The perception of control as a predictor of emotional trends during gameplay

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1. Introduction

The potential of serious games as multimedia learning tools is recognised as a possibility for offering experiences "in which participants learn through a grammar of doing and being" (Squire, 2006, p. 24). By enabling students to become engaged and to take control over their own learning through the challenging and interactive nature of games, gameplay is generally linked with the positive emotion of enjoyment (Vorderer, Klimmt, & Ritterfeld, 2004). Generating enjoyment is considered one of the key determinants in the potential for learning from games (Anolli, Mantovani, Confalonieri, Ascolese, & Peverie, 2010). Ideally, when learning through playing, the player undergoes a pleasurable experience that leads to knowledge and skill acquisition (Graesser, Chipman, Leeming, & Biedenbach, 2009). However, research (e.g., Rodrigo & Baker, 2011b; Wong et al., 2007) has indicated that a positive emotional response does not necessarily follow active engagement in a game.

Appraisal theory approaches such as the control-value theory of achievement emotions (Pekrun, 2000, 2006) might explain the differing results concerning emotions and games. According to these approaches, in the context of classroom learning emotions are experienced as a function of learners' perceived control and the value of the current learning and achievement situation. AIn line with these theoretical assumptions as well as findings from Respondek, Seufert, Stupnisky and Nett (2017) in academic contexts, one could conclude that, in a learning situation the learner will more probably experience enjoyment if he or she also perceives a high level of control. According to this, one could assume that with a reduced level of perceived control, anger and frustration are more likely the emotions that arise. Adapting these findings to situations when learning with serious games, emotions during game play may be a function of the challenge that a game provides players linked with players' actual perception of being in control.

Thus, in the current research, the influence of perceived control on achievement emotions was investigated. Achievement emotions

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are defined as emotions that are directly linked to learning achievement (Pekrun, 2000; Pekrun, Elliot, & Maier, 2006). By manipulating participants' perception of control through the games' design, it was possible to examine the differences in the reporting experiences of the more prominent achievement emotions, namely enjoyment, which is positively valenced, as well as boredom, anger and frustration, which are negatively valenced. These emotions and the perception of control over rounds of play were assessed in order to explain how different levels of control perception are responsible for differences in the experience of each emotion.

The findings may lead to practical implications from a human-computer interaction point of view. Achievement emotions in educational settings have been shown to foster engagement and learning as demonstrated in research in the fields of psychology (e.g., Dweck, 2000), education (e.g., Meyer & Turner, 2006; Schutz & Pekrun, 2007) and clinical neuropsychology (e.g., Cowley, Ravaja, & Heikura, 2013). These studies have provided evidence that emotional trends are linked to learners' appraisal in response to the design of learning material and highlight the importance of design adaption in order to induce and regulate particular emotional states.

2. Theoretical background

2.1. Emotions during learning with serious games

As reported in various studies, gaming is one of the preferred leisure activities among children and youth (for an overview of studies see the literature review by Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). The main motives of players for playing games are to improve one's mood, to generate positive emotions, and to fight boredom. Theoretical gaming approaches such as those of Oerter (1999) and Vorderer et al. (2004) incorporate enjoyment as the main benefit of playing games.

As emotions are linked to learning by affecting the use of cognitive resources and the way information is processed and stored into long-term memory, learners are more willing to invest mental effort into enjoyable learning activities such as gaming rather than boring or frustration-inducing activities. Enjoyment directs attention (Meinhardt & Pekrun, 2003) and facilitates recall (Isen, Shalker, Clark, & Karp, 1978). Boredom and frustration are in some cases negatively correlated with learning (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011) because bored or frustrated learners have trouble focussing attention and persisting in given tasks.

A number of studies have indeed found that learning with serious games can result in greater enjoyment and better learning outcomes compared to other media (e.g., Barab, Arici, & Jackson, 2005; Ricci, Salas, & Cannon-Bowers, 1996). In contrast, Rodrigo and Baker (2011a) who examined teenagers who learned math with a game versus an intelligent tutor system found the incidence of negative affect (boredom and frustration) was higher for gameplay compared to learning with a tutor system. Furthermore, they found that students who learned with the tutor system spent significantly more time engaged with the learning material. By comparing a game, replay, hypertext and printed text, Wong et al. (2007) reported similar effects. Whereas the game used in this study was perceived as more enjoyable compared to traditional text, non-significant differences were found between the game and the hypertext version. Further, non-significant differences in learning gains were found between all conditions.

These disparate findings demonstrate that gaming can have benefits of positive emotions and enhance learning performance, but can also result in negative emotional responses.

The studies also underscore the need for further research to determine the specific conditions when achievement emotions, both positive and negative, appear during gameplay. The existing research lacks experimental studies that go beyond the influence of games as a whole. Because serious games are available in a variety of forms with diverse features, it is difficult to draw conclusions about the influence of games on emotions. Focussing on the impact of gaming characteristics rather than on the games in general should be explored. The crucial question for serious games, therefore, is not whether serious games would be more enjoyable as other educational media, but rather what specific design features contribute to different emotional responses. Ravaja et al. (2004), for example, compared the effect of entertainment games by examining differences in the point of view from which the game is played and the amount of violence on players' emotional responses. Participants who played a less violent game reported significantly more positively valenced emotional responses compared to those who played a more violent game. To our knowledge, there is no research on the concrete impact of specific design features on players' changes in emotional trends, at least not in regard to serious games.

Existing studies have tended to retrospectively measure participants' emotional states (e.g., Barab et al., 2005; Wong et al., 2007); however, it is critical to avoid focussing only on retrospective assessment in order to understand how students perceive and give meaning to a current situation (Op't Eynde & Turner, 2006). By measuring trends of emotions during learning processes, research in the context of intelligent tutoring (e.g., D'Mello & Graesser, 2011), for example, demonstrated that a broader range of emotions can occur during learning at the same time and that these are dynamic. Thus, rather than retrospectively measuring emotions, there is a need for systematic research identifying the current trend of players' emotional experiences during learning with serious games. Therefore, the focus of this study is on the impact of game design on the trends of players' emotional states processed during learning in serious games and the consequences for performance. This can shed light on the dynamics of emotions during gameplay and may also serve as a useful first step in determining whether and when an adaptive change in specific design characteristics is needed for subsequent game tuning in order to achieve an optimal gameplay experience and performance.

