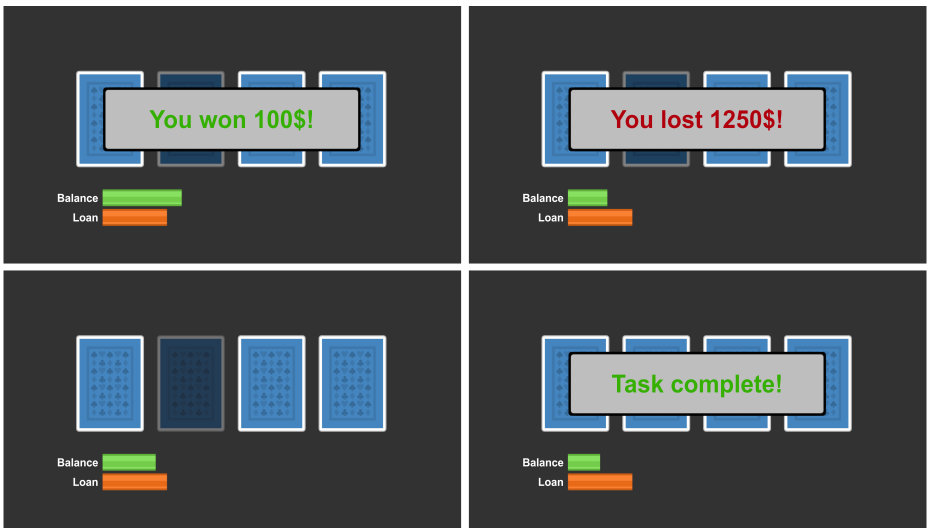


Fig. 4: The user interface of our virtual IGT uses emotional color-coding of wins and losses.

(1) *selection* of a card deck and (2) *drawing* a card from the selected card deck. We selected the HTC Vive Pro [16] as output device and hence mapped the interactions to the HTC Vive game controller as depicted in Figure 3. The virtual IGT displays the position of a controller using its 3D model. We defined four zones on the touchpad each representing a card deck to allow for a selection of one of the four card decks. A user selects a card deck by merely touching a specific zone or moving the finger over the touchpad. The currently selected card deck is marked by a black frame. A user can draw a card from the selected card deck by pressing the touchpad. Subsequently, the virtual IGT first adds the respective card deck's payout to the player's balance before subtracting the drawn card's loss value. The VR application displays the player's current balance and initial loan with two labeled bars. While a green bar changes its length according to the win and loss of a game round to indicate a player's balance, an orange bar shows the initial loan. The virtual IGT displays respective wins and losses of each card directly over the four card decks for two seconds. Following emotional color-coding, we use a green color for displaying wins and a red color for displaying losses. We made this decision to increase the emotional reaction to each decision

as displayed in Figure 4. A user cannot draw a new card while the win and loss information are displayed. After drawing 40 cards from a single card deck, the respective card deck becomes inactive. The virtual IGT informs a user about the completion of the task after the 100th card is drawn. The VR application logs the decision for each turn, thus allowing for an analysis of a user's performance.

We developed the virtual IGT with Unity 2019.3.10f1 [43] using the SteamVR plugin version 1.2.3 [44]. The virtual IGT is a prefab allowing for a free positioning inside of VEs.

4 Method

Based on the theoretical considerations in Section 2 and our design choices in Section 3, we assume that a higher visual angle on the IGT leads to a stronger emotional reaction to the results of a participant's card draws. As a consequence, the assumed change in mood in turn influences the participant's decision-making in the IGT. Therefore, we assume the following hypotheses.

- H1: A higher visual angle on the IGT causes a stronger affect.
- H2: IGT decision-making differs between the three visual angles.
- H3: IGT decision-making differs between the three visual angles in block 2.

We conducted a between-subjects design user study to investigate the effects of different visual angels on the IGT and to test our hypotheses. Our conditions only differed with respect to the visual angle on the IGT: *IGT20°*, *IGT35°*, and *IGT50°*. The participants were randomly assigned to either one of these conditions. Our study was approved by the Human-Computer-Media institutional ethics review board of the University of Würzburg.

