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No Pain, no Gain? Investigating motivational mechanisms of game elements in cognitive tasks☆

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ABSTRACT

The literature on serious games and gamification suggests that game elements have a positive influence on learning and performance in cognitive tasks. However, the mechanisms by which game elements affect these outcomes are not well understood. Building on theorizing in the self-control literature, the present research investigated whether game elements change the subjective experience of a cognitive task in terms of the positive affect, motivational conflict, and subjective effort experienced. Further, we tested whether people with a low versus high level of self-control benefit more from game elements in terms of their performance. The results of two experimental studies suggest that the gamification of an n-back task did not improve task accuracy (i.e., correct responses) directly but reduced task disengagement (i.e., non-responses). Further, gamification prevented positive affect from dropping over the course of the task and reduced motivational conflict and subjective effort experienced. Only positive affect mediated the effect of game elements on task disengagement. Further, game elements had an indirect effect on task accuracy via subjective effort. There was no indication that individuals with lower delay of gratification or lower trait self-control would profit more from gamification. The implications of these findings for the literature on self-control and gamification are discussed.

Although cognitive effort is necessary in order to acquire knowledge and skills, research suggests that it is usually experienced as aversive (Inzlicht, Bartholow, & Hirsh, 2015; Kurzban, Duckworth, Kable, & Myers, 2013). Recent models of cognitive control argue that when people engage in a cognitive task, they face a motivational conflict between engaging in "cognitive labor", which is aversive in the present moment but will pay off in the future, and engaging in "cognitive leisure", which is rewarding in the present but will not produce any future rewards (Kool & Botvinick, 2014; Kurzban et al., 2013). An implicit assumption of these models is that people can only have one thing at a time: labor or leisure.

The literature on *serious games* and *gamification*, however, suggests that the agreeable can be combined with the beneficial by adding game elements to cognitive tasks. The basic idea is that game elements increase the pleasantness of otherwise boring or strenuous tasks and thereby increase people's engagement, leading to better cognitive performance. Indeed, research suggests that game elements impact outcomes (performance, learning) indirectly through changes in individuals' attitudes and behaviors (Landers, 2014; Landers, Auer, Collmus, & Armstrong, 2018), motivation, and affect (Clark, Tanner-Smith, & Killingsworth, 2016; Greipl, Moeller, & Ninaus, 2020; Sailer & Homner, 2020). Despite the already wide application of game elements in a variety of domains, the mechanisms underlying these effects are not yet understood well (Boyle et al., 2016).

Building on recent theorizing in the literature on self-control, we argue that game elements add immediate rewards to cognitive tasks and thereby change people's experience with regard to positive affect, motivational conflict, and their subjective experience of effort. Following this idea, we further investigated whether game elements are particularly effective for people with low levels of self-control. If this were the case, gamification might be an easy and inexpensive way to improve academic and professional performance in these groups

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(Duckworth, Taxer, Eskreis-winkler, Galla, & Gross, 2019; Moffitt et al., 2011).

1. Effects of gamification on performance in cognitive tasks

Cognitive tasks, as well as learning, are typically considered to be effortful and sometimes even frustrating and repetitive. These aversive affective states can lead to task disengagement or the termination of the training or learning activity (Kurzban et al., 2013; Pekrun, Goetz, Titz, & Perry, 2002). In recent years, the use of game elements in education and cognitive training has increased considerably, as results indicated that game elements or games more generally promote performance and motivation (Lumsden, Edwards, Lawrence, Coyle, & Munafò, 2016; Sailer & Homner, 2020). The integration of game elements or attributes, such as immersion, game fiction, challenge, assessment, etc. (Bedwell, Pavlas, Heyne, Lazzara, & Salas, 2012) into conventional (cognitive) tasks is commonly referred to as *gamification* (Deterding, Dixon, Khaled, & Nacke, 2011). The idea behind gamification is that it engages users, leading to greater persistence (e.g., prolonged or more frequent training) and more effort being invested, and as a result to better cognitive performance. In line with this idea, Mekler, Brühlmann, Tuch, and Opwis (2017), for instance, have demonstrated that participants provide a significantly higher number of tags in an image annotation task when this is augmented by game elements (i.e. conflict/challenge, rules/goals, and assessment) as compared with participants confronted with the same task without game elements.

In a similar vein, research has demonstrated positive effects of game elements in a short training program for working memory capacity (Ninaus et al., 2015). In a 25-min-long training session, participants were supposed to train their working memory capacity either using a task that contained game elements (e.g., immersion, rules/goals, etc.) or using a control version without game elements. Although the groups did not differ in the maximum number of information units recalled, the group with game elements trained more efficiently by staying closer to their maximum cognitive capabilities throughout the training session. This indicates that participants were more engaged and invested more cognitive effort into the training when game elements were present (Ninaus et al., 2015).

Not surprisingly, the effects of game elements seem to play out especially in the long run, when persistence in aversive tasks usually relapses. Accordingly, a three week long training study among children with ADHD found increased persistence, effort, and performance for a working memory training program with game elements compared to regular working memory training (Prins, Dovis, Ponsioen, ten Brink, & van der Oord, 2011). However, in a different study on the use of game elements in cognitive training, Lumsden, Skinner, Coyle, Lawrence, and Munafo (2017) did not observe differences in attrition rates between a gamified version of the stop-signal task (Verbruggen, Logan, & Stevens, 2008) and a non-gamified version of the same task. Although some studies found no positive effects of game elements, several systematic meta-analyses of the literature overall conclude that the combination of game elements and cognitive tasks promises great potential for improving learning and training interventions (Baptista & Oliveira, 2019; Clark et al., 2016; Sailer & Homner, 2020; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013).

Although research on serious games and gamification has been flourishing in recent years, the underlying mechanisms by which these elements work are not yet well understood (Boyle et al., 2016). Further, research examining individual differences with regard to the effectiveness of gamification is scarce. As the investigation of both underlying mechanisms and individual differences might enhance the understanding of heterogeneous effects on cognitive performance found in the literature (e.g., Lumsden et al., 2017; Ninaus et al., 2015; for a review see; Lumsden, Edwards, Lawrence, Coyle, Munafò, et al., 2016), the present research aimed to address both these gaps.

1.1. Gamification and self-control

Engaging in a strenuous cognitive task requires people to direct their attention towards the task, regulate aversive feelings associated with it (e.g., boredom), and resist the temptation of doing something more pleasurable instead (e.g., day dreaming, Kurzban et al., 2013; Miller et al., 2012). Engagement in cognitive tasks is therefore a major domain of self-control, which more broadly describes people's capacity to alter or override their responses, including thoughts, but also their emotions and actions (Baumeister, 2002). Self-control is particularly relevant in situations when the activity itself is experienced as being aversive but engaging in it will pay off at a later point in time (e.g., studying math to perform well in an exam). Early research on self-control focused on the imbalance between short-term and long-term rewards and studied children's ability to delay gratification—that is, their capacity to forego a smaller, immediate reward for the sake of a larger, delayed reward (Mischel, Shoda, & Rodriguez, 1989). In the context of learning and education, this motivational conflict between immediate and delayed rewards has also been referred to as want-should conflicts (Bitterly, Mislavsky, Dai, & Milkman, 2014; Grund, Grunschel, Bruhn, & Fries, 2015). While engaging in an activity, want conflicts describe the feeling of wanting to do something else (i.e., usually directed at something that is more rewarding in the present), while should conflicts describe the feeling that one should do something else (i.e., usually directed at something that is more rewarding in the future). In general, motivational conflicts are experienced as being aversive and associated with lower cognitive (and academic) performance (Duckworth et al., 2019; Inzlicht et al., 2015).

Recent theorizing has linked motivational conflict not only to performance but also to the subjective experience of effort. *The Opportunity Cost Model of Subjective Effort and Task Performance* (Kurzban et al., 2013) assumes that engaging in a cognitive task is experienced as more effortful if there is a salient alternative activity that is regarded as more rewarding in the present (want conflict) or in the future (should conflict). Feelings of effort, in turn, function as a signal to the person to disengage from the current activity and motivate task disengagement.