2.2. The interplay between the perception of control and emotions

An important consideration in the current study is the effect of design features on achievement emotions and their trends during learning with serious games. Control is seen as one of the key design features in games that trigger emotions (Grodal, 2000; Jabbar & Felicia, 2015). From a technological perspective, control is defined as the potential of any medium to allow users to handle control devices flexibly and intuitively (Bryant & Love, 1996). Besides the technical perspective, game design features, such as such as the extent users are allowed to manage direction of gameplay activities, and the number and pace of game elements that have to be handled at the same time while playing define the amount of control (Alkhafaji, Grey, & Hastings, 2013). In addition to the concept of control being an attribute of a medium itself, control can also be defined as a psychological factor given that the extent of control allowed by a medium is a function of the individual's perception of control, which reflects the user's competence to influence a medium, or at least to master certain aspects of it (Klimmt, Hartmann, & Frey, 2007). As such, users' perception of control can be seen as an outcome of the relation between the provided challenges and user's experience of fulfilling these challenges (Chen, Wigand, & Nilan, 1999). Wang, Shen, and Ritterfeld

(2009) conducted a content analysis of existing game reviews to examine game features associated with enjoyment. Their findings showed that besides overall game design, audio-visual representation, and diversity, control over gameplay was one of the top five categories frequently mentioned by game reviewers that plays a decisive role in whether games are enjoyable. Being in control over gameplay is viewed as enjoyable, while a lack of control might engender anger and frustration (Grodal, 2000).

The assumed effects of control on feelings of achievement can be explained by the control-value theory (Pekrun, 2000, 2006) and in particular by the self-determination theory (Ryan & Deci, 2000). Prompted by the belief that learners generally prefer situations that they can control and try to avoid situations where other forces dominate, both theories predict that the experience of enjoyment is supported if learners perceive an activity as being controllable. However, if activities cannot be handled successfully, frustration might be experienced. Boredom is also an emotion that is closely linked to the perception of control (Pekrun, Hall, Goetz, & Perry, 2014). In contrast to enjoyment and frustration, however, it is not linearly linked but will occur if the perception of control is either too low or too high. Daschmann, Goetz, and Stupnisky (2011) found both being overchallenged and being underchallenged to be a precursor to boredom. These predictions were confirmed in a study that investigated the relationship between the extent of control over gameplay and enjoyment (Ryan, Rigby, & Przybylski, 2006). As the amount of control provided increased, enjoyment also increased, demonstrating that the provided extent of control over gameplay is a significant predictor of emotional responses. The authors concluded that players generally do not enjoy games with high complexity, instead viewing complexity as a price of admission to master it successfully. In a related study, Ryan et al. (2006) compared two entertainment games, differing in the complexity of control interface, on enjoyment. Undergraduate students were randomly assigned to play one of the two games. Students in the game condition with a simple control interface reported significantly greater enjoyment afterwards than those who played a game with a complex control mechanism, which made it more difficult to master the game. Van Lankveld, Spronck, Van Den Herik, and Rauterberg (2010) investigated enjoyment as well as frustration and boredom. Three versions of a game were compared: easy, difficult, and balanced. The versions differed in the number and type of enemies that players had to fight against. The aim of the study was to investigate the effectiveness of the balanced game version compared to the easy and difficult versions. Means of retrospective measurement show that the easy and balanced versions generated more enjoyment and lower frustration than the difficult game version, whereas non-significant differences in boredom among all versions and non-significant effects for all emotions between the easy and balanced versions were found. The research of Klimmt et al. (2007) reveals a more complex picture of provided control and emotional responses. In their study, all participants played one round with a standard condition and then were randomly assigned to the standard condition and a reduced control condition for the second round. In the reduced control condition, there was a higher difficulty for players to handle the given game-objects due to the pace of objects and the lower responsiveness of the objects on users' actions. There was also a reduced effectance condition (i.e., the influence on the game world in general), not relevant to the scope of this study. Measured after both the first and second round of play, non-significant differences in enjoyment between first and second round of play were reported for participants who played the reduced control version, and non-significant differences compared to participants who played a standard condition of the game were found. These results may be partially a function of the interplay between the given extent of control and players' actual perception of control with regard to dynamic changes in players' gameplay competence. Enjoyment, for example, is seen as a sense of achievement that occurs if the given challenge matches players' competence (Csikszentmihalyi, 1990) and thus increases the perception of control over gameplay. However, because individual competencies can increase during gameplay, it should not be assumed that the perception of control linked with enjoyment always disappears in complex and more difficult conditions. Thus, the player's actual perception of control, in addition to changes in both control perception and emotions while playing, has to be taken into account.

3. Research questions and hypotheses

In the present study, the interplay between the perception of control and achievement emotions while playing three rounds of a tower defense game was investigated. The game was conceptualised to teach functionalities of the human liver. The perception of control was induced by the amount and timely appearance of given interactive game elements. Participants were randomly assigned to one of three conditions: high, moderate, and reduced control of the game. Perceived control and achievement emotions (i.e., enjoyment, boredom, anger, and frustration) of the participants were assessed repeatedly after each of the three rounds of gameplay.

In a first step, these time series data enabled the examination of the relationship between the perceived control and achievement emotions for each round of play and the effects of values from one round to the next. The relationship between both variables was investigated as preliminary analysis by computing path models analysing autoregressive effects, cross-lagged effects and correlations between both.

As a second step, the induction of perceived control through the game design and its effects on the strength of each of the achievement emotions across the rounds of gameplay was explored. Therefore, the effects of each of the three game conditions (i.e., high, moderate and reduced control) linked with differences in perceived control on emotions across the rounds of play were analysed using a mixed between-within measures ANOVA.

In line with Pekrun (2006) and the empirical game research studies mentioned above (e.g., Klimmt et al., 2007), it was hypothesised that emotions would be partially explained by players' experience of control. Therefore, a relation between the perception of control and emotions across the rounds of gameplay was expected. Further, it was hypothesised that the subjective perception of being in control over gameplay would result in greater enjoyment but also in higher boredom. A high perception of control would further result in lower anger and frustration compared to reduced perception of control across the rounds of gameplay.

Additionally, in order to control for the potential of the tower defense game, and since emotions are linked to learning processes, students' knowledge about the academic content and their gaming performance was also considered.

4. Method

4.1. Participants

A total of 124 university students participated in this experiment. Participants consisted of 89 bachelor- and 35 master-level students in the fields of psychology, computer science, economics, and biology at Ulm University, Germany. Students were recruited through an email that was sent to all students registered at the university and to students registered with the university's

Facebook page. Their ages ranged between 18 and 38 years with a mean age of 22.89 years ($SD = 3.01$). Female participants comprised 54.8% of the sample, and 45.2% were male. Regarding frequency of gameplay, 26.8% reported playing games frequently each day, 30.1% played games up to once a week, 15.3% every month, and 23.4% less than every month. Missing data were handled through listwise deletion.