4.1 Measures

We used the following measures in our user study.

Demographics We assessed a participant's *age* (in years), *gender*, *video game experience*, and *VR experience* as demographic data. As an additional control variable, the demography questionnaire included the *Immersive Tendency Questionnaire* (*ITQ*) [48] to assess a participant's immersive tendency, their current alertness as well as fitness, and their ability to focus. Cronbach's alpha for ITQ was .62.

Decision-Making We used our virtual IGT to measure decision-making. As described in Subsection 2.1, the IGT requires participants to draw 100 cards from four card decks which are either advantageous or disadvantageous. The total number of advantageous *minus* disadvantageous selections determines a participant's IGT decision-making [3]. We analyzed the total score as well as the score per 20-card block. A higher number of advantageous cards drawn indicates a better IGT decision-making.

Positive Affect and Negative Affect We use the *Positive and Negative Affect Schedule* (*PANAS*) [46] to measure a participant's affect. The PANAS consists of two 10-item 5-point Likert scales (5 = very much). Each scale measures one of the two primary dimensions of mood, i.e., positive (PA) and negative affect (NA). As we wanted to determine the overall effect of differences in the visual angle, we only administered the PANAS after the completion of the IGT. Cronbach's alpha was .86 for PA and .75 for NA.

Presence Since presence is closely connected to the experience of emotions [34, 19], the study included the *presence questionnaire – version 3.0* (*PQ*) consisting of the 19 core items [47] as a control variable. The PQ consists of 7-point Likert scales (7 = high perceived presence). We only report the total average score. Cronbach's alpha was .84.

4.2 Procedure

The study took place during the Covid 19 pandemic. To ensure protection and hygiene, we took the following precautions. (1) Each participant was required to disinfect their hands before and after the study, wear a mask at all times, and report if they were in a risk area or showed signs of illness. (2) The experimenter was required to disinfect their hands, wear a mask at all times, and report daily if they showed signs of illness. (3) The experimenter and participant were required to maintain a minimum distance of 1.5 meters. (4) All surfaces touched and equipment used, such as HMD, controller, keyboard, had to be cleaned with a disinfectant after each experiment. (5) The laboratory had to be ventilated for at least 15 minutes after each experiment.

The experimental setup consisted of a desk, a chair, a computer (CPU: i7–9700K, RAM: 16GB, GPU: RTX 2070), one 28 inches computer screen (resolution: 3840x2160 px), an HTC Vive Pro HMD (1440x1600 px resolution per eye, 110° field of view), a single HTC Vive controller, a mouse, and a keyboard.

After being welcomed, the experimenter told the participant to sit down at the desk, to read the study information, and to sign an informed consent form. Each participant had to fill in the Problem Gambling Severity Index (PGSI) [7]. We conducted the PGSI as a safety measure to protect them from 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 [11]. We only allowed participants that scored 0 on the PGSI to participate. Afterwards, participants filled in the demography questionnaire. Upon completion of the questionnaire, the participants received written and illustrated instructions about the possible interactions with our virtual IGT. Here, we also used Figure 3 to explain the card selection interaction technique. We also informed them about the functionality of the HMD and potential symptoms of cybersickness. The participants completed the IGT in their randomly assigned condition. After completing the IGT, the participants filled in the post-questionnaire consisting of PANAS and PQ. Finally, we explained the goal of the experiment as well as

Table 3: Descriptive statistics per group.

	IGT20°		IGT35°		IGT50°	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
IGT score[a]	-8.08	22.97	-7.36	23.82	-4.54	25.49
PA[b]	2.69	0.57	2.35	0.59	2.65	0.82
NA[b]	1.36	0.37	1.51	0.50	1.59	0.44
ITQ[c]	4.43	0.63	4.39	0.57	4.36	0.45
Presence[c]	4.35	0.76	4.15	0.66	4.19	0.82

[a] Calculated means from -80 to 80.
[b] Calculated means from 1 to 5.
[c] Calculated means from 1 to 7.

the IGT's fixed schedule of win and loss, showed a short educational video about problem gambling, reminded them of the effects of cybersickness, and thanked them for participating.