Recent research supports the assumptions of the opportunity cost model in that they show that a task is experienced as being more effortful, if a more immediately rewarding alternative activity is made salient (Rom, Katzir, Diel, & Hofmann, 2020). The subjective experience of effort in turn predicts task disengagement (Rom et al., 2020). Depending on the situation, task disengagement can result in task switching or in performance deficits, for instance, if a student engages in daydreaming instead of doing math problems (Kurzban et al., 2013; Levinson, Smallwood, & Davidson, 2012).

While the proposed relationship between opportunity costs and subjective effort is new, the idea that the perceived value of an activity plays an important role in learning is not (Eccles & Wigfield, 1995; Fries, Dietz, & Schmid, 2008). Further, empirical evidence and new theoretical approaches point to motivational explanations of self-control failure (Inzlicht & Schmeichel, 2012; Job, Bernecker, Miketta, & Friese, 2015; Muraven & Slessareva, 2003).

Based on this research and theorizing, the present study aimed to investigate how game elements change people's subjective experience while engaging in a cognitive task. The basic idea was that game elements add immediate rewards to a cognitive task (e.g., by providing immersion, assessment, and a game fiction), which should be reflected by an experience of more positive affect (e.g., Brom, Šisler, Slussareff, Selmbacherová, & Hlávka, 2016; Ninaus et al., 2019). Further, if a gamified task is more immediately rewarding than a non-gamified task, people should experience it as being less effortful and perceive less motivational conflict, because it is less likely for more rewarding alternatives to become salient (Kurzban et al., 2013). Note, that this prediction is not inconsistent with the finding that, on a behavioral level, people invest *more* effort into gamified versus non-gamified tasks (Ninaus et al., 2015; Prins et al., 2011). Here we are referring to people's subjective feeling of effort, which should be lower following the assumptions of the opportunity cost model. In fact, the idea that game elements add immediate rewards might explain why on the behavioral level people are willing to invest more effort, because they get more rewards in return for their investment (Kool & Botvinick, 2014).

1.2. Individual differences in self-control as a moderator for the effects of game elements

Individual differences in trait self-control and the delay of gratification are both known predictors of people's academic and occupational success (Duckworth et al., 2019; Kirby, Winston, & Santiesteban, 2005; Moffitt et al., 2011; Shoda, Mischel, & Peake, 1990). However, the mechanisms that underlie these relationships are still a topic of debate and understanding them is vital in order to design interventions for people in whom these traits are less pronounced. A commonly discussed mechanism involves beneficial habits and strategies to avoid self-control conflicts in the first place (Duckworth et al., 2019; Galla & Duckworth, 2015; Gillebaart & De Ridder, 2015). This idea arose from the finding that people with higher levels of trait self-control experience less motivational conflict in their everyday lives and, when confronted with a temptation, perform *less* well in resisting it (Hofmann, Baumeister, Förster, & Vohs, 2012; Imhoff, Schmidt, & Gerstenberg, 2013). This 'ironic effect' of trait self-control led to the idea that these people might have strategies in place to avoid situations requiring self-control (e.g., studying in the library) rather than being specifically successful in suppressing their immediate desires. In a similar vein, more recent research suggests that self-reports of trait self-control capture people's achievement values—that is, how much people value hard work—rather than their actual ability to overcome self-control conflicts in everyday life (Grund & Carstens, 2019; Grund & Senker, 2018; Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018).

Contributing to the question of underlying mechanisms and possible ways of intervening, the present research aimed to test whether individual differences in trait self-control and the delay of gratification moderate the effects of game elements on cognitive task performance. So far, we have argued that game elements add immediate rewards to a cognitive task and thereby change how a task is experienced. As a result, game elements might be more effective for people who are more sensitive to immediate versus delayed rewards. Although all people have the tendency to discount rewards relative to their delay, stable individual differences exist in terms of how much they do so (Hirsh, Morisano, & Peterson, 2008; Kirby, 2009). For some people, the difference between receiving 10€ now versus tomorrow is greater. In a similar vein, trait self-control might reflect how sensitive people are to immediate versus delayed rewards. In line with this idea, research suggests that people with higher levels of trait self-control experience the desire for an immediate reward (e.g., food, media consumption, alcohol) less often and less intensely than people with lower levels of trait self-control (Bernecker, Job, & Hofmann, 2018; Hofmann, Vohs, & Baumeister, 2012). These differences might be explained by the use of strategies, butso far trait self-control has only been linked to strategy use, which in turn did not explain why it was related to greater persistence in aversive tasks (Hennecke, Czikmantori, & Brandstätter, 2019). Thus, another explanation might be that people with higher levels of trait self-control do not feel as strongly attracted by things that are immediately rewarding. In other words, they care more about future than about present rewards. If this is the case, adding game elements to a cognitive task might be more effective the lower people's trait self-control – a prediction that will be tested in the present research.

1.3. The present research

We conducted two experimental studies and assessed people's performance and subjective experience (i.e., positive affect, motivational conflict, and subjective experience of effort) in a gamified vs. non-gamified n-back task (Jaeggi, Buschkuehl, Perrig, & Meier, 2010). We hypothesized that participants doing the gamified version of the n-back task would perform better (H1) than those doing the non-gamified version and would experience more positive affect, less motivational conflict, and less subjective experience of effort over the course of the task (H2a-c). Further, we hypothesized and tested whether positive affect, motivational conflict, and the subjective experience of effort mediate the positive effects of gamification on task performance (H3a-c). Last, we hypothesized and tested whether people with a low delay of gratification or a low level of trait self-control would benefit more from game elements in terms of increased performance (H4a-b).

1.4. Study 1

To test our hypotheses, we designed a gamified and a non-gamified version of the spatial n-back task (Jaeggi et al., 2010). The task requires participants to constantly update their working memory and was originally developed to train working memory performance, but has also been used in previous research as a measure of self-control or executive functioning (e.g., Miller et al., 2012). The study was approved by the institutional review board.

2. Method

2.1. Design

The study had one between-subjects factor (task version: gamified vs. non-gamified/control). In the *gamified/experimental condition,* participants worked on a gamified version of the spatial 2-back task, which entailed typical game elements (Bedwell et al., 2012), namely immersion (i.e. game-like visual design), game fiction (i.e. game narrative), as well as rules/goals and assessment (i.e. individual score, progress bar, streaks [extra points for 5 correct answers in a row]). In the *non-gamified/control condition,* participants worked on the task in a version that did not include any of these game elements (see Fig. 1).

2.2. Participants

We recruited $N = 190$ participants (147 female, 42 male, 1 na, $M_{age} = 22.47$, $SD_{age} = 2.46$) via the institute's participation tool, which holds mainly Caucasian students from the University of Tübingen. Students with a major in psychology were not invited to participate. Asked about their experience with video games, 9% replied that they game every day, 15% multiple times per week, 23% multiple times per month, 23% multiple times per year, and 30% never game. Participants received 8.00 € (8.93 USD) for participating in a 60-min study.

2.3. Procedure

Upon registration for the study, participants received an automatic email with a link to an online preliminary survey that they were asked to fill in at least 2 days before coming to the lab. This online questionnaire was to measure trait self-control independently of the cognitive task to prevent demand effects. Unfortunately, $n = 44$ (23%) participants did not fill in the online preliminary survey before coming to the laboratory, which is why data on trait self-control is only available for $n = 146$ participants.

Upon arrival in the laboratory, an experimenter welcomed the participants and collected their written informed consent. The rest of the procedure was fully computer-based and participants worked individually in separate cubicles. First, participants worked on a task for another, independent study for about 15 min. We then assessed individual differences in delay of gratification and afterwards the baseline measures for momentary affect and motivational conflict. Next, participants read the instructions of the spatial 2-back task and completed 50 practice trials. During practice, all participants received trial-based

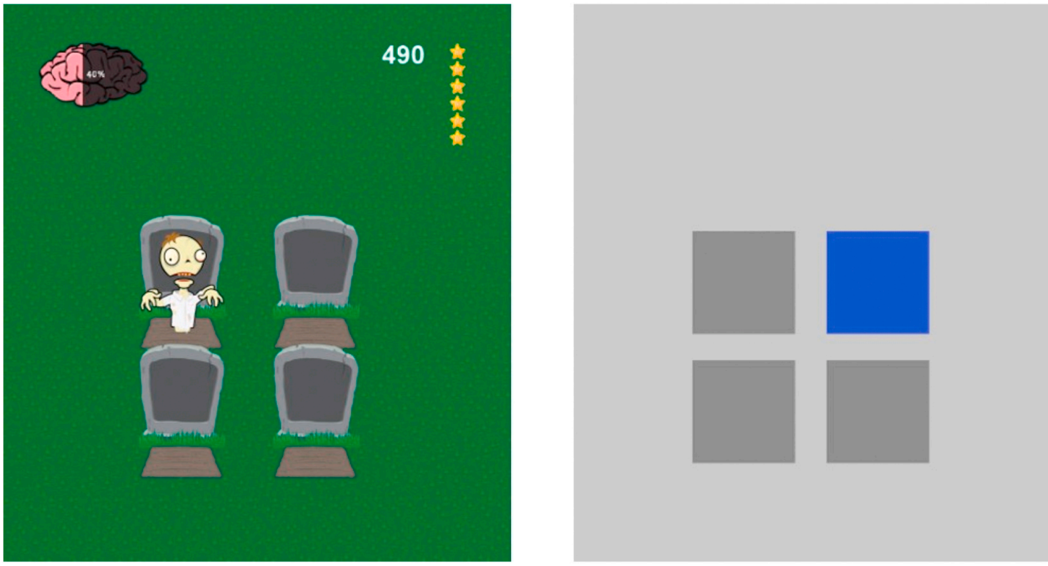

Fig. 1. Design of the gamified/experimental (left) versus non-gamified/control (right) version of the spatial n-back task.

feedback on whether their answer was right or wrong. Participants then completed two blocks, each consisting of 120 trials. During the two blocks of the test phase, participants did not receive trial-based feedback. After each of the two blocks, we assessed positive and negative affect, motivational conflict, and subjective experience of effort. Last, participants answered questions about their user experience during the n-back task, their general experience in gaming, and demographics.

2.4. Measures

2.4.1. Non-gamified 2-back task

The spatial 2-back task was programmed in PsychoPy (Pierce, Jussila, & Cummings, 2009). In each trial, a stimulus (i.e., a blue square) was randomly presented in one of four locations on the screen for 900 ms (see right-hand image of Fig. 1). Each location was assigned to a key (Q, A, P, L, on a QWERTZ keyboard). After presenting the stimulus, participants had 900 ms to indicate the location of the stimulus presented 2 trials prior to the current trial (this means that for the first two trials of each block no location could be indicated). Independently of whether participants pressed a key or not within this time window, the next stimulus would appear after 500 ms. Thus, overall the interval between two stimuli was 1400 ms.

The proportion of *correct responses* relative to the number of responses in each block served as the dependent measure in this study, with higher scores indicating a better performance. This measure was calculated by subtracting the number of incorrect from the number of correct responses and dividing this count by the overall number of valid responses. Since participants could also choose not to respond within a given trial, we also explored how the condition affected the number of *non-responses,* as a measure of task disengagement.

2.4.2. Gamified 2-back task

In the gamified version, the task was introduced as a “game” entitled “Brains vs. Zombies”. The first game element was a game fiction presented prior to the instructions:

> “The cemetery in Tübingen is haunted and zombies appear on every gravestone. The zombies are about to reach the cemetery gate and infiltrate the city. They can only be eliminated with a remote-controlled weapon. In order for the weapon to eliminate the zombies, the exact position of the zombies must be found. The zombies are very fast and only visible for a short moment. Only a brave mastermind like you can save us now. Sneak to the cemetery and report every position of the zombies … You are our last hope.”

The game fiction was followed by the identical instructions as in the non-gamified version, except that immersive game elements were used. That is, the background of each screen showed the graveyard game design as presented in Fig. 1. To enhance the task with further immersive game elements, zombies were presented as stimuli in each trial and four tombstones indicated the possible locations. Rules/goals and assessment were used as additional game elements. In particular, we implemented an *individual score* (raised by 10 points for each correct answer), a *progress bar* (i.e., indicating the progress within each block in the form of a brain that filled up as players progressed) and *streaks* (i.e., players collected a star and 10 extra points, if they gave 5 correct answers in a row).

2.4.3. Positive and negative affect

Although we only entertained hypotheses for positive affect, we also assessed negative affect and are reporting the effects for the sake of transparency. Both types of affect were assessed using the German short version of the Positive and Negative Affect Schedule (PANAS; Krohne, Egloff, Kohlmann, & Tausch, 1996; Watson, Clark, & Tellegen, 1988). The scale consists of 12 items (6 for positive affect [PA], e.g., “active”, “interested”, “excited”, and 6 for negative affect [NA] e.g., “distressed”, “upset”, “irritable”). Participants rated to what extent they felt the way described by each item on a scale from 0 = *not at all* to 100 = *very much* by moving a slider along a continuous horizontal line (PA: $\alpha_{\text{Baseline}} = .69$, $\alpha_{\text{Block1}} = .78$, $\alpha_{\text{Block2}} = .86$; NA: $\alpha_{\text{Baseline}} = .81$, $\alpha_{\text{Block1}} = .79$, $\alpha_{\text{Block2}} = .84$).

2.4.4. Motivational conflict

Motivational conflict was assessed using two items adapted from previous work asking participants, “How strongly do you feel that you would prefer/ought to be doing something else at the moment?” (Grund et al., 2015). Participants rated their agreement with each item on a scale from 0 = *not at all* to 100 = *very much* (Spearman-Brown’s $\rho_{\text{Baseline}} = .55$, $\rho_{\text{Block1}} = .59$, $\rho_{\text{Block2}} = .68$).

2.4.5. Subjective experience of effort

We assessed subjective task effort using three items, by asking participants “How strenuous/difficult/effortful has the task been so far?” (adapted from Job, Dweck, & Walton, 2010). Participants rated their agreement with each item from 0 = *not at all* to 100 = *very much* (α_{Block1}

= .88, α_{Block2} = .90).

2.4.6. Delay of gratification

Delay of gratification was assessed using the German version of the Delay Discounting Task (DDT; Forstmeier, Drobetz, & Maercker, 2011; Richards, Zhang, Mitchell, & de Wit, 1999). The DDT is a measure of people's tendency to prefer smaller, immediate monetary rewards over larger, delayed rewards. To assess this tendency, participants were asked repeatedly to decide between receiving, for instance, 4 € now versus 10 € at a later point in time. The immediate reward varied continuously between 0 and 10 € and the delay of reward varied between 0, 2, 30, 180 and 365 days. We used a random adjustment algorithm to produce discount estimates (i.e., indifference points) for these delays. The indifference point is the value of the immediate reward at which the individual switches from choosing the larger later reward to the smaller immediate reward. From these indifference points, we calculated participants' individual *k* values using the least squares nonlinear regression to fit a curve to the data points (Reed, Kaplan, & Brewer, 2012). The parameter k denotes an individual's degree of temporal discounting (i.e., the steepness of the curve or how rapidly the subjective value drops as a function of the delay). Higher k values (i.e., steeper curves) translate to a lower delay of gratification or higher impulsivity.

2.4.7. Trait self-control

Due to time constraints, trait self-control was assessed using 9 items instead of 13 items from the German version of the Trait Self-Control Scale (Bertrams & Dickhäuser, 2009; Tangney, Baumeister, & Boone, 2004; e.g., "I am good at resisting temptation.", α = .82). Items were rated on a 5-point Likert-type scale (1 = *not at all like me*, 5 = *very much like me*). On the averaged scale, high values represent high levels of trait self-control.

2.5. Results

2.5.1. Descriptive statistics

The descriptive statistics and zero-order correlations are summarized in Table 1 (for a full correlation table of individual measurement points, please see Table S1 in the online supplement). The mean proportion of correct responses was 0.77, which is significantly better than the random level of 0.25, $t(188) = 35.03$, $p < .001$. Further, all mediators were significantly correlated with task accuracy in the predicted direction, which is a necessary precondition for mediation. Delay of gratification was negatively related to task accuracy and positively to task disengagement (i.e., proportion of non-responses), suggesting that higher delay of gratification was associated with better task performance and lower task disengagement. Trait self-control was not associated with the task performance measures.

2.5.2. Task accuracy

We applied a repeated measures ANOVA with the measurement block as a within-subject factor with 3 levels (1 = practice, 2 = block 1, 3 = block 2) and the condition as a between-subjects factor with 2 levels (0 = control, 1 = gamified). The Greenhouse–Geisser adjustment was used to correct for violations of sphericity. The results showed that condition had no significant effect, $F(1,186) = 0.003$, $p = .959$, η_p^2=.000, there was a strong linear trend for measurement block, $F(1.70, 316.99) = 31.27$, $p < .001$, η_p^2=.144, and no interaction between the factors, $F(1.70, 316.99) = 0.05$, $p = .934$, η_p^2=.000. Participants in the gamified condition did not achieve a higher proportion of correct responses. While participants' performance increased from practice to the first and second task block, this positive trend was similar for both conditions.

2.5.3. Task disengagement

We explored whether condition would affect the number of non-responses. We applied a log(y+0.1)-transformation to this measure to correct for its right skewness before running the same repeated measures ANOVA as described above. There was a nonsignificant trend for participants in the gamified condition to commit fewer non-responses, $F(1,187) = 2.65$, $p = .105$, η_p^2=.014, and there was a linear trend of block, $F(1.54, 288.73) = 19.94$, $p < .001$, η_p^2=.100, but no interaction between the factors, $F(1.54, 288.73) = 0.66$, $p = .481$, η_p^2=.004 (see Fig. 2a).

2.5.4. Subjective experience of the task

We tested whether condition affected the subjective experience of the task and also explored whether this effect changed over time. We conducted separate repeated measures ANOVAs for positive and negative affect, motivational conflict, and subjective experience of effort.

For positive affect, there was a significant effect of condition, $F(1,187) = 20.62$, $p < .000$, η_p^2=.100, a significant linear trend of measurement block, $F(1.62, 303.66) = 28.16$, $p < .001$, η_p^2=.131, and the interaction between factors was also significant, $F(1.62, 303.66) = 18.72$, $p < .001$, η_p^2=.091. The effects of condition and measurement point were medium to large in size (Cohen, 1988). For participants in the control condition, positive affect steadily decreased, while participants in the gamified condition remained at baseline levels of positive affect (see Fig. 2b).

For negative affect, condition had no main effect, $F(1,187) = 0.27$, $p = .602$, η_p^2=.001, but measurement block displayed a significant linear trend, $F(1.81, 337.71) = 75.69$, $p < .001$, η_p^2=.288. Further, the interaction between factors was significant, $F(1.81, 337.71) = 3.63$, $p = .032$, η_p^2=.019. After starting out with *more* negative affect before the manipulation (indicating that random group assignment failed to spread negative affect evenly among the groups), participants in the gamified condition experienced *less* negative affect in the last two blocks of the task (see Figure S1 in the online supplement).

For motivational conflict, condition had no effect, $F(1,187) = 0.00$, $p = .986$, η_p^2=.000, measurement block displayed a significant linear trend, $F(1.72, 323.04) = 20.78$, $p < .001$, η_p^2=.100, and the interaction between factors was not significant, $F(1,187) = 0.69$, $p = .480$, η_p^2=.004. Independently of the condition, motivational conflict increased over the

Table 1
Descriptive statistics and zero-order correlations of the main variables in Study 1.

	Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1	Task Accuracy	0.77	0.20								
2	Task Disengagement	0.18	0.17	**-.31**							
3	Positive Affect[a]	41.73	16.88	**.12**	**-.24**						
4	Negative Affect[a]	25.99	16.42	**-.23**	.12	-.01					
5	Motivational Conflict[a]	46.11	25.19	**-.20**	**.22**	**-.19**	**.37**				
6	Subjective Effort[a]	51.45	20.14	**-.24**	.06	-.04	**.45**	**.34**			
7	Delay of Gratification	0.15	1.00	**-.15**	**.22**	.04	-.06	.04	.00		
8	Trait Self-Control	2.92	0.65	-.07	.03	-.05	**-.18**	.06	-.15	.05	
9	Condition[b]	–	–	-.01	-.11	**.37**	-.08	-.06	**-.18**	-.01	.05

Note.
[a] Average for all measurement points excluding baseline measures.
[b] 0 = control condition, 1 = gamified condition. Significant correlations are presented in bold, $p < .05$.

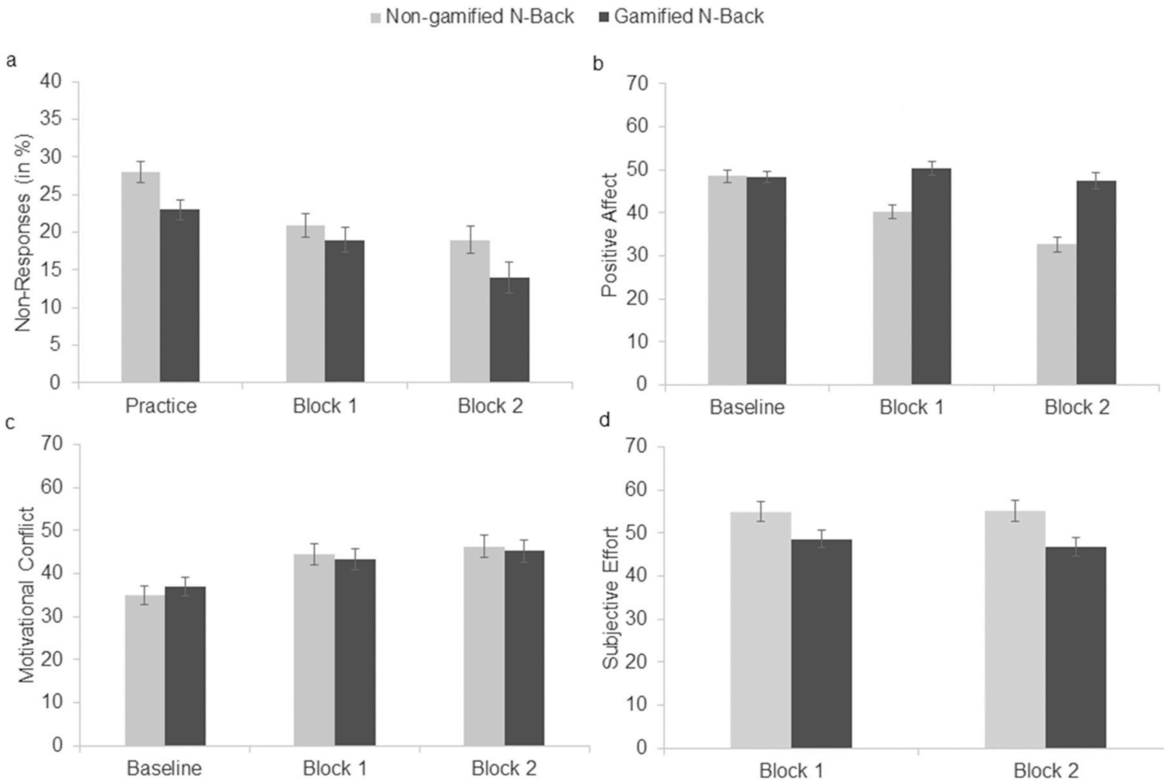

Fig. 2. Non-responses (a), positive affect (b), motivational conflict (c), and subjective effort (d) by measurement point and condition in Study 1. Error bars show ± 1*SE*.

course of the task (see Fig. 2c).