4.2. Material and perception of control induction

A tower defense game named "Liver Defense" (see Fig. 1) was used in this study. Tower defense games are a type of strategy game with the challenge of buying, placing and organizing towers to successfully defend against the deployment of different types of enemies. For each enemy destroyed by the towers, the player typically earns resources. The single-player computer-based tower defense game used in this study was developed by a students' group consisting of master-level students in the field of psychology and informatics. The game aims to teach basic human liver functionalities to players with little or no prior knowledge in this area. By using animation, sound and haptic stimuli, players learn how waste material such as ammonia, alcohol, and pharmaceuticals are metabolised by different corresponding enzymes within the liver cells, with a focus on a single bloodstream inside the liver. In the traditional manner of tower defense games, the players' task is to build liver cells that serve as towers and that create enzymes specialised to defend against the incoming waste materials. Further, the liver cells can be temporarily assigned to manufacture glucose to manage the ever-decreasing blood sugar level, and Kupffer cells can be activated to defend the liver cells against bacteria. During gameplay, players had continuous access to brief descriptions of the relevant waste materials and liver enzymes. The game is lost when 100 health points are gone. In general, the ability to control and interact with game elements and immediately see the consequences of one's actions are key design features of games that are proven to offer a challenging way of learning (Jabbar & Felicia, 2015).

For the induction of perceived control, three different conditions of Liver Defense were created: *a high control condition* to provide students with a positive experience of being in control over gameplay, a *reduced control condition* expected to confer a sense of lack of control and a *moderate control condition* as a control condition, falling between both. Whereas in all conditions the instructions, academic content, design, and rules of play were identical, the conditions differed in the provided glucose balance and the amount and time between incoming particles as well as the blood sugar decrease per second. The provided initial glucose balance in the high control condition (35 initial glucose) was higher than what was provided in the moderate (25) and reduced (20) conditions. Participants had to attend to one harmful substance at a time in the high control condition (2 s allotted between particles), whereas those in the moderate control condition were required to handle two or three substances at a time (1.5 s). In comparison, in the reduced control game condition, high numbers of harmful substances entered the liver all at once (every second), making them more difficult to handle. Furthermore, the amount of blood sugar decrease was lowest in the high control condition (0.2 per second; 0.35 per second in the moderate control condition; 0.5 per second in the reduced control condition).

4.3. Measurements

The measurements in this study can be divided into three groups: (a) perceived control, (b) achievement emotions, and (c) learning and gaming performance.

(a) *Perception of control.* To determine whether the manipulations of control in the tower defense game were effective, participants' perceived control was assessed before and during gameplay via a single-item measure asking "How much did you experience in being control over gameplay?" on a 7-point Likert scale. As Wanous, Reichers, and Hudy (1997) demonstrated in a meta-analysis, single item measures are highly correlated with multi-item scales and thus are fairly valid and more economic in specific situations, such as when lengthy questionnaires are not practical.

(b) *Achievement emotions.* Before and during gameplay, participants used a 7-point Likert scale to convey how much of each discrete achievement emotion (i.e., enjoyment, boredom, anger and frustration) they experienced. For this, also single-item measures were used.

(c) *Learning outcomes and gaming performance.* Both learning outcomes and gaming performance were assessed. For learning outcomes, the pre- and post-test measured participants' knowledge of the biological processes of the functionalities of the human liver. Both tests consisted of 8 questions measuring participants' understanding of liver functionalities using two different question types: open questions (e.g., *"Please describe the main functionalities of the human liver"*) and multiple-choice questions (e.g., Which enzyme is important to defend against alcohol?). After deleting two questions due to technical problems, 6 items remained in both tests with a maximum possible score of 14 points. Internal consistencies were $\alpha = 0.51$ for the pre-test and $\alpha = 0.65$ for the post-test. Along with learning outcomes, log-file data were stored in order to extract how often students failed during gameplay (i.e., how often students received the "Game Over" message). This information was used to assess gaming performance.

4.4. Procedure

The experiment took place at Ulm University. Participants were first given the pre-test to measure their prior knowledge of human liver functions. After completing the test, students were introduced to the game and given the instruction that they could learn about the functions of the human liver. Students played a tutorial with moderate control. After playing the tutorial, students completed a second questionnaire with respect to their perception of control and to their emotions. This information was used as baseline data. Afterwards, for the experiment, the 124 students were randomly assigned to one of the three game versions, with each version representing one of the induction conditions of control: high game-control ($n = 41$), moderate game-control ($n = 42$) or reduced game-control ($n = 41$). There were no significant differences among the three conditions for gender (male = 18, female = 23 in the high game-control condition; male = 20, female = 22 in the moderate game-control condition; and male = 18, female = 23 in the reduced game-control condition). Students played three rounds of the game version to which they had been randomly assigned. Participants worked on an individual basis on a computer. They could interact with the game by using both a keyboard and a mouse. After each round, participants rated their emotional state and their perceived level of control using scales displayed in the gaming environment. After finishing the game, which lasted approximately 10 min, students completed the knowledge post-test. All tests were presented digitally on the computer. A visual overview of the procedure is provided in Appendix A.

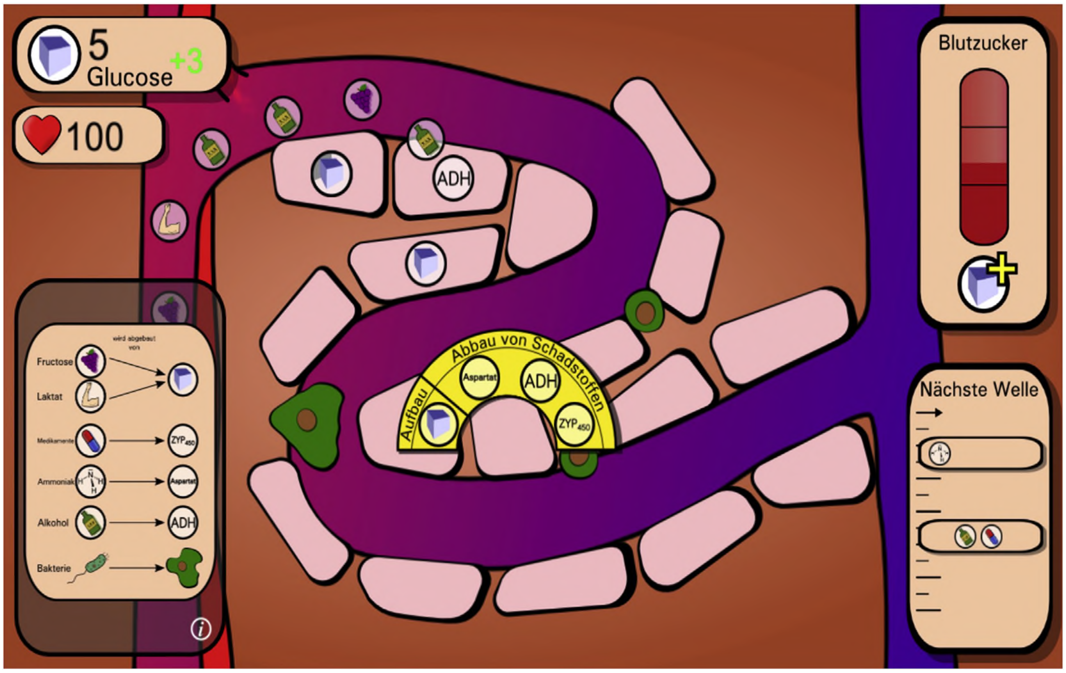

Fig. 1. Screenshot of the Liver Defense interface.

5. Results

5.1. Preliminary analyses: the interplay of control perception and trends of achievement emotions

To evaluate in a first step whether there exist an interplay between perceived control and achievement emotions across the round of play and to analyse their relation, four manifest autoregressive models with two indicators (perceived control and one discrete achievement emotion) and four measurement points (baseline before starting the gameplay and the three rounds of play) were used.

The path model analyses were computed using the Mplus 7.2 software package (ML estimator). Within these models, autoregressive effects, cross-lagged effects and correlations between perceived control and achievement emotions of the baseline variables as well as correlations between the residuals within each round of play were analysed (for bivariate correlation see Appendices B & C). All further correlations between residuals were fixed to zero. As fit indices, the comparative-fit-index (CFI) and the standardized root mean squared residual (SRMR) were applied. A CFI above 0.95 and a SRMR below 0.08 indicate a satisfactory model fit (Hu & Bentler, 1999). Due to the small sample size, the Tucker-Lewis index (TLI) or root mean squared error of approximation (RMSEA) are not applied as they tend to overreject adequate models (Hu & Bentler, 1999).

Perception of control and enjoyment. Altogether, the fit indices for the path model ($\chi^2 = 33.89$, $df = 12$, $p < 0.001$, $CFI = 0.96$, $SRMR = 0.07$) indicated a satisfying model fit. The correlations between the baseline variable of perceived control and enjoyment and between the respective residuals at the measurement points round 1 to round 3 were significant and of medium to high effect size. Also, all autoregressive effects were significant. Only the cross-lagged effect from baseline control to enjoyment at round 1 was significant. Altogether, for control variables 15%–42% of variance was explained, while for enjoyment variables 42%–51% of variance was explained.

Perception of control and boredom. In total, the fit indices for the path model were satisfying ($\chi^2 = 24.49$, $df = 12$, $p = 0.02$, $CFI = 0.97$, $SRMR = 0.05$). The correlation between the baseline variable of perceived control and joy was significant but of small effect size. All autoregressive effects were significant and of medium to high effect size. Further, there were significant small cross-lagged effects from the baseline measurement to measurement in round 1 of gameplay. For control variables, 23%–44% of variance was explained; for the boredom variables 25%–68% of variance was explained.

Perception of control and anger. Comprehensively, the fit indices for the anger path model were close to adequate ($\chi^2 = 39.25$, $df = 12$, $p < 0.001$, $CFI = 0.94$, $SRMR = 0.07$). The effect pattern was similar to the pattern of the path model with perceived control and joy. All correlations within each point of measurement (baseline and rounds 1–3) and autoregressive effects were of medium to large effect size. The cross-lagged effects were not significant, with the exception of the effect from the baseline control variable to the anger variable at round 1 of gameplay. In total, 21%–44% of perceived control variance and 18%–37% of the anger variance was explained.

Perception of control and frustration. The following model fits were calculated: $\chi^2 = 31.19$, $df = 12$, $p = 0.002$, $CFI = 0.96$, $SRMR = 0.07$. Correlations between the baseline variables as well as between the residuals at measurement points round 1 to round 3 were of medium to large effect size. Further, the autoregressive effects were also medium to high. The cross-lagged effects were not significant aside from a small effect from the baseline frustration to perceived control at round 1. Of the perceived control variables, 23%–43% of variance was explained; of the frustration variance, 25%–45% was explained.

5.2. Manipulation check of control induction: participants' perception of control

After the preliminary analysis, the interaction between the game control conditions and round of play for participants perception of control was analysed to test for a successful manipulation of the participants' sense of control across the rounds of play across all conditions.

For this, a mixed between-within repeated measures ANOVA was conducted. Game conditions were used as between-subject factors, and the perception of control during the three rounds of play were the repeated within-subject factors. The baseline of perceived control was a covariate. Furthermore, the question was addressed as to whether an equalization of trends across rounds of play between the different conditions existed. All results were assessed at a significance level of 0.05. Descriptive statistics are presented in Table 1. Mauchly's sphericity test indicated that the assumption of sphericity for the main effects of perception of control had been violated $\chi^2(2) = 8.17$, $p = 0.017$; therefore, Wilks' lambda test is reported.

There was a significant main effect of game conditions on the perception of control, $F(2, 114) = 12.36$, $p < 0.001$, $\eta^2 = 0.17$. Follow-up Bonferroni post hoc tests revealed significant differences between the following groups: high and moderate ($p = 0.01$, $d = 0.69$) and the high and reduced control condition ($p < 0.001$, $d = 0.80$). The difference between the moderate and reduced groups was not significant ($p = 0.052$). These findings suggest that our control induction was at least partially successful, as evidenced by students in the high control condition reporting the highest sense of control compared to those in the moderate and reduced control conditions across all rounds of play.

Overall, there was a non-significant increase in perceived control across the three rounds of play, as was shown by the non-significant main effect for the rounds of play, $p = 0.31$. The interaction graph (see Fig. 2) shows that the positive experience of being in control was more pronounced for the high control condition and the sense of control increased across the rounds of play, especially in the reduced control condition. Further, the moderate control condition did not show an increase across all three rounds. There was an unexpected decrease in the perception of control for the moderate condition between round 2 and round 3, leading to an unexpected difference between the moderate and the reduced condition.

Further, a significant interaction effect for rounds of play and game-control condition was observed, Wilks' lambda = 0.80, $F(4, 226) = 6.84$, $p < 0.001$, $\eta^2 = 0.10$. This interaction effect indicates that trends of perception of control during gameplay differed in the high, reduced and moderate control conditions. To observe where the differences lay, contrasts were performed comparing the perception of control from one round of play to the next round of play across the game conditions. Contrasts revealed a significant interaction after the first round of play compared to the second round of play, $F(2, 114) = 10.09$, $p < 0.001$, $\eta^2 = 0.15$, indicating that there was a difference in the perception of control between these rounds of play among the three game conditions. However, the second contrast, which compared the experienced sense of control after the second and third round of play, was non-significant, $p = 0.38$, indicating a similar perception for both rounds among all three of the game conditions.

5.3. *Differences in trends of achievement emotions during gameplay*

Next, the effects of control induction and the resulting differences in achievement emotion trends during gameplay were examined. Again, a mixed between-within repeated measures ANOVA was conducted to compare each of the four experienced emotions among the three game conditions across the three rounds of play, controlling for the emotions at baseline.

Enjoyment. For enjoyment, there was a significant main effect for game conditions, $F(2, 114) = 3.07$, $p = 0.05$, $\eta^2 = 0.05$, indicating differences in enjoyment among the three conditions. Also, a main effect for rounds of play on enjoyment after controlling for the effect of the baseline enjoyment was found $F(2, 228) = 4.76$, $p = 0.01$, $\eta^2 = 0.04$, with all three conditions showing an increase in enjoyment across the rounds of play. A significant (Condition x Rounds of play) interaction, $F(4, 228) = 4.77$, $p = 0.001$, $\eta^2 = 0.07$ was observed. Contrasts revealed a significant interaction when comparing enjoyment after the first round compared to the second round of play across all three game conditions, $F(2, 114) = 6.31$, $p = 0.002$, $\eta^2 = 0.10$, suggesting a difference in enjoyment between these rounds among the three conditions. Enjoyment in the second round compared to the third round of play was non-significant, $p = 0.74$, indicating that these differences vanished for the ensuing rounds. The interaction graph (see Fig. 3) reveals that enjoyment in the high and moderate control conditions was rated highest compared to the condition with reduced control in the first and second rounds, whereas enjoyment in all three game conditions slightly increased across the rounds of play. The increase of enjoyment between the first and third round of play, however, appears larger in the reduced control condition compared to the others.

Boredom. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(2) = 10.79$, $p = 0.006$, therefore extents of freedom were corrected using Wilks' lambda estimates of sphericity. Analyses yielded a significant main effect for game conditions $F(2,113) = 3.05$, $p = 0.05$, $\eta^2 = 0.05$, but a non-significant main effect for rounds of play after controlling for boredom at baseline ($p = 0.83$). However, a significant Condition x Rounds of play interaction was observed, Wilks' lambda = 0.82, $F(4, 226) = 5.65$, $p < 0.001$, $\eta^2 = 0.09$. There were significant contrasts in boredom in the first round of play compared to the second round of

Table 1
Mean scores and standard deviation for each group on control perception, emotions, pre- and post-test learning and gaming performance in baseline measures and each round of play.

	M(SD)		
	Baseline/Round1/Round2/Round3		
	High Control Condition	Moderate Control Condition	Reduced Control Condition
Perception of Control	4.59(1.72)/5.09(0.21)/5.17(0.22)/5.36(0.24)	4.51(1.81)/4.54(0.19)/4.24(0.21)/4.26(0.23)	4.55(1.66)/3.27(0.19)/4.18(0.21)/4.64(0.23)
Enjoyment	3.87(1.60)/4.42(0.19)/4.46(0.19)/4.58(0.21)	4.07(1.33)/4.26(0.18)/4.24(0.19)/4.34(0.20)	4.17(1.37)/3.27(0.18)/4.09(0.19)/4.36(0.20)
Boredom	2.35(1.08)/2.07(0.17)/2.33(0.17)/2.51(0.18)	2.37(1.29)/1.95(0.16)/1.87(0.17)/1.69(0.18)	2.32(1.35)/2.11(0.16)/1.60(0.17)/1.80(0.17)
Anger	1.45(0.80)/1.68(0.21)/1.60(0.20)/1.48(0.20)	1.42(1.14)/1.92(0.21)/2.27(0.19)/2.08(0.19)	1.43(0.86)/3.19(0.20)/2.51(0.19)/2.15(0.19)
Frustration	2.10(1.59)/1.96(0.23)/1.81(0.22)/1.61(0.23)	2.02(1.44)/2.69(0.22)/2.97(0.21)/2.67(0.22)	1.90(1.24)/4.34(0.22)/3.18(0.21)/2.72(0.21)
Pre-test	2.70(1.63)	2.62(1.40)	2.60(1.63)
Post-test	10.14(2.51)	8.47(3.38)	9.92(2.46)
Gaming Performance	0.24(0.59)	0.72(0.59)	1.60(0.73)

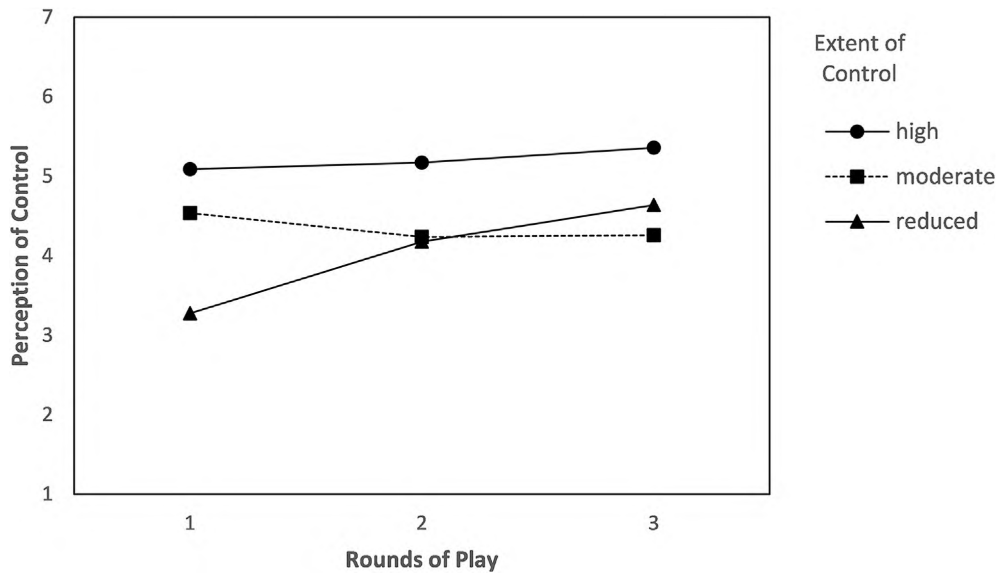

Fig. 2. Interaction of control conditions and rounds of play on the perception of control.

play, when comparing the three game conditions, $F(2, 114) = 6.58$, $p = 0.002$, $\eta^2 = 0.10$, and the second compared to the third round of play $F(2, 114) = 3.72$, $p = 0.02$, $\eta^2 = 0.06$, all significant with small effect sizes. This indicates that boredom between the rounds of play differed between the game conditions. As the interaction graph (see Fig. 3) demonstrates, all conditions showed similar boredom at the beginning of gameplay. Boredom then slightly increased in the high control condition and decreased in the reduced and moderate conditions across the rounds of play, suggesting that the game became less boring when playing the second and third round in conditions with reduced and moderate control compared to the high control condition.

Anger. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(2) = 8.65$, $p = 0.01$, therefore Wilks' lambda was conducted. There was a significant main effect of game condition, $F(2, 113) = 10.58$, $p < 0.001$, $\eta^2 = 0.15$. No main effect was found for rounds of play on anger, controlling for the anger at baseline, $p = 0.64$, but a significant Condition x Rounds of play interaction was observed, Wilks' lambda = 0.86, $F(4, 226) = 4.17$, $p = 0.003$, $\eta^2 = 0.06$, indicating that anger was different depending on the level of control at which the game was played. Contrasts, again, were used to examine this interaction. The first contrast, which compared anger after the first and second round among the game conditions, was significant, $F(2, 114) = 6.56$, $p = 0.002$, $\eta^2 = 0.10$. The second contrast revealed a non-significant difference between game conditions when comparing students' anger after rounds two and three, $p = 0.62$. Fig. 3 indicates that anger seems to slightly decrease across the rounds of play in the high and reduced control condition, whereas in the moderate condition anger slightly increased between the first and second round and decreased afterwards. However, these trends were not found to be significant.

Frustration. A main effect of game conditions was found, $F(2, 114) = 21.26$, $p < 0.001$, $\eta^2 = 0.27$, but the effect of rounds of play on frustration was non-significant, $p = 0.93$. Furthermore, an interaction effect between conditions and rounds of play for frustration was found, Wilks' lambda = 79, $F(4, 228) = 8.35$, $p < 0.001$, $\eta^2 = 0.12$. Contrasts showed a significant interaction when comparing the game conditions and frustration between the first round to the second round, $F(2,114) = 11.85$, $p < 0.001$ $\eta^2 = 0.17$ and a non-significant difference between rounds two and three, $\rho = .69$. The interaction graph (see Fig. 3) shows that frustration decreased during gameplay in the high and the reduced control conditions. Participants in the reduced control condition, however, experienced a higher degree of frustration across all rounds of play than students in the high control condition.

5.4. *Differences in learning outcomes and gaming performance*

Finally, the impact of control induction linked with emotions on learning outcomes and on gaming performance was observed.

For learning outcomes, the mixed between-within repeated measures ANOVA demonstrated an increase in academic knowledge (pre-vs. post-test) concerning the functionalities of the human liver through gameplay, $F(2, 114) = 726.08$, $p < 0.001$, $\eta^2 = 0.86$. However, the main effect of game conditions was not significant, $p = 0.09$, indicating no differences between the three groups in learning outcomes. Further, a non-significant interaction effect, $p = 0.10$, was found.

Comparing how often students failed during gameplay, measured by how often the health status in the game declined, revealed a significant main effect of game condition on gaming performance, $F(2,115) = 44.72$, $p < 0.001$ $\eta^2 = 0.44$. Follow-up Bonferroni post hoc tests revealed significant differences between the high and reduced control groups ($p < 0.001$, $d = 2.05$), high and moderate ($p = 0.005$, $d = 0.81$), and moderate and reduced groups ($p < 0.001$, $d = 1.31$). As the level of control decreased (moderate and reduced control condition), participants failed more often during gameplay compared to participants in the high control condition.

6. Discussion and conclusion

The current study investigated the interactions of the perception of control and trends of achievement emotions during gameplay. To induce different levels of control perception, the balance, amount and time of incoming gameplay elements that had to be handled were manipulated. Manipulating game elements in that manner has already been established in previous game research regarding the perception of control (e.g., Ryan et al., 2006). The intervention for manipulating the perception of control was

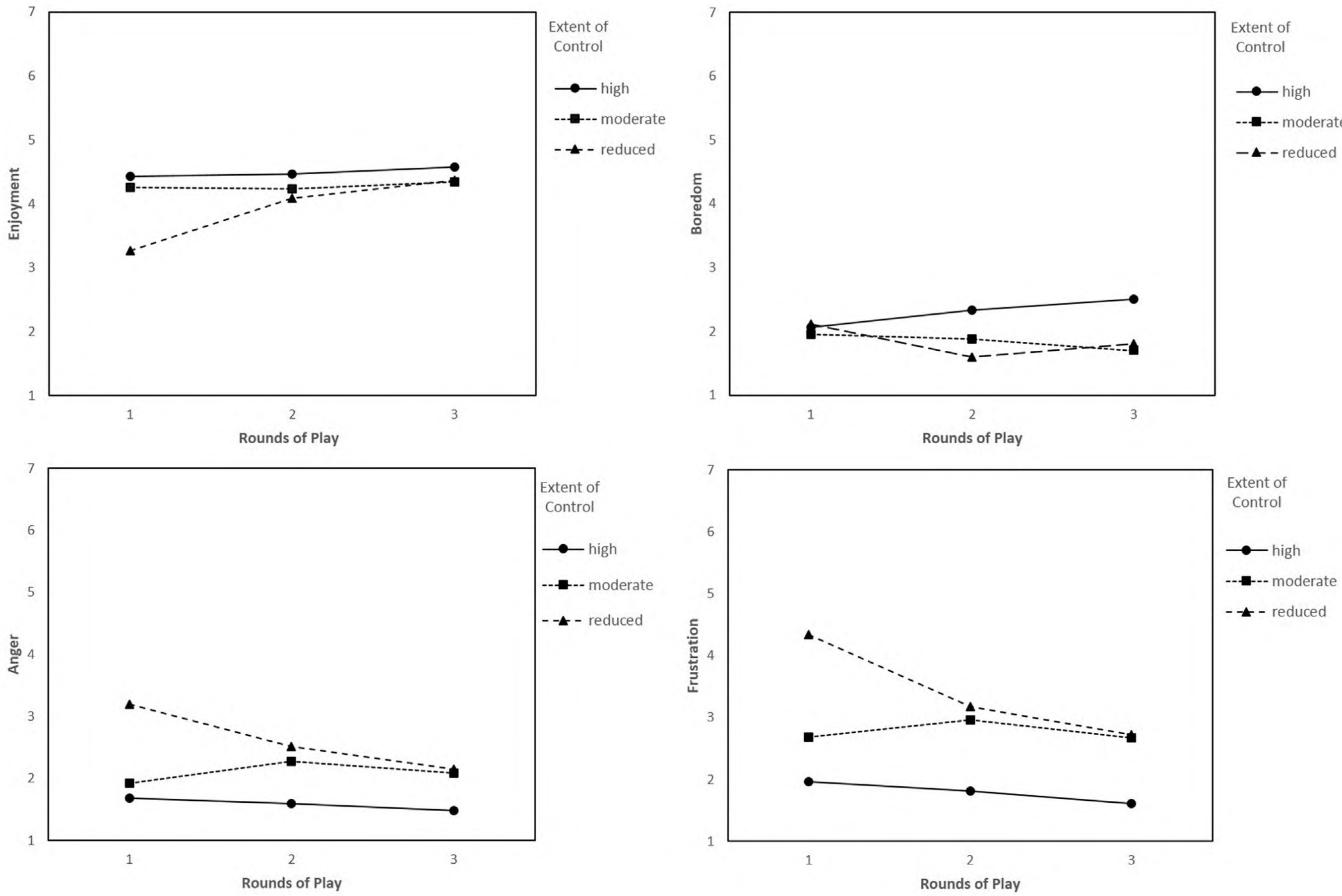

Fig. 3. Interaction of game control conditions and rounds of play for enjoyment, boredom, anger and frustration.

successful as evidenced by participants differing in their experience of control. Participants in the high control condition perceived the highest sense of control compared to those who played with a moderate or reduced level of control.

The second analyses examined the interplay between perception of control and achievement emotions. Results provided initial evidence of associations between the perception of control and each achievement emotion (enjoyment, boredom, anger, and frustration) after each round of play, with the exception of boredom. As expected, the relationship between control perception and enjoyment was positive, whereas a negative relationship was found between control perception and anger and frustration. These results suggest that control and emotion are connected closely during the round of play, whereas there are only negligible impacts from one round to the following round.

The third analyses examined the interaction among three different levels of control and trends of emotions across the rounds of gameplay. In general, as expected, the higher perception of control induced through the game design maintained higher enjoyment compared to a moderate and reduced control condition, which is in line with previous research (e.g., Van Lankveld et al., 2010). The results for boredom, anger and frustration also follow our expectations, demonstrating a lower level of boredom but a higher extent of anger and frustration with the decrease of given and perceived control. Based on these results, it is tempting to conclude that a high level of control design is needed to maintain positive emotions. However, differences in the control perception and emotions emerged only between the first and second round. Non-significant interaction effects were found between the second and third rounds of play for control perception and each emotion with the expectation of boredom. This indicates an increase in participants' gameplay competence linked with a gain in the perception of control leading to an approximation in trends of these emotions among the different conditions.

This outcome expounds upon the recent discussion (Van Lankveld et al., 2010) on how players' skills adapt to the amount of control provided. Further, it is important to mention that the relations between the students' perceived control and discrete emotions are not identical, mirrored by the interaction between the given three different levels of control and the trends of emotions. As already demonstrated by the results of the manipulation check, the perception of control could individually differ from the intended inducement due to the subjective experience of how individuals appraise actual situations.

While the game itself leads to an increase in knowledge about the functionalities of the human liver, no differences could be found between the three experimental groups in learning outcomes. This finding indicates that while the level of perceived control seems to determine the emotional experience of participants, there appears to be no direct effect on learning outcomes themselves. However, when interpreting these findings, one has to recall that the period of time playing the game was quite limited. According to Pekrun (2000, 2006), the emotional experience has an impact on learning outcomes in more complex, lengthier, and more extensive learning situations. Further, these results have do be interpreted with caution, as the reliability of the knowledge test is rather low.

7. Limitations and conclusions for future research

Besides the limited time frame of this experiment, further limitations include the population used for this research. The academic content integrated in the game is not curriculum embedded in the participants' field of study. Therefore, it is likely that participants did not pursue any value for learning during gameplay aside from their gameplay progress. As already stated in the theoretical part above, both the appraisals of control and of a value of a learning activity and outcome are central to the level of achievement emotions (vgl. Pekrun, 2006). Thus, in future studies, the appraisal of value should be additionally taken into consideration. There might be interaction effects between control and value that strengthen the effect of control on the experience of academic emotions when experiencing higher value (e.g., medical students). However, for these participants, the level of prior knowledge is likely to provide a bigger variance, thus the level of perceived control might be not as easily manipulated and controlled. Further, the nature of tower defense games (i.e., the replication of functions, integrated content, and given tasks) may have been too simple and might have an effect not only on learning outcomes and gaming performance but also on the perception of control and on emotions.

Along with these critical issues related to the non-significant findings in learning outcomes between the three conditions, there are additional limitations to the generalizability of our findings. No overall conclusions can be made because the provided extent of control seems to function differently in different games and with different types of players. For the study, the balance, amount and time of given game elements in play were chosen as the control induction. Examining the descriptive results, all conditions of the game were rated as moderately controllable even if there were significant differences between the descriptive means. Furthermore, the high control condition was not found to be as boring as expected, as reflected by the means. One explanation might be that the game, even in its simplest form, is still too sufficiently entertaining to create low degrees of boredom. In addition, even if there was a significant difference between the high and low control conditions, the low control condition was not highly frustrating according to the means. It has to be noted that not every challenging task linked with a reduction in control might directly lead to high frustration and to players giving up. As the link between emotions and learning is complex, it can also be seen as a positive force when activating negative emotions to affect the extrinsic motivation to avoid failure (Pekrun, 2006). Further research is needed to examine the role of frustration on motivation and performances during gameplay.

Lastly, the current study only examined emotions via repeated self-report after each round of gameplay. While self-report is a direct method to detect discrete emotions, it suffers from limitations such as individual differences in social desirability as well as alexithymia, and it interrupts gameplay. Intrusive methods such as assessing physiological activities (e.g., bodily activation) and linking these to emotions, in contrast, enable a continuous measurement that is unbiased by personal characteristics (Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2010).

Summarizing, the results of the current study reinforce empirical as well as theoretical research that highlights the importance of considering the level of control within the design of serious games. The level of given control has a meaningful impact on the interaction between players' control perception, emotional experience, and gaming performance, and thus might have an indirect impact on learning persistence and learning outcomes in the long term. As both the perception of control and discrete emotions dynamically change over time, an auto-dynamic adaptation of design features to the actual changes and needs of players seems to be a pertinent issue for future study.

Acknowledgements

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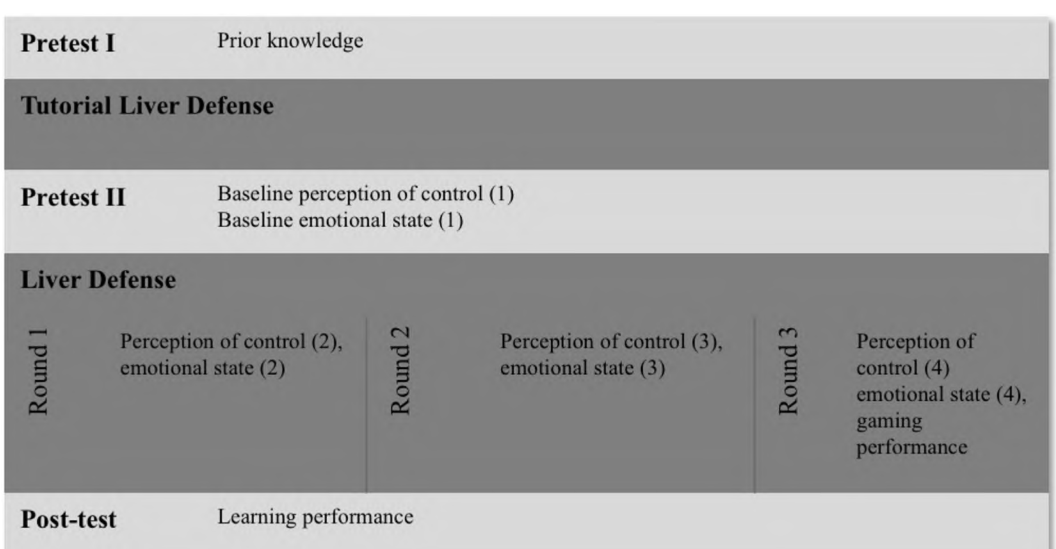
Appendix A. Procedure of the study



Appendix B. Correlations between emotions and between emotions and perception within each round of play

	r (p)							
	Enjoyment		Boredom		Anger		Frustration	
Boredom								
Baseline	−0.25	(0.003)						
Round 1	−0.24	(0.006)						
Round 2	−0.34	(<0.001)						
Round 3	−0.35	(<0.001)						
Anger								
Baseline	−0.11	(0.228)	0.33	(<0.001)				
Round 1	−0.38	(<0.001)	0.08	(0.403)				
Round 2	−0.42	(<0.001)	0.13	(0.159)				
Round 3	−0.35	(<0.001)	0.04	(0.647)				
Frustration								
Baseline	−0.34	(<0.001)	0.20	(0.020)	0.51	(<0.001)		
Round 1	0.54	(<0.001)	0.18	(0.039)	0.79	(<0.001)		
Round 2	−0.47	(<0.001)	0.12	(0.190)	0.81	(<0.001)		
Round 3	−0.38	(<0.001)	0.07	(0.425)	0.84	(<0.001)		
Perception of Control								
Baseline	0.35	(<0.001)	−0.20	(0.020)	−0.23	(0.008)	−0.48	(<0.001)
Round 1	0.54	(<0.001)	−0.08	(0.358)	−0.53	(<0.001)	−0.67	(<0.001)
Round 2	0.58	(<0.001)	−0.18	(0.036)	−0.53	(<0.001)	−0.64	(<0.001)
Round 3	0.45	(<0.001)	0.01	(0.929)	−0.56	(<0.001)	−0.62	(<0.001)

Appendix C. Correlations of each emotion, pre- and post-test learning and gaming performance between rounds of play

	r (p)					
	Baseline	Round 1	Round 2	Pre-test Learning	Post-test Learning	Gaming Performance
Enjoyment						
Baseline				0.34(<0.001)	0.17(0.059)	−0.10(0.258)
Round 1	0.62(<0.001)			0.21(<0.05)	0.17(0.068)	−0.38(<0.001)
Round 2	0.54(<0.001)	0.69(<0.001)		0.26(<0.01)	0.03(0.771)	−0.25(<0.01)
Round 3	0.34(<0.001)	0.57(<0.001)	0.70(<0.001)	0.25(<0.01)	0.08(0.416)	−0.14(0.121)
Boredom						
Baseline				−0.14(0.135)	−0.16(0.090)	0.18(0.051)
Round 1	0.51(<0.001)			−0.08(0.372)	−0.06(0.545)	0.20(<0.05)
Round 2	0.43(<0.001)	0.69(<0.001)		−0.16(0.084)	−0.17(0.070)	0.02(0.874)
Round 3	0.41(<0.001)	0.68(<0.001)	0.83(<0.001)	−0.22(<0.05)	−0.10(0.293)	0.06(0.504)
Anger						
Baseline				−0.03(0.745)	−0.02(0.793)	−0.02(0.837)
Round 1	0.40(<0.001)			−0.03(0.770)	−0.17(0.062)	0.31(<0.01)
Round 2	0.44(<0.001)	0.60(<0.001)		−0.04(0.681)	−0.09(0.335)	0.31(<0.05)
Round 3	0.29(<0.001)	0.45(<0.001)	0.64(<0.001)	−0.00(0.970)	0.03(0.757)	0.17(0.067)
Frustration						
Baseline				−0.09(0.357)	−0.28(<0.01)	0.15(0.106)
Round 1	0.48(<0.001)			−0.05(0.582)	−0.23(<0.05)	0.48(<0.001)
Round 2	0.46(<0.001)	0.67(<0.001)		−0.74(0.423)	−0.12(0.212)	0.34(<0.001)
Round 3	0.35(<0.001)	0.52(<0.001)	0.66(<0.001)	−0.02(0.852)	−0.03(0.746)	0.24(<0.01)
Perception of Control						
Baseline				0.20(<0.05)	0.06(0.533)	0.13(0.170)
Round 1	0.42(<0.001)			0.08(0.377)	0.23(<0.05)	−0.56(<0.001)
Round 2	0.45(<0.001)	0.69(<0.001)		0.17(0.069)	0.11(0.233)	−0.45(<0.001)
Round 3	0.39(<0.001)	0.51(<0.001)	0.61(<0.001)	0.11(0.224)	0.10(0.265)	−0.27(<0.01)

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