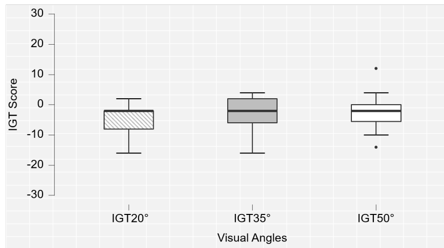
4.3 Participants

We recruited participants from the students enrolled in the bachelor programs Media Communication and Human-Computer Interaction at the University of Würzburg. Participants were rewarded with credits mandatory for obtaining their program of study's degrees. Overall, 76 individuals with a mean age of 21.75 (SD = 2.70) took part in the study. Twenty-nine participants self-indicated as male (age: M = 21.69, SD = 2.73), whereas the majority of 47 self-indicated as female (age: M = 21.79, SD = 2.68). None of the participants reported being diverse gender. Concerning video game experience, 9 participants had never played a video game before, whereas most of them played at a daily (n = 11), weekly (n = 13), monthly (n = 19), or at least yearly (n = 20) basis (one missing value). Four participants had only played video games in past studies. Regarding VR usage, the majority of 42 participants had only experienced VR in past studies and 17 persons had never experienced VR before. Only four participants used VR on a weekly basis, eight persons used VR once a month, and, last, five participants stated to use VR once in a year (one missing value).

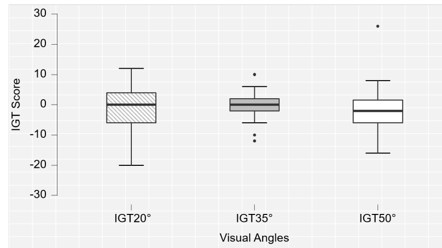
Being randomly assigned to one of the three conditions, 26 participants completed IGT20° (9 male, 16 female; age: M = 21.84, SD = 2.85), while 25 persons completed IGT35° (9 male, 16 female; age: M = 21.92, SD = 2.53). Last, 26 participants completed IGT50° (11 male, 15 female; age: M = 21.50, SD = 2.73).

5 Results

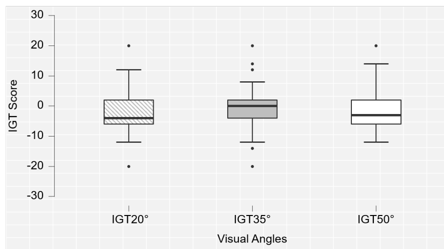
All analyses were conducted using *JASP* version 0.16.0.0 [18] and an alpha-level of .05. Descriptive data is presented in Table 3. Calculated Levene's tests



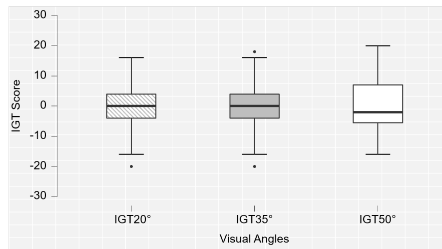
(a) Phase 1.



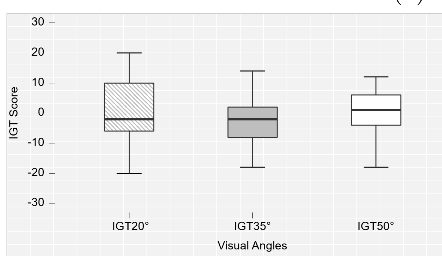
(b) Phase 2.



(c) Phase 3.



(d) Phase 4.



(e) Phase 5.

Fig. 5: IGT values per phase. Error bars display standard errors.

indicated homogeneity of variances for all scales, ps $> .05$, whereas Shapiro-Wilk tests revealed violation of the normality assumption for the overall IGT score and NA.

First, we analyzed the control variables. No significant group differences were spotted for **ITQ** values, $F(73, 2) = 0.10$, $p = .901$. Similarly, **presence** did not significantly differ between the three conditions, $F(73, 2) = 0.53$, $p = .593$.

In terms of affect (H1), no significant group differences were obtained for **PA**, $F(73, 2) = 1.88$, $p = .161$. Alike, no significant difference was found between the conditions concerning **NA**, $\chi^2(2) = 4.38$, $p = .112$.

Regarding **IGT** decision-making over all blocks (H2), no significant differences were found between the visual angles conditions, $\chi^2(2) = 0.07$, $p = .965$. Focusing on block 2 (H3, see Figure 5), again no significant group differences were indicated, $F(73, 2) = 0.30$, $p = .741$.

6 Discussion

The analysis of the measured control variables revealed no significant differences between our three groups with respect to immersive tendency and between the conditions in regards to presence. Therefore, it is possible to assume that neither the composition of our groups nor the overall design of our VR application influenced the measurements.

Our results revealed no differences in affect or IGT performance between the three groups after completing the respective version of the virtual IGT. These results stand in contrast to the observation that a larger visual angle leads to a higher emotional response to audiovisual stimuli [12]. Based on the analysis of the theoretical background in section 2, we assumed that a higher visual angle on the IGT would result in a stronger emotional reaction to the outcomes of a participant's card draws. As a consequence, the assumed change in mood would in turn influence the participant's decision-making in the IGT.

One potential reason could be a shift from decision-making on an emotional level to a cognitive level over the course of the IGT. While the participants might have been emotionally activated at the beginning of the task, this emotional activation potentially declined over time, thus leading to non-significant differences in mood between the conditions at the end of the study. However, the insignificant IGT decision-making differences in the second block suggest that there was no emotional activation at the beginning of the task. The second block of IGT can be strongly influenced by a participant's mood [9]. Another potential explanation could be an execution of the IGT with primarily cognitive processes [25, 10]. Instead of reacting in an emotional way to the outcomes of drawing cards, the participants might have cognitively analyzed the results to develop explicit knowledge about the task's underlying principles. Based on this assumption, it is possible to infer that visual angle size does not evoke or moderate emotional response to purely cognitive stimuli. Finally and in alignment with the previous explanation, the mood of the participants might not have been influenced by their performance in the IGT but by the surrounding emotional positive VE. This is supported by the rather low NA values and mid-range PA values indicating a predominantly positive state across all conditions. As IGT decision-making can be influenced by a participant's mood [9, 17], the induction of a similar mood across all conditions using the same VE could account for the insignificant differences between the conditions with respect to IGT decision-making.

As a result of this, a higher visual angle on the IGT did not cause a stronger affect, thus leading to the rejection of **H1**. IGT decision-making also did not differ among the three conditions, either for overall performance or for decisions made in the second block. This leads to the rejection of **H2** and **H3**.

Taken together, our results suggest that a higher visual angle does not affect a task that is influenced by emotion but is generally cognitive. Combining these results with findings from Oberdörfer et al. [28], although emotional influences from a higher visual angle cannot be ruled out, this could mean that when transferring cognitive decision tasks from normal computer screens to VR, and thus potentially higher visual dimensions, there is no risk of influencing the outcome of the task through a higher level of emotion. This is an important insight as even scientific analyses can be carried out in VR [21].

7 Conclusion

As an approach to investigate the influence of visual angle size on emotional activation during a decision-making task, we measured IGT decision-making in VR. We embedded the IGT in an emotional positive VE and presented it in either one of three visual dimension to our participants.

Our results showed no statistical difference between the three visual angle conditions in terms of affect and decision-making. Although we cannot rule out an emotional influence of a higher visual angle on a stimulus, our results potentially suggest that the size of the visual angle has no influence on a repetitive decision task that may be influenced by emotions but is mainly cognitive.

Future work should investigate whether different sizes of visual angle lead to differences in decision-making in a purely emotional decision task. Another research direction is to investigate whether other VR factors such as embodiment or social presence influence IGT decision-making.

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