For subjective experience of effort, condition had a significant effect, $F(1,187) = 6.49$, $p = .012$, $\eta_p^2 = .034$, measurement block displayed no linear trend, $F(1,187) = 0.42$, $p = .516$, $\eta_p^2 = .002$, and there was no interaction, $F(1,187) = 0.68$, $p = .412$, $\eta_p^2 = .004$. Participants in the gamified condition experienced the task as being less effortful than participants in the control condition. This effect was stable over the two blocks and small in size (see Fig. 2d).

2.6. Mediation

Although, the condition had no main effect on accuracy and disengagement, we tested whether any of the possible mediators might have an indirect effect on the two outcomes. According to Hayes (2017), mediation can occur in the absence of a significant direct effect, for instance, if a manipulation causes opposing effects on an outcome. Mediation analyses were done with the PROCESS macro in SPSS (Preacher & Hayes, 2004). We specified model 4 and 5000 bootstrap samples to estimate the 95% confidence intervals (CIs) for the indirect effects. The dependent variables were the proportion of correct responses or the proportion of non-responses (log[y+0.1]-transformed to correct for right skewness). The independent variable was the condition (0 = control, 1 = gamified). As mediators, we specified the averaged levels for positive affect, negative affect, motivational conflict, and subjective experience of effort averaged for the first and second block (omitting baseline measurement, because they were assessed before the experimental manipulation). All mediators were entered into the model simultaneously. The results showed that there were two significant, positive indirect effects of gamification on task accuracy, one mediated by positive affect and one by subjective effort (see Table 2). Further, there was a significant negative indirect effect of gamification mediated by positive affect. The direct effects of condition on accuracy and disengagement were (still) not significant when controlling for the mediators, $b = -0.04$, $se = 0.03$, $t = -1.38$, $p = .168$, 95% CI [-0.11; 0.02], and $b = 0.01$, $se = 0.11$, $t = 0.06$, $p = .954$, 95% CI [-0.21; 0.22], respectively. These results suggest that gamification indirectly fosters task accuracy and task engagement via a positive subjective experience of the task.

2.6.1. Individual differences

Last, we tested whether delay of gratification or trait self-control moderated the effect of the condition on accuracy and disengagement.

Table 2
Bootstrapped indirect effects for subjective experience of the task on task accuracy and task disengagement in Study 1.

	Task Accuracy				Task Disengagement			
			95% CI				95% CI	
Variable	Effect	*SE*	lower	upper	Effect	*SE*	lower	upper
Positive affect	0.021	0.011	0.001	0.045	−0.102	0.044	−0.190	−0.017
Negative affect	0.004	0.005	−0.004	0.017	−0.016	0.019	−0.061	0.014
Motivational conflict	0.002	0.004	−0.005	0.012	−0.018	0.023	−0.069	0.023
Subjective effort	0.013	0.008	0.000	0.032	0.005	0.025	−0.036	0.065

Note. Baseline measurements of the mediators were omitted.

We ran two regression models predicting correct responses or number of non-responses (averaged over the two blocks) with condition (0 = control, 1 = gamified), z-standardized scores of trait self-control and *k*-values, and their respective two-way interaction with the condition (Aiken & West, 1991). For task accuracy, neither the main effect of delay of gratification nor its interaction with the condition was significant, *ts* < 1.13, *ns*. Similarly, trait self-control had no main effect and no interaction effect with the condition, *ts* < 1.04, *ns*.

For task disengagement, the main effect of delay of gratification was significant, $\beta = .24$, $b = 0.13$, $SE = 0.05$, $t(182) = 2.53$, $p = .012$, while its interaction with the condition was not, $t(182) = -0.17$, $p = .869$. Independently of the condition, people with a low delay of gratification (higher impulsivity) had more non-responses. Trait self-control did not have a significant main effect on disengagement, $t(182) = 1.56$, $p = .120$, but the interaction with condition was significant, $\beta = -.33$, $b = -0.25$, $SE = 0.09$, $t(182) = -2.70$, $p = .008$. The pattern of the interaction is depicted in Fig. 3. Contrary to our expectations, participants with a high level of trait self-control (i.e., 1 SD above sample average) gave *more* non-responses in the control versus the gamified condition. Participants with low trait self-control (i.e., 1 SD below sample average) showed no difference in disengagement between the conditions.

2.7. Brief discussion

Contrary to our hypothesis, game elements did not directly foster task accuracy, but they did improve people's subjective experience. More specifically, participants working on the gamified n-back reported higher levels of positive affect and experienced the task as being less effortful. Further, mediation analyses suggest that gamification improved task accuracy *indirectly* via positive affect and subjective effort. Last, we found no indication of game elements being more effective for people with low levels of delay of gratification or trait self-control compared with those with high levels. Instead, people with high trait self-control seemed to benefit from game elements and made fewer non-responses in the gamified versus the control condition. These findings add to the previously found 'ironic effects' seen in the measure of trait self-control, which does not seem to capture successful self-control in the 'heat of the moment' (Grund & Carstens, 2019; Imhoff et al., 2013). However, because some participants did not fill in the preliminary survey, we had no data on trait self-control for 44 (23%) participants. Thus, before drawing final conclusions, we set out to replicate these findings in a second study.

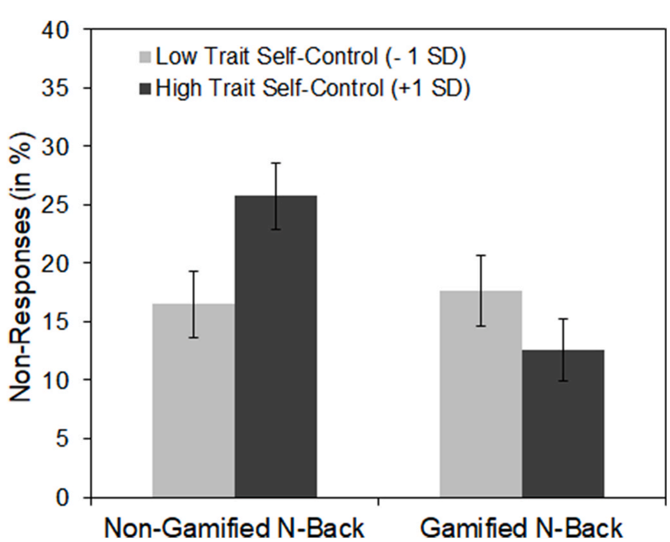

Fig. 3. Predicted number of non-responses by condition and levels of trait self-control.

2.8. Study 2

Study 2 was an almost exact replication of Study 1 and the hypotheses were preregistered on aspredicted.org (https://aspredicted.org/gy5xu.pdf). Based on the findings of Study 1, we expected gamification to have a positive effect on task disengagement but not on accuracy. Second, we expected that gamification would lead to higher positive affect and lower motivational conflict and subjective effort. Further, we hypothesized that these differences in the way the task is experienced would mediate the positive effects of game elements on task disengagement. Finally, we kept the hypothesis that people with low self-control would benefit more from game elements than those with high levels, that is, they would display better task accuracy and less task disengagement in the gamified versus the control condition.

3. Method

In terms of the design and procedure, Study 2 was almost identical to Study 1. For the sake of readability, only changes will be described below.

3.1. Design

As in Study 1, we used a repeated measures design with a between-subjects factor in the form of task version (gamified vs. control).

3.2. Participants and procedure

We preregistered recruiting at least $N = 158$, based on an a-priori power analysis with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to detect a small effect with a power of 1-β = .95 ($\alpha = .05$, $f^2 = .10$). We recruited $N = 183$ participants (73.8% female, $M_{age} = 22.65$, $SD_{age} = 3.46$) via the institute's participant pool. Because it was the same participant pool as in Study 1, we invited only subjects who had not participated in Study 1. In this study, we did not assess video game experience. Participants received €8.00 (8.93 USD) for participating in a 60-min study.

The procedure was identical to Study 1 with the exception that we assessed trait self-control directly in the lab session and not in an online questionnaire, to prevent missing data due to noncompliance.

3.3. Measures and materials

The measures and materials were identical to those in Study 1, except that trait self-control was assessed using the 13 items of the short-version of the Self-Control Scale (Bertrams & Dickhäuser, 2009). The descriptive statistics and zero-order correlations of Study 2 are presented in Table 3 (for a full correlation table of individual measurement points, please see Table S2 in the online supplement). Cronbach's αs for the measures were comparable to those in Study 1, $0.75 < \alpha s < 0.93$. Spearman-Brown's reliability for the two-item measure of motivational conflict was higher than in Study 1 ($\rho_{Baseline} = .64$, $\rho_{Block1} = .75$, $\rho_{Block2} = .77$).

3.4. Results

3.4.1. Task accuracy

We conducted a repeated measures ANOVA with the measurement block as the within-subject factor with 3 levels (1 = practice, 2 = block 1, 3 = block 2) and the condition as the between-subjects factor with 2 levels (0 = control, 1 = gamified). The Greenhouse–Geisser adjustment was used to correct for violations of sphericity. Results showed that there was no significant effect of condition, $F(1,181) = 0.003$, $p = .958$, $\eta_p^2 = .000$, while there was a strong linear trend for block, $F(1.47, 266.15) = 31.83$, $p < .001$, $\eta_p^2 = .150$, and a nonsignificant interaction between the factors, $F(1.47,266.15) = 2.37$, $p = .111$, $\eta_p^2 = .013$. Thus,

Table 3
Descriptive statistics and zero-order correlations of the main variables in Study 2.

	Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1	Task Accuracy	0.80	0.18								
2	Task Disengagement	0.20	0.19	-.09							
3	Positive Affect[a]	46.84	15.05	.14	**-.19**						
4	Negative Affect[a]	20.29	14.30	**-.17**	**.15**	**-.19**					
5	Motivational Conflict[a]	44.58	23.98	-.04	.13	**-.40**	**.42**				
6	Subjective Effort[a]	54.77	20.52	**-.22**	.09	**-.25**	**.55**	**.35**			
7	Delay of Gratification	0.68	8.81	-.02	-.07	.01	.11	.04	.03		
8	Trait Self-Control	3.12	0.57	-.06	.12	**.15**	**-.31**	**-.26**	**-.15**	-.12	
9	Condition[b]	–	–	-.06	**-.16**	**.15**	-.07	**-.15**	**-.31**	**.16**	-.04

Note.
[a] Averaged measures of all measurement points excluding baseline measures. Significant correlations are presented in bold, $p < .05$.
[b] 0 = control condition, 1 = gamified condition.

accuracy improved over the course of the task. Importantly, however, participants in the gamified condition did not achieve a higher accuracy, which replicates our findings from Study 1.

3.4.2. Task disengagement

Next, we tested whether gamification affected the proportion of non-responses given. We corrected the right skewness of the distribution by log(y+0.1)-transforming the measure before running a similar repeated measures ANOVA to that described above. Results showed a significant effect of condition, $F(1,181) = 7.99$, $p = .005$, η_p^2=.042, a linear effect of block, $F(1.63, 294.71) = 24.46$, $p < .001$, η_p^2=.119, but no interaction between the factors, $F(1.63, 294.71) = 0.63$, $p = .504$, η_p^2=.003 (see Fig. 4a). The effect of condition was small to medium in size. Overall, participants in the gamified condition gave fewer non-responses than participants in the control condition.

3.4.3. Subjective experience of the task

We tested whether the condition affected the subjective experience of the task and also explored whether this effect changed over time. We applied repeated measures ANOVAs for each of the outcomes.

For positive affect, a main effect was seen for condition, $F(1,181) = 4.06$, $p = .046$, η_p^2=.022, a significant linear trend for the measurement block, $F(1.54, 274.62) = 11.50$, $p < .001$, η_p^2=.061, and a significant interaction between the factors, $F(1.54, 274.62) = 4.98$, $p = .013$, ^2_p=.027. The effects were all small in size and the pattern was similar to that in Study 1: While positive affect decreased steadily over the course of the task among participants in the control condition, participants in the gamified condition remained at baseline levels (see Fig. 4b).

For negative affect, there was no significant effect of condition, $F(1,178) = 0.87$, $p = .352$, η_p^2=.005, but a significant linear trend for the measurement block, $F(1.74, 309.06) = 86.32$, $p < .001$, η_p^2=.327, and a significant interaction between factors, $F(1.74, 309.06) = 5.66$, $p = .006$, η_p^2=.031. After starting out with more negative affect, participants in the gamified condition experienced less negative affect over the course of the task (see Figure S2).

For motivational conflict, there was a marginal significant effect for

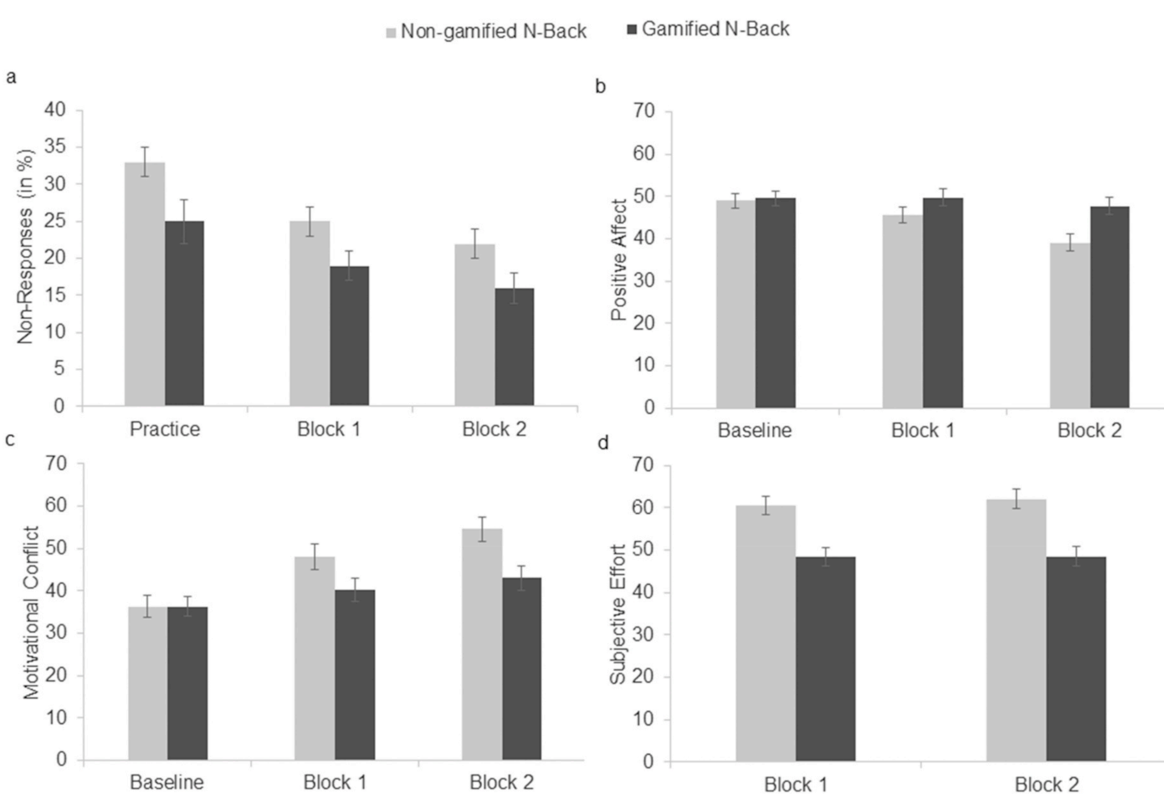

Fig. 4. Non-responses (a), positive affect (b), motivational conflict (c), and subjective effort (d) by measurement point and condition in Study 2. Error bars show ± 1*SE*.

condition, $F(1,181) = 3.20$, $p = .075$, η_p^2=.018, a significant linear trend for the measurement block, $F(1.54, 273.53) = 36.24$, $p < .001$, η_p^2=.169, and the interaction between factors was significant, $F(1.54, 273.53) = 7.89$, $p = .001$, η_p^2=.042. All effects were small in size. While motivational conflict increased over the course of the task for participants in the control condition, participants in the gamified condition only showed little increase over time (see Fig. 4c).

For subjective experience of effort, there was a significant effect for condition, $F(1,178) = 19.18$, $p < .001$, η_p^2=.097, but no trend for the measurement block, $F(1,178) = 0.42$, $p = .517$, η_p^2=.002, and no interaction between factors, $F(1,178) = 0.42$, $p = .519$, η_p^2=.0002. The effect of condition was medium to large in size. Participants in the gamified condition experienced the task as being less effortful and this effect was stable over time (see Fig. 4d).

3.4.4. Mediation

We examined which of these variables could account for the effect of game elements on task disengagement and also tested whether we could replicate the indirect effect on task accuracy. We conducted the same mediation analyses as described in Study 1. The results are summarized in Table 4. We replicated the indirect effect of gamification on task accuracy via subjective effort, whereas the indirect effect via positive affect was not replicated. The direct effect of condition on accuracy was still not significant after controlling for the mediators, b = -.10, se = 0.09, $t = -1.20$, $p = .223$, 95% CI [-0.28; 0.07]. For task disengagement, the indirect effect of gamification via positive affect was replicated. The direct effect of gamification on task disengagement was no longer significant after controlling for the mediators, b = -.04, se = 0.03, $t = -1.67$, $p = .096$, 95% CI [-0.10; 0.01], suggesting mediation.

3.4.5. Individual differences

We tested again whether delay of gratification or trait self-control moderated the effects of the condition on task accuracy and task disengagement in two multiple regression models. The main effects of delay of gratification were not significant in either case, $ts(178) < 0.83$, $ps > .411$, and the expected interaction effects were not significant either, $ts(178) < 0.80$, $ps > .427$. For trait self-control, there was no significant main effect, $ts(178) < 1.22$, $ps > .224$, and neither of the interaction effects were significant either, $ts(178) < |1.56|$, $ps > .120$. Overall, the results did not support the hypothesis that gamification is more effective for people with a low delay of gratification or trait self-control.

3.5. Brief discussion

The findings largely replicate those of Study 1. While gamification did not directly foster task accuracy, it significantly reduced task disengagement. Participants in the gamified condition gave significantly fewer non-responses than participants in the control condition. Further, gamification improved participants' subjective experience of the task. In the gamified version of the task positive affect remained at baseline levels over the course of the task and participants experienced lower levels of motivational conflict and effort. Only positive affect served as a mediator for the effect of gamification on task disengagement. This suggests that the level of positive affect experienced is vital to keep people engaged in cognitive tasks. Further, we replicated the indirect effect of gamification on task accuracy via subjective experience of effort. Finally, our findings did not support the idea that gamification is particularly helpful for people with a low level of self-control.

3.6. General discussion

The present research investigated mechanisms by which game elements affect cognitive tasks from a self-control perspective. The results of two experimental studies (one pre-registered) suggest that integrating game elements into cognitive tasks does not necessarily improve task performance (i.e., accuracy) but instead prevents task disengagement. While the number of correct responses was similar with and without game elements, participants gave fewer non-responses when the task was enriched with game elements. Thus, game elements seem to affect people's motivation to engage in a cognitive task, which may or may not result in improved performance depending on the specific measure of task performance. This may also explain the heterogeneity in the effects of gamification on performance reported in the literature (Lumsden et al., 2017; Lumsden, Edwards, Lawrence, Coyle, & Munafò, 2016; Ninaus et al., 2015).

Further, both studies showed that game elements improve the subjective experience of the task. In both studies, participants in the gamified condition experienced more positive affect, less motivational conflict (the latter was not significant in Study 1), and the task was experienced as less effortful. Positive affect served as a mediator for the effect of gamification on task disengagement, suggesting that lack of positive affect motivates people to disengage from a cognitive task. Further, despite the absence of a direct effect of gamification on task accuracy, we found evidence for an indirect effect via subjective effort in both studies. Gamification lowered the experience of effort, which was in turn negatively related to task accuracy. Finally, we did not find systematic differences in the effectiveness of gamification with regard to individual differences in self-control. People with lower delay of gratification or lower trait self-control did not benefit more from game elements in terms of task accuracy and engagement. Thus, gamification seem to be efficient in reducing task disengagement (directly) and increasing task accuracy (indirectly) independently of individuals' self-control.

3.7. Theoretical contribution to the literature on self-control

Overall, the findings of the present research support the assumptions of the opportunity cost model of task performance and subjective effort (Kurzban et al., 2013). This model makes two main assumptions, both of which were tested in the present studies. First, the model posits that the subjective feeling of effort is the conscious experience of opportunity costs that arise from continuing a given task instead of applying one's cognitive resources to another task (e.g., daydreaming). To test the first assumption of the model, we assessed people's subjective experience of effort and motivational conflict as indicators of opportunity costs (see Rom et al., 2020, Study 2). Supporting the model's assumption, motivational conflict and subjective experience of effort were both lower in

Table 4
Bootstrapped indirect effects of the subjective experience of the task on task accuracy and task disengagement in Study 2.

	Task Accuracy				Task Disengagement			
			95% CI				95% CI	
Variable	Effect	*SE*	lower	upper	Effect	*SE*	lower	upper
Positive affect	0.008	0.008	−0.004	0.027	−0.037	0.023	−0.090	−0.001
Negative affect	0.005	0.006	−0.004	0.019	−0.030	0.024	−0.085	0.006
Motivational conflict	−0.006	0.006	−0.020	0.005	0.005	0.019	−0.032	0.049
Subjective effort	0.023	0.013	0.001	0.051	0.011	0.037	−0.064	0.082

Note. Baseline measurements of the mediators were omitted.

the gamified versus the control condition. Integrating game elements (i.e., immersion, game fiction, rules/goals, and assessment) seems to make a cognitive task more rewarding, resulting in lower perceived opportunity costs.

The second main assumption is that the subjective experience of effort motivates disengagement from a task. Supporting this assumption, motivational conflict and the subjective experience of effort were positively related to task disengagement and negatively related to task accuracy in both studies. However, the correlation with task disengagement were small in size, which also explains why neither worked as a mediator for the effect of game elements on task disengagement. The effects would perhaps have been larger, if people had the chance to actually switch to another task. However, Kurzban et al. (2013) argue that people can always engage in "daydreaming" and, therefore, the model's assumptions should also apply when no alternative activity is offered.

Further, we did not find that game elements were particularly effective for people with a low delay of gratification and low trait self-control. If anything, people with high trait self-control profited more from gamification in Study 1 but not in Study 2. The former finding would be in line with the idea that people with high trait self-control are less well prepared for situations requiring self-control, because they apply strategies to avoid such situations in everyday life (Imhoff et al., 2013). While this argument seems valid for avoiding temptations, it does not seem plausible that people can completely avoid working on unpleasant cognitive tasks in everyday life (e.g., at school, at work). Of course, people with high self-control might reduce the possible distractions and temptations, but this was actually the case in the present study, where participants worked in the controlled setting of a laboratory. Thus, it is not clear why people with high trait self-control did not do better in terms of task accuracy or disengagement in the first place. One reason might be that the 2-back task was too easy, because accuracy was relatively high in both studies, causing ceiling effects. Another reason might be that the n-back task did not require the type of self-control assessed by the Trait Self-Control Scale (Tangney et al., 2004). There is growing evidence to suggest that self-reports of trait self-control do not actually reflect successful self-control in the 'heat of the moment' (Grund & Carstens, 2019; Imhoff et al., 2013; Saunders et al., 2018). Further, more recent measures of self-control discriminate between self-control by inhibition, initiation, and continuation (Hoyle & Davisson, 2016, pp. 396–413). Perhaps, the measure of 'self-control by continuation' would have tapped more closely into the type of self-control required for the n-back task.

Another interesting point to discuss in this regard is the question whether self-control is still needed to perform a gamified task, as people may also engage in it for immediate pleasure. We have argued that game elements add immediate rewards to a cognitive task and thereby motivate people to persist in an otherwise unpleasant cognitive task. This idea is also in line with research showing that persistence in long-term goals is predicted by immediate rewards (e.g., fun of working out) rather than delayed rewards (Woolley & Fishbach, 2016, 2017). But rather than turning a task into a completely hedonic activity, game elements provide additional rewards that should motivate people to apply self-control (see also Dixon & Christoff, 2012). In the end, participants in the gamified condition still had to update and retrieve the content of their working memory, keep their attention on it, resist the urge to daydream, etc. Nevertheless, because many recent models include motivation as a key component of self-control (Inzlicht & Schmeichel, 2012; Kotabe & Hofmann, 2015; Kurzban, Duckworth, Kable, & Myers, 2014), it would be important to define more closely, whether or not the source of control motivation (e.g., immediate rewards/intrinsic, delayed rewards/extrinsic) matters for a behavior to reflect self-control. At a certain point, immediate rewards might change the essence of a task so much that it is not clear whether we are still observing (effortful) self-control or rather a behavior that is in line with some task or goal but is mainly hedonic in nature.

3.8. *Theoretical contribution to the literature on gamification*

In both studies, positive affect mediated the effect of gamification on task disengagement. This finding replicates previous research suggesting that positive affect is a major mechanism by which game elements affect cognitive performance (e.g., Brom et al., 2016; Plass, Heidig, Hayward, Homer, & Um, 2014). Further, it is in line with findings from a recent meta-analysis and a model which proposes "hedonic value" (i.e., users' perception of fun, pleasure, and excitement) and "enjoyment" (i.e., the extent to which the use of the information system is perceived as enjoyable on its own) as two of four mediators for the effects of gamification (Baptista & Oliveira, 2019). In particular, both concepts are in line with the idea that game elements add immediate rewards to tasks that usually only produce rewards in the future. In the present research, we operationalized the presence of such rewards in terms of the general positive affect experienced. Future studies testing the proposed model might assess more specific affective states, such as fun, pleasure, or excitement (Cowen & Keltner, 2017; Weidman & Tracy, 2019).

Going beyond most previous research (for a review see e.g., Mekler, Bopp, Tuch, & Opwis, 2014), the subjective experience of the task was assessed not only before and after but also during the task. This allowed us to explore how levels of positive affect changed over the course of the task. Rather than increasing levels of positive affect, game elements prevented positive affect from decreasing over the course of the task. Game elements changed people's affective experience of the n-back, at least for the duration of 15 min that participants had to work on it. This in turn motivated people to stay engaged in the task. It is very likely that differences in positive affect not only increase engagement in one instance, but may also affect whether people choose to engage in a cognitive task repeatedly (Baptista & Oliveira, 2019). The so-called peak-end rule suggests that in retrospect people systematically overweight the affective states they experience at the end of a given time period (Do, Rupert, & Wolford, 2008; Geng, Chen, Lam, & Zheng, 2013; Kemp, Burt, & Furneaux, 2008). As a result of this bias, people are more likely to reengage in an activity the more positive they felt at the end of that activity (Redelmeier & Kahneman, 1996). Thus, for game elements to work effectively, it should be important not to stretch a single instance of training too long, because even in a gamified task levels of positive affect might eventually drop. In the future, artificial intelligence might help to adjust the duration of a single training session to levels of positive affect or to adapt the training according to participants' needs (e.g. Yannakakis & Togelius, 2011). Facial emotion recognition software seems promising as a continuous and behavioral indicator of positive affect. In fact, recent research suggests that it is possible to use machine learning to discriminate gamified versus non-gamified versions of a cognitive task based on facial emotion recognition data alone (Ninaus et al., 2019).

Another point worth discussing is the absence of a direct effect of gamification on accuracy, despite an indirect effect via subjective experience of effort. One reason for the absence of the direct effect might have been ceiling effects, because accuracy was fairly high in both studies. Apart from this possibility, our findings might also suggest that the benefits of game elements are tied to the specific task and its respective indicator of performance. If the mechanisms by which game elements work are mainly motivational (i.e., increase task engagement; Boyle et al., 2016; Mekler et al., 2017), then game elements should improve performance only for tasks in which higher task engagement results in greater performance (e.g., in longer-term training programs). Further, the presence of a positive indirect effect while the direct effect remains absent could also point to other negative effects of gamification that counteract their positive effects on motivation. For instance, the literature on the seductive details effect argues that illustrations in texts distract learners and harm their performance (Garner, Gillingham, & White, 1989; Sanchez & Wiley, 2006). At the same time, illustrations increase levels of emotional interest (e.g., Harp & Mayer, 1997). The same might be the case for game elements in cognitive tasks. For instance, the participants' gaze might sometimes be drawn to one of the game elements (e.g., the progress bar), giving them less time to observe and encode the position of the next cue. Thus, they might provide an answer but not the correct one. In this respect, future research on gamification should use tasks that allow the motivational and cognitive effects of gamification to be distinguished from each other. This could help to better understand the actual mechanisms by which gamification helps or hinders performance, but also to integrate the heterogeneous effects found in the literature (e.g. Lumsden et al., 2017; Ninaus et al., 2015; for a review see; Lumsden, Edwards, Lawrence, Coyle, & Munafò, 2016).

3.9. Limitations and future directions

A major limitation of the present research is that we examined the combined effect of four popular game elements and compared a version of the task with and without those elements. As a result, we cannot test which specific game element affects people's experience and prevents their disengagement. However, it is reasonable to assume that a coherent integration of several game elements rather than a single game element yields larger effects. Nevertheless, it is possible that simply providing continuous feedback throughout the task alone has profound effects on people's motivation, affect, and their engagement in a task (Carver & Scheier, 1982; Fishbach, Eyal, & Finkelstein, 2010; Fishbach & Finkelstein, 2012). Importantly though, in a similar study, Ninaus et al. (2019) compared emotional engagement between a gamified and non-gamified math task. The authors maintained continuous feedback in both conditions and – similarly to the current results – identified increased emotional engagement when game elements were present. Therefore, the presence or absence of continuous feedback alone cannot account for differences in people's experiences. Future research should disentangle the effects of different game elements and their systematic combination on performance and the subjective experience of the task in greater detail.

A second limitation concerns the use of self-reporting to assess the subjective experience of the task (i.e., positive and negative affect, motivational conflict, subjective experience of effort). As self-reports can be biased, for instance in the form of demand effects, their use is subordinate to behavioral measures. However, we used a between-subjects design, which should preclude demand effects, and administered self-report measures for motivational conflict and subjective experience of effort that had already been used in previous studies (Grund et al., 2015; Job et al., 2010). Nevertheless, before drawing final conclusions, the present findings need to be replicated using behavioral measures of motivational conflict, effort, and affect (e.g., Gendolla & Richter, 2010; Kleiman & Hassin, 2011; Ninaus et al., 2019). The use of cardiovascular measures or pupillometry as objective measures of effort mobilization should be particularly interesting (e.g., Appel et al., 2019), to test whether game elements increase the effort invested by reducing the subjective effort experienced.

Finally, the present findings might be limited in their generalizability to real-world situations, where engagement in a cognitive task is usually tied to personal goals or other delayed rewards. While the present studies allowed a more controlled investigation of the underlying processes of gamification, they need to be replicated in more natural settings. To further increase generalizability, these replications should also involve different and more representative samples.

4. Conclusion

The present research combined research on gamification with recent theorizing in the field of self-control. Its results suggest that game elements have the power to substantially change people's experience of a cognitive task, such as their affective experience, motivational conflict, and subjective experience of effort. By using game elements in cognitive tasks, people can be motivated to stay engaged, thus helping them to earn a greater reward in the future.

CRediT authorship contribution statement

Katharina Bernecker: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing - original draft. **Manuel Ninaus:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing - review & editing.

Declarations of competing interest

none.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2020.106542.

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