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How feedback boosts motivation and play in a brain-training game

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ABSTRACT

Games are important vehicles for learning and behavior change as long as players are motivated to continue playing. We study the impact of verbal feedback in stimulating player motivation and future play in a brain-training game. We conducted a 2 (feedback valence: positive vs. negative) × 3 (feedback type: descriptive, comparative, evaluative) between-subjects experiment (N = 157, 69.4% female, M_{age} = 32.07). After playing a brain-training game and receiving feedback, we tapped players' need satisfaction, motivation and intention to play the game again. Results demonstrate that evaluative feedback increases, while comparative feedback decreases future game play. Furthermore, negative feedback decreases players' feeling of competence, but also increases immediate game play. Positive feedback, in contrast, satisfies competence and autonomy needs, thereby boosting intrinsic motivation. Negative feedback thus motivates players to repair poor short-term performances, while positive feedback is more powerful in fostering long-term motivation and play.

1. Introduction

Games are an increasingly important mechanism for educational and behavior-change interventions due to their ability to keep players motivated to play (Baranowski, Buday, Thompson, & Baranowski, 2008; Erhel & Jamet, 2013). However, the mechanisms by which games motivate players to persist in game play are still unclear. While several models of game motivation have been developed, most are typologies of uses and gratifications derived from games (Lucas & Sherry, 2004) common player types (Yee, 2006) or based in usability studies from HCI or persuasive technology (Fogg, 2007). Recently, psychological theories which can explicate motivational processes in other areas of life have been applied successfully to understand how and why people continue playing entertainment games. Namely, Self Determination Theory (SDT) has been used to explicate game enjoyment, desire to play, and role of games in changing player behavior beyond the game world (cf. Przybylski, Rigby, & Ryan, 2010; Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). According to SDT, the intrinsic appeal of games is due to their ability to satisfy basic psychological needs for competence, autonomy, and relatedness (Ryan, Rigby, & Przybylski, 2006).

Yet, two challenges still remain in terms of using SDT to understand the motivation to play educational or behavior-change type games. First, although intrinsic motivation is central to games for entertainment, the effects of intrinsic motivation on continued play in education and behavior change games is still not well understood. Second, the particular game elements of educational games which satisfy these basic psychological needs have only begun to be explored (Peng, Lin, Pfeiffer, & Winn, 2012). One element in particular which is critical to education and behavior-change games is feedback, such as verbal or non-verbal messages delivered in-game (Lester, Stone, Converse, Kahler, & Barlow, 1997). The current study, therefore, tests the role of feedback in an educational brain-training game on intrinsic motivation to continue playing, enjoyment of the game, and attitude towards the agent.

Feedback can have differential effects in terms of motivating behaviors, and results testing the effects of feedback in games on motivation have been inconclusive (Lin, Atkinson, Christopherson, Joseph, & Harrison, 2013). After all, feedback can have disparate effects on motivation based on how it is delivered, how the recipient interprets the feedback, and how the behavior is related to the feedback. In the health-behavior domain, *Feedback Intervention Theory* (FIT, Kluger & DeNisi, 1996) has been used to account for these differential effects. Feedback can compare, evaluate, or simply describe performance. These three types of feedback have very

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distinct effects on performance and motivation for health behaviors (cf. Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008). To the best of our knowledge, these questions have not yet been explored in the context of educational games.

The current study thus extends the literature on educational and behavior-change games in three ways: by (1) using FIT to understand specific effects of different types of feedback on persistence and motivation within a game environment, (2) by examining the role of FIT in terms of satisfying basic psychological needs in games and (3) by further unraveling the relationship between basic game and motivational processes.

1.1. Games and motivation

Although various scholars have focused on the ways in which games *can* be used as persuasive behavior-change tools (Baranowski et al., 2008; Peng, Crouse, & Lin, 2013), little research has focused on the how the elements which make games so compelling to play motivate players. The research which does exist has focused on games' ability to induce *intrinsic motivation*, or the motivation to pursue an activity for its own sake (Przybylski et al., 2010; Ryan et al., 2006; Tamborini, Bowman, Eden, Grizzard, & Organ, 2010).

The most comprehensive theory of intrinsic motivation is SDT (Deci & Ryan, 1985, 2000). SDT is a theory of human motivation that posits that individuals are motivated to pursue activities which provide a sense of pleasure and satisfaction even when no external rewards, such as money, are present (Deci & Ryan, 1985). A sub-theory of SDT, called *Cognitive Evaluation Theory* (CET), suggests that this type of intrinsic motivation arises particularly from the satisfaction of psychological needs for autonomy and competence (Ryan & Deci, 2000). The need for autonomy involves the ability to choose for oneself to engage in an activity. Opportunities for choice, use of rewards as informational feedback (rather than to control behavior), and non-controlling instructions have all been shown to enhance autonomy and in turn intrinsic motivation. The need for competence is defined as an individual's inherent desire to feel effective in interacting with the environment (Deci & Ryan, 2000). It is prominent in individuals' propensity to explore and manipulate the environment and to actively seek challenges to extend one's skills.

CET has been applied to explain motivation to play different types of games such as entertainment games (Ryan et al., 2006, Przybylski et al., 2010; Tamborini, Grizzard, Bowman, Reinecke, Lewis, & Eden, 2011) and serious games (Peng et al., 2012). Most research in this area has focused on how particular game mechanics may satisfy psychological needs. For example, Ryan et al. (2006) and Tamborini et al. (2011) focused on how games satisfy basic psychological needs for competence and autonomy via manipulations of difficulty and interface controls, leading to greater intrinsic motivation and affective rewards (e.g., enjoyment) within the game setting. In line with this past research, we predict that:

H1. The extent to which needs for competence and autonomy are satisfied in the game positively predicts intrinsic motivation to play the game, both immediately and in the future.

1.2. Feedback and motivation

Often, game elements are not easy to manipulate or change for the researcher or game designer. One element that may be particularly easy to adapt, and have a significant effect on motivation, is feedback. In computerized learning environments, feedback can be as simple as a confirmation of a correct response (simple feedback) or as difficult as including a lengthy explanation of a recommendation (elaborate feedback). Elaborate feedback produces larger effects on learning behavior and motivation compared to simple feedback, however, this depends on the learner's attention and ability to correct their action (e.g., Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Serge, Priest, Durlach, & Johnson, 2013). Some studies revealed that spoken explanatory feedback (i.e., elaborate feedback) provided by agents to guide learners to deeper learning promoted learning more effectively than simple corrective feedback (Moreno, 2004). For written verbal feedback, in contrast, no differences between simple and elaborate feedback were found on user motivation or behavior (Lin et al., 2013).

Studies from the field of health psychology demonstrated that verbal feedback can be linguistically formulated in different ways, and that these differential formulations can be important determinants of feedback performance in health interventions (e.g., Hawkins et al., 2008; Kluger & DeNisi, 1996; Van-Dijk & Kluger, 2004). Kluger and DeNisi (1996) proposed an overarching theory (FIT) to account for the most important differences in feedback effects. FIT proposes that receivers of feedback typically decide to adjust their behavior (or not) by comparing it to a standard or a goal. If a behavior does not match this standard or goal, addressees may decide to adjust their behavior, as long as they are aware of the gap between their actual behavior and their goal or standard. Negative feedback (e.g., *you did poorly*) is thus most effective under a learning goal when addressees aim to increase their performance (Cianci, Klein, & Seijts, 2010) and in situations that are negatively motivated (e.g., failure to meet obligations; Van-Dijk & Kluger, 2004). Under this perspective, negative feedback may be more persuasive than positive feedback (e.g., *you did well*), because negative feedback emphasizes the gap between the desired goal and the actual behavior.

However, positive feedback could also have positive effects on behavior, through need satisfaction and motivation. FIT proposes that goals are organized hierarchically into task-learning goals, task-motivation goals and meta-task processes. As attention is limited, most addressees pay attention to moderate levels of goals (i.e., task motivation; Kluger & DeNisi, 1996). Thus, positive feedback may be more persuasive than negative feedback, because the former provides an affirmation of competence in respondents (Cusella, 1982; Henderlong & Lepper, 2002). Furthermore, a recent addition to FIT also states that control over feedback (i.e., autonomy) is an important predictor of feedback effectiveness (Alder, 2007). Receiving positive (vs. negative) feedback can motivate addressees to voluntarily set higher goals for their tasks, and thereby increasing performance (Krenn, Würth, & Hergovich, 2013; Mumm & Mutlu, 2011). This indicates that positive (vs. negative) feedback could also satisfy a feeling of autonomy in recipients. Furthermore, participants who receive positive feedback during a learning task also complete that task faster than (and at the same level of accuracy as) participants who received negative feedback (Barrow, Mitrovic, Ohlsson, & Grimley, 2008).

Therefore, under these conditions, we predict that written positive feedback in a game may increase feelings of competence and autonomy compared to written negative feedback. This increase in need satisfaction should in turn lead to increased motivation to play the game. This reasoning leads to our next hypothesis:

H2. Positive feedback will positively affect need satisfaction and intrinsic motivation, compared to negative feedback.

Next to differences in valence, the feedback literature also distinguishes different types of feedback types. Three different feedback types are typically identified: (1) Descriptive feedback, which reports back to individuals summing up their attitudes or behavior, either based on participants own input (e.g., *you say that you don't like serious games*) or based on observational data (e.g., *you completed level 1 in less than five minutes*), (2) Comparative feedback, which provides social comparison information by comparing the performance to those of others (e.g., *you completed level 1 faster than anyone*) and (3) Evaluative feedback, which adds a level of judgment to an individual's performance (e.g., *you did well to complete level 1*; Hawkins et al., 2008). Various studies show differential effects of these three feedback types. For example, descriptive feedback (vs. no feedback) can lead to such positive outcomes as a reduction in energy use (Grønhøj & Thøgersen, 2011), a reduction in alcohol consumption (McCambridge et al., 2013) or an increase in recycling behavior (Schultz, 1999). Similarly, comparative feedback (Mumm & Mutlu, 2011; Nomura, John, & Cotterill, 2011) and evaluative feedback (Khemlani & Moore, 2012; Schultz, 1999) can also positively affect pro-social behavior. While these feedback types individually can thus all lead to positive effects (but not always, cf. Moreira, Oskrochi, & Foxcroft, 2012 for an exception), results of studies that compare the three feedback types are mixed.

For instance, Siero, Bakker, Dekker, and van den Burg (1996) show that comparative feedback is generally more persuasive than descriptive feedback. In contrast, other scholars argue that comparative feedback is only more persuasive only under certain conditions (e.g., Lipkus & Klein, 2006): Comparative feedback was more effective than descriptive feedback under negative framing (when the target person was more at risk than average), but equally effective as descriptive feedback under positive framing (when the target person was less at risk than average).

Similarly, evaluative feedback is seen as more persuasive than descriptive feedback: evaluative feedback that clearly states both the evaluation (e.g., *you did well*) and the evaluated behavior (e.g., *you completed level 1*) was more effective in improving task performance than evaluative feedback that included only the evaluation or descriptive feedback that only reinforced the behavior (Johnson, 2013). Finally, the formulation of the feedback can influence its persuasiveness. Comparative feedback, for instance, was found to be most persuasive when it was a bit vague about the comparison (e.g., by saying that somebody scored higher/lower than average) than when factual information about this average was present (Zell & Alicke, 2013). Evaluative feedback, in turn, was most effective when it referred to both the evaluation and the evaluated behavior (Johnson, 2013).

Such differences between feedback types may also be explained by the fact that the different feedback types provide differential information which may satisfy different needs. Following predictions from CET, it may be expected that evaluative feedback may be most effective in satisfying both autonomy and competence needs as it directly pinpoints if a task has been completed satisfactorily (e.g., Henderlong & Lepper, 2002; Johnson, 2013). Second, we may expect that comparative feedback may also be better at satisfying competence needs than descriptive feedback given the assessment of skill entailed. Due to the use of a comparative measure, comparative feedback may be less able to satisfy autonomy needs than evaluative feedback (e.g., Lipkus & Klein, 2006; Siero et al., 1996). Thus, we expect that:

H3a. Evaluative feedback, compared to comparative and descriptive feedback will increase perceived competence, which will in turn increase intrinsic motivation.

H3b. Comparative feedback, will increase intrinsic motivation over descriptive feedback.

Finally, some studies demonstrate that the effectiveness of one feedback type over another may depend on the valence of the feedback (e.g., Lipkus & Klein, 2006). Thus, as an exploratory question we ask:

RQ1. To which degree do feedback valence and type interact in determining intrinsic motivation and desire to play?

2. Method

2.1. Participants and design

A total of 157 respondents participated in this online experiment with a 2 (feedback valence: negative vs. positive) × 3 (type of feedback: descriptive, comparative, evaluative) between-subjects experimental design. Participants were recruited via different social media (e.g., *Facebook*, *LinkedIn*) and did not receive financial compensation for participation. The average age of participants was 32.07 years (SD = 14.03). Of all participants, 109 were female (69.4%) and 48 were male (30.6%). Most participants were highly educated (75.2%). Randomization checks show that randomization of participants was successful, as no differences were observed in age ($F(5, 151) < 1$), gender ($\chi^2(5) = 8.94$, $p = .11$) or education level ($\chi^2(10) = 8.65$, $p = .57$) between experimental conditions.

2.2. Materials

2.2.1. Game

After clicking on a link and filling out some demographic information, respondents were told they would play a brain-training game. Before they started playing, the game was introduced by a static virtual agent who informed respondents that, for optimal brain training, they had to complete the game as fast as possible. After the introduction, respondents played an online version of the game *Concentration*, a game that is good at testing and improving visuospatial memory (Schumann-Hengsteler, 1996). In our version of *Concentration,* participants had to match ten picture pairs. If participants made a mistake, the two cards were flipped back over again, without any verbal feedback. An invisible timer recorded respondents' time of play. After excluding two outliers (z-scores > 3), an average game of *Concentration* lasted 98.57s (SD = 35.56). However, as delivered feedback was false feedback independent of performance, these two participants remained in the dataset.

A game consisted of a single cycle of ten picture pairs to match. When respondents completed the game, the same virtual agent who introduced the game gave feedback on their performance. To control for agent effects, all participants received feedback from the same agent: a static cartoon-like green owl named Sam who gave feedback within a text bubble. The agent's gender and name were ambiguous, leaving participants free to imagine whether the agent was male or female.

2.2.2. Feedback

In the condition with descriptive feedback, respondents were informed they completed the game either faster (positive feedback condition) or slower (negative feedback condition) than the optimal time. In the condition with evaluative feedback, respondents were told that their completion time was either excellent (positive feedback) or poor (negative feedback). In the condition with comparative feedback, respondents' completion time was compared to peers in their age group, and respondents were informed that they either performed faster (positive feedback) or slower (negative feedback) than the average time for their age group. To increase the relevance of the feedback to participants (Midden, Meter, Weenig, & Zieverink, 1983), all messages were personalized by either referring to the respondents' time of play (descriptive, evaluative feedback) or their age group (comparative feedback). Table 1 gives an overview of the feedback in the various experimental conditions.

Table 1
Overview of feedback manipulations in the different experimental conditions.

Type of feedback	Negative feedback	Positive feedback
Descriptive	You train your memory optimally if you complete the game in [RECORDED TIME − 20] seconds. You did not achieve this	You train your memory optimally if you complete the game in [RECORDED TIME + 5] seconds. You achieved this
Comparative	You completed the game in a time that is above the average of people in your age group of [AGE GROUP OF PARTICIPANT]	You completed the game in a time that is below the average of people in your age group of [AGE GROUP OF PARTICIPANT]
Evaluative	Poorly done! You completed the game rather slowly, in [RECORDED TIME − 15] seconds. Try to be faster next time!	Well done! You completed the game rather quickly, in [RECORDED TIME − 15] seconds. Keep it up!

Note: The recorded time includes 15s to load the game. The age groups included in the condition with comparative feedback were 17 years and younger, 18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, and 65+ years.

2.3. Measures

We designed a questionnaire to measure participants' *game behavior*, *need satisfaction*, *intrinsic* and *extrinsic motivation*, the *attitude towards the feedback* and *agent perceptions*. Directly after playing *Concentration*, participants were asked if they immediately wanted to play the game again (*immediate game behavior*, yes or no) and if they were willing to play the game again in the coming week (*future game behavior*, yes or no). A total of 38.2% of participants were willing to immediately play again and 42.0% of participants were willing to play in the coming week. Participants indicating that they immediately wanted to play again also actually played the game a second time.

All other items were measured on 7-point Likert type scales, ranging from 1 = *completely disagree* to 7 = *completely agree.* To measure *need satisfaction*, we tapped both *perceived autonomy* and *perceived competence*. *Perceived autonomy* was measured with a 5-item scale based on Ryan et al. (2006). Sample items include "I did things in the brain-training game because they interested me" and "The brain-training game gave me interesting options and choices" ($\alpha = .71$, $M = 3.39$, $SD = 1.06$). *Perceived competence* was tapped with a 5-item scale based on Vos, van der Meijden, and Denessen (2011). Sample items include "I think I am pretty good at the brain-training game" and "I am satisfied with my performance in the brain-training game" ($\alpha = .96$, $M = 4.45$, $SD = 1.38$).

As measures of *intrinsic motivation*, we used a 5-item scale based on Vos et al. (2011). Sample items include "I would want to play the brain-training game again, because I think it is quite enjoyable" and "I would want to play the brain-training game again, because I think it is interesting" ($\alpha = .92$, $M = 3.81$, $SD = 1.52$).

We also included a number of control variables. First, we wanted to control for the effects of extrinsic motivation. While it is true that games are most attractive for behavior change interventions due to their ability to induce intrinsic motivation, we felt that verbal feedback or rewards in game may also be perceived as extrinsically motivating. As Deci, Koestner, and Ryan (1999) suggest that perception of rewards as extrinsic may decrease the internal motivation to play games, we controlled for these effects by measuring three different types of extrinsic motivation: *identification*, *introjection* and *external motivation* (Guay, Vallerand, & Blanchard, 2000). The variable of *identification* was measured with four items such as "I would want to play the brain-training game again, because training my memory is important to me" and "I would want to play the brain-training game again, because training my memory is good for me" (Guay et al., 2000; $\alpha = .92$, $M = 4.26$, $SD = 1.59$). *Introjection* was tapped with four items like "I would want to play the brain-training game again to prove myself I am capable of improving my memory" and "I would want to play the brain-training game again to prove myself I am an intelligent person" (Vallerand, Blais, Briere, & Pelletier, 1989; $\alpha = .90$, $M = 3.89$, $SD = 1.55$). *External motivation* was measured with two items such as "I would want to play the brain-training game again to prevent my memory from deteriorating later" (Ryan & Connell, 1989; $\alpha = .70$, $M = 3.25$, $SD = 1.53$).

Second, we wanted to control for possible differences in liking of the different feedback types and valence by measuring *attitude towards the feedback* on a 5-item scale. Participants were for instance asked whether they thought the feedback was reliable and unclear (reverse-coded; sampled from Bruner, 1998, $\alpha = .66$, $M = 4.11$, $SD = 1.01$).

Finally, we wanted to control for differential perceptions of the agent. To measure these *agent perceptions*, we used the procedure and items by Nowak and Rauh (2008), who identify three dimensions of agent perceptions: *Credibility, anthropomorphism* and *androgyny*. *Agent credibility* was measured with three items asking participants to assess whether they thought the agent seemed intelligent, well informed, and reliable ($\alpha = .88$, $M = 4.10$, $SD = 1.41$). *Anthropomorphism* was tapped with three items asking participants to indicate whether the agent seemed human, realistic and cartoon-like (reverse-coded). Because of low inter-item correlations, the final item was dropped, leaving the first two items ($\alpha = .83$, $M = 2.39$, $SD = 1.22$). *Androgyny*, finally, was asked by two items asking participants to assess whether the agent seemed masculine and feminine. In line with Nowak and Rauh (2008), we subsequently calculated the absolute difference between these two items, with a low score indicating high androgyny (i.e., the agent seemed equally masculine and feminine, $M = 2.03$, $SD = 2.04$).

3. Results

3.1. Control analysis

To make sure that the different types of feedback did not influence agent perception, we first ran a 2 (feedback valence: negative vs. positive) × 3 (type of feedback: descriptive, comparative, evaluative) MANOVA with agent credibility, anthropomorphism and androgyny as dependent variables. This analysis showed no main effects of feedback valence (Wilks' $\lambda = .98$, $F(3, 149) = 1.16$, $p = .33$), feedback type (Wilks' $\lambda = .97$, $F(6, 298) < 1$) as well no interaction of feedback valence * type on agent perceptions (Wilks' $\lambda = .93$, $F(6, 298) < 1$). This means the type of feedback did not influence agent perceptions (cf. Table 2 for descriptive statistics).

3.2. Effects of feedback valence and type on attitude towards the feedback

To check how the different feedback types and valence were liked, we ran a 2 (feedback valence: negative vs. positive) × 3 (type of feedback: descriptive, comparative, evaluative) ANOVA with attitude towards the feedback as the dependent variable. This analysis showed no main effects of feedback type ($F(2, 151) = 1.75$, $p = .18$) as well no interaction of feedback valence * type ($F(2, 151) = 1.68$, $p = .19$). We did find a main effect of feedback

Table 2
Means (and standard deviations) of dependent variables by condition.

	Negative feedback			Positive feedback		
	Descriptive	Comparative	Evaluative	Descriptive	Comparative	Evaluative
Agent credibility	4.10 (1.45)	3.87 (1.50)	3.91 (1.31)	3.89 (1.40)	4.07 (1.54)	4.81 (1.11)
Anthropomorphism	2.30 (1.23)	2.29 (1.27)	2.13 (.95)	2.44 (1.08)	2.62 (1.42)	2.56 (1.37)
Agent androgyny	1.96 (2.07)	1.54 (2.02)	2.30 (2.02)	2.00 (2.13)	2.16 (1.97)	2.24 (2.15)
Attitude feedback	3.93 (.95)	3.80 (1.14)	3.89 (.90)	4.10 (1.03)	4.22 (.95)	4.75 (.85)
Perceived competence	3.84 (1.23)	4.06 (1.35)	4.03 (1.36)	4.95 (1.27)	5.08 (1.06)	4.81 (1.51)
Perceived autonomy	3.04 (.86)	3.38 (1.18)	3.09 (.92)	3.39 (.85)	3.94 (1.22)	3.55 (1.15)
Intrinsic motivation	3.72 (1.51)	3.85 (1.56)	3.62 (1.41)	3.67 (1.47)	4.15 (1.54)	3.87 (1.73)
Identification	4.05 (1.61)	4.43 (1.38)	4.23 (1.68)	4.08 (1.48)	4.27 (1.68)	4.53 (1.81)
Introjection	4.23 (1.47)	3.88 (1.58)	4.04 (1.35)	3.68 (1.63)	3.68 (1.66)	3.85 (1.70)
External motivation	3.37 (1.52)	3.06 (1.71)	3.48 (1.38)	3.06 (1.41)	3.36 (1.70)	3.16 (1.58)
Immediate behavior	.59 (.50)	.35 (.49)	.59 (.50)	.11 (.32)	.20 (.41)	.44 (.51)
Future behavior	.30 (.46)	.31 (.47)	.48 (.51)	.33 (.48)	.56 (.51)	.56 (.51)

Note: Agent androgyny was measured such that higher scores meant less androgynous.
With the exception of immediate and future behavior, all scores were measured on 7-point Likert scales. Immediate and future behavior were measured as dichotomous variables (0 = will not play again, 1 = will play again).

valence on attitude towards the feedback ($F(1, 151) = 9.74$, $p < .01$, $\eta_p^2 = .06$), which showed that participants appreciated positive feedback more than negative feedback.

3.3. Effects of feedback valence and type on need satisfaction and motivation

We ran a 2 (feedback valence: negative vs. positive) × 3 (type of feedback: descriptive, comparative, evaluative) MANOVA with the two need-satisfaction variables (perceived competence, perceived autonomy), intrinsic motivation, and the three extrinsic motivation variables (identification, introjections, external motivation) as dependent variables. This analysis showed no main effect of feedback type (Wilks' $\lambda = .92$, $F(12, 292) = 1.07$, $p = .39$) as well no interaction of feedback valence ∗ type (Wilks' $\lambda = .96$, $F(12, 292) < 1$). We did find a multivariate main effect of feedback valence (Wilks' $\lambda = .78$, $F(6, 146) = 7.01$, $p < .001$, $\eta_p^2 = .22$). Univariate analyses showed that feedback valence affected perceived competence ($F(1, 151) = 21.66$, $p < .001$, $\eta_p^2 = .13$) and autonomy ($F(1, 151) = 7.60$, $p < .01$, $\eta_p^2 = .05$), in that participants who received positive feedback perceived themselves as more competent and autonomous than participants who received negative feedback. All other analyses were non-significant.

Next, we wanted to investigate whether these effects of feedback valence transferred to intrinsic motivation via perceived competence and autonomy. In other words, we wanted to test for a causal sequence in which feedback valence impacts both perceived competence and autonomy, which in turn impacts intrinsic motivation (cf. Hayes, 2013 for a detailed explanation of this type of mediation analysis). We conducted a mediation analysis with multiple mediators using the PROCESS macro by Hayes (2013, model 4, 10,000 bootstrap samples, see Fig. 1 for descriptive statistics). This analysis shows significant indirect effects of feedback valence via both perceived competence ($b = .19$, 95%CI = [.03, .41]) and perceived autonomy ($b = .34$, 95%CI = [.10, .34]). This means that positive feedback increases both perceived competence and perceived autonomy, and that perceived competence and autonomy, in turn, increase intrinsic motivation.

3.4. Predicting game behavior

Subsequently, we conducted logistic regression analyses to investigate whether immediate and future game behavior (0 = does not play the game again, 1 = does play the game again) were predicted by feedback valence and type, agent perceptions, attitude towards the feedback and need satisfaction and motivation. In the first step, we included the demographic variables of age and gender. Subsequently, we included feedback valence and type. In the third step, we included the interaction of feedback valence ∗ type. The fourth and fifth steps saw the inclusion of agent perceptions and attitude towards the feedback. In the sixth and seventh steps, we included need-satisfaction and motivation variables, respectively (cf. Tables 3 and 4 for results).

Most importantly, the results show that feedback is an important predictor of game behavior. Both analyses show a positive effect of attitude towards the feedback, in that participant who appreciate the feedback are more likely to play the game again both immediately and in the near future. Furthermore, feedback

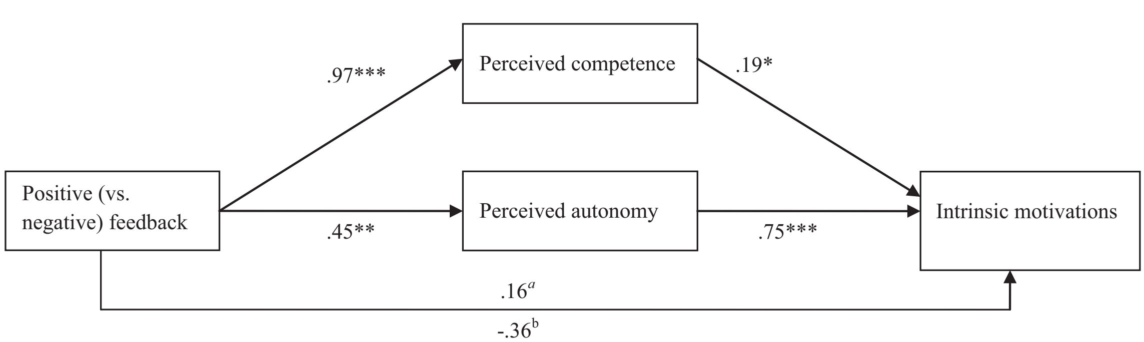

Fig. 1. Multiple mediator model with the perceived competence and autonomy as hypothesized mediators of the feedback valence on intrinsic motivations. Path values represent unstandardized regression coefficients. Dummy variables related to the main effects of feedback type are included as covariates (paths not shown). [a]Regression of feedback valence on intrinsic motivation when mediators are not entered. [b]Regression of feedback valence on intrinsic motivation when mediators are entered. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 3
Logistic regression model of *B* value and 95% CI of immediately playing the game again.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	B	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI
Gender	−.46	−1.31, .29	−.58	−1.55, .27	−.72	−1.78, .15	−.73	−1.95, .23	−.75	−2.03, .19	−.82•	−2.19, .10	−1.00•	−3.24, .14
Age	−.02	−.04, .01	−.02	−.05, .01	−.02	−.05, .01	−.01	−.05, .02	−.02	−.05, .02	−.03	−.07, .01	−.01	−.07, .04
Feedback valence			−1.30**	−2.20, −.60	−2.58**	−21.64, −1.13	−2.64***	−21.76, −1.33	−2.93***	−22.09, −1.61	−3.35***	−22.70, −2.00	−3.46***	−23.41, −1.94
Feedback type														
Comparative			−.44	−1.45, .46	−1.03•	−2.46, .12	−1.04	−2.68, .20	−1.10•	−2.92, .17	−1.53•	−3.72, −.23	−1.69*	−4.94, −.24
Evaluative			.68	−.17, 1.59	−.13	−1.44, 1.10	−.05	−1.44, 1.29	−.06	−2.57, 1.38	−.12	−1.92, 1.55	.24	−1.98, 2.86
Feedback valence * type:														
Positive comparative					1.63•	−.50, 20.60	1.62•	−.57, 20.49	1.67•	−.55, 20.55	1.57	−.82, 20.48	1.78	−.92, 21.16
Positive evaluative					1.95*	.14, 20.94	1.69•	−.24, 20.63	1.60	−.46, 20.54	1.90•	−.27, 20.97	1.92	−.83, 21.46
Agent credibility							.29•	−.04, .72	.07	−.35, .49	.002	−.54, .50	.01	−67, .76
Anthropomorphism							.13	−.24, .54	.11	−.27, .55	−.11	−.72, .42	−.17	−1.24, .50
Agent androgyny							−.06	−.31, .17	−.09	−.39, .16	−.03	−.36, .25	−.11	−.62, .23
Attitude feedback									.64*	.09, 1.43	.42	−.14, 1.28	.58	−.14, 2.07
Perceived competence											−.06	−.49, .40	−.32	−1.18, .23
Perceived autonomy											.93**	.48, 1.84	.69•	−.09, 2.09
Intrinsic motivation													.77***	.51, 1.99
Identification													−.08	−.85, .58
Introjection													.27	−.27, 1.21
External motivation													−.37	−1.31, .13
−2 log likelihood	204.25		184.20		179.27		173.09		166.49		150.71		129.63	
Cox & Snell R^2	.029		.145		.172		.204		.236		.309		.396	
Nagelkerke R^2	.039		.197		.233		.277		.321		.421		.539	
Model Chi Square	4.60		24.64		29.57		35.76		42.35		58.14		79.22	
Degrees of freedom	2		5		7		10		11		13		17	

95%CI = 95% Confidence Interval of *B* value, based on 5000 bootstrap samples.
• $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 4
Logistic regression model of *B* value and 95%CI of playing the game in the coming week.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
	B	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI	*B*	95%CI
Gender	−.22	−1.02, .52	−.08	−.90, .73	−.05	−.90, .77	−.11	−1.02, .77	−.16	−1.10, .75	−.16	−1.19, .86	.25	−1.00, 2.07
Age	.029*	.01, .06	.030*	.01, .06	.03*	.01, .06	.04*	.01, .07	.04*	.01, .07	.03*	.00, .07	.04*	.01, .11
Feedback valence			.50	−.18, 1.26	−.06	−1.48, 1.33	−.08	−1.55, 1.37	−.30	−2.01, 1.25	−.26	−1.98, 1.32	.16	−2.08, 2.35
Feedback type														
Comparative			.62	−.23, 1.57	.01	−1.27, 1.32	.04	−1.30, 1.44	.04	−1.37, 1.47	−.32	−2.04, 1.23	−.45	−2.81, 1.40
Evaluative			.94*	.07, 1.94	.67	−.55, 2.02	.76	−.49, 2.15	.81	−.41, 2.25	.83	−.54, 2.44	1.34$^{\bullet}$	−.11, 3.90
Feedback valence ∗ type:														
Positive comparative					1.17	−.57, 3.11	1.15	−.74, 3.36	1.21	−.72, 3.57	1.21	−.87, 3.82	1.50	−1.06, 5.52
Positive evaluative					.51	−1.30, 2.47	.24	−1.70, 2.25	.07	−1.99, 2.22	.13	−2.00, 2.35	−.16	−3.14, 2.81
Agent credibility							.23	−.06, .60	−.05	−.44, .34	−.12	−.58, .29	−.15	−.87, .40
Anthropomorphism							.24	.09, .61	.25	−.11, .64	.07	−.37, .49	.08	−.59, .68
Agent androgyny							−.02	−.24, .20	−.03	−.27, .18	.03	−.19, .28	−.03	−.39, .30
Attitude feedback									.75**	.31, 1.42	.57*	.05, 1.27	.66$^{\bullet}$	−.04, 1.98
Perceived competence											−.19	−.62, .20	−.48*	−1.39, −.02
Perceived autonomy											.81**	.41, 1.54	.27	−.51, 1.30
Intrinsic motivation													.84***	.45, 2.14
Identification													.23	−.27, 1.14
Introjection													.19	−.44, 1.02
External motivation													−.01	−.68, .62
−2 log likelihood	207.66		200.49		198.58		190.62		181.29		168.43		135.12	
Cox & Snell R^2	.037		.080		.092		.136		.186		.250		.394	
Nagelkerke R^2	.050		.108		.123		.184		.251		.337		.529	
Model Chi Square	5.99		13.16		15.07		23.04		32.36		45.22		78.53	
Degrees of freedom	2		5		7		10		11		13		17	

95%CI = 95% Confidence Interval of *B* value, based on 5000 bootstrap samples.
$^{\bullet}$ $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

valence affects immediate game behavior, in that participants who received negative feedback were likelier to immediately play the game again than participants with positive feedback. We also find that receiving evaluative feedback increases the likelihood to play the game again in the near future. Comparative feedback, however, decreases the likelihood to immediately play the game again.

With respect to need satisfaction, we find that people who perceive themselves as low in competence are likelier to play again immediately than people who perceive themselves high in competence. A high perception of autonomy also increases the likelihood to play the same again immediately and in the future. Our motivation variables consistently show that intrinsic motivation is positively related to both immediate and future game play, while none of the extrinsic variables are related to play.

Finally, we find that some demographic variables are related to game behavior in that men are likelier than women to immediately play the game again. Older participants were likelier to play the game again in the future than younger participants.

4. Discussion

The aim of this study was to understand the role of feedback in intrinsic motivation to play an online brain-training game. We combined FIT with CET to understand specific effects of different types of feedback on need satisfaction in game, subsequent effects on motivation, and free-choice behavior. Our findings overall replicate past research on the role of intrinsic motivation and desire to play games. We found that intrinsic motivation is positively related to choice to play the game again now and in the future (see also Przybylski et al., 2010; Ryan et al., 2006; Tamborini et al., 2010). Supporting the notion that *intrinsic* motivation is most critical to gaming behavior, even with regards to non-entertainment games, we found no significant effect of extrinsic motivations on desire to play the game immediately or in the future. These findings provide additional empirical support for the hypothesis of CET that most gamers are intrinsically motivated, and that understanding the determinants of intrinsic motivation is critical to understanding how games may best motivate players to continue playing.

Our first hypothesis predicted that intrinsic motivation would be a result of perceived need satisfaction in game. In line with H1, we indeed found the expected relationships, in that competence and autonomy need satisfaction was positively related to intrinsic motivation. In terms of need satisfaction and free choice behavior, we found that as expected a high perception of autonomy-need satisfaction, as well as high intrinsic motivation, increased the likelihood to play the game again immediately and in the future. These findings underscore the importance of satisfying intrinsic needs for autonomy in motivating people to play educational games.

However, H1 was disconfirmed for competence-need satisfaction: players who felt low in competence after play (i.e. less competence need satisfaction) were likelier to immediately play again compared to those experiencing high competence satisfaction. This effect can perhaps best be explained by the type of game we used. The success of a ‘‘*brain training*’’ game in which a particular skill is tested or trained may actually depend on people feeling less competent, so that they desire to improve in the future. Thus, if players feel very competent with regards to the skill tested in the game, they have no reason to continue playing in the future.

Our second hypothesis predicted that participants receiving positive feedback would feel themselves to be more competent and autonomous, which in turn, would increase intrinsic motivation. This hypothesis was confirmed. This demonstrates that feedback can be an important motivator and thus an important addition to the literature on motivation (e.g., Deci & Ryan, 2000). We found that feedback valence affected perceived competence and autonomy, in that participants receiving positive feedback (vs. negative feedback) perceived themselves as more competent and autonomous. The mediation analysis additionally revealed positive indirect effects of feedback valence on intrinsic motivation through both perceived competence and autonomy. Although the direct effect of positive feedback on intrinsic motivation is negative, once adding the mediating variables of competence and autonomy, the overall relationship is positive. This may be explained by the perception of positive feedback as less controlling than negative feedback (Deci et al., 1999). This implies that it is useful to further explore how feedback interventions (as predicted by FIT, Kluger & DeNisi, 1996) can satisfy competence and autonomy needs to increase intrinsic motivation in a range of behavioral applications.

Additionally, we found a surprising result of feedback valence on game play based on the time frame that play would take place: results show that participants receiving negative feedback were likelier to play the game immediately than participants receiving positive feedback. This finding is conceptually similar to our findings regarding competence need satisfaction. Perhaps players wanted to play again immediately in order to redeem themselves, or to succeed better at the task. This implies that a reduction of competence can lead to more game play in brain-training games, because players want to immediately repair and improve their performance. These findings are in line with work by Reinecke et al. (2012) who found that thwarted competence needs in a false-feedback task led to desire to restore competence needs via immediately playing a video game at a lower difficulty level. In essence, our negative feedback may have acted like an initial task in a false-feedback manipulation, such that we would see the expected positive relationships between competence and motivation in the second round of play. It could also be that prior studies (Reinecke et al., 2012; Tamborini et al., 2010, 2011) were more interested in enjoyment of the game vs. desire to play again – it could well be that competence has differential effects for enjoyment of current play vs. desire to play again.

Our hypotheses regarding feedback effectiveness specifically predicted that evaluative feedback would be most effective (H3a), followed by comparative feedback (H3b). Receiving evaluative feedback indeed increased the likelihood to play the game again both immediately and in future, thus confirming H3a. Comparative feedback, however, decreased the likelihood to immediately play the game again, which disconfirms H3b. Thus, comparative feedback may be less motivating than descriptive or evaluative feedback. Although we did not measure the perception of competition in this game, comparative feedback could elicit perceived social competition in the eyes of players. This perceived social competition may be perceived as more ‘‘controlling’’ of player behavior in some way, even though the competition is implied and not explicit. However, this notion warrants further testing. Evaluative feedback was positively related to playing the game in the future compared to descriptive feedback. This is similar to the findings for perceived competence – the evaluation itself may make players want to do better in future. In contrast to Lipkus and Klein (2006), we did not find any interaction effects for valance and feedback.

In addition to our hypotheses tests, we also found some unexpected results that warrant further investigation. First, age was positively related to playing game in future. This may be perhaps due to the nature of game; brain training is more applicable to older than to younger adults. We also found a different set of effects of feedback on motivation to play the game immediately vs. playing it later. This suggests that current and future plans for games are affected both by motivations for play and intended play time. Although we did not ask people to actually come back and play the game in the future, these findings suggest that further research on free choice future behavior should include a future behavioral measure of future choice behavior in addition to self-report.

Our study may also serve as the launching point for future research. First, we used a game that was played one time by participants. Future research may investigate the differential role of feedback if players play a game multiple times. In such studies, it would be particularly relevant, if players have played the game a number of game, to base the feedback on players' past performance rather than on a false-feedback manipulation. For instance, descriptive feedback could focus on the completion time compared to past performance (e.g., *You have set your third fastest time ever!*). Comparative feedback could be given to inform participants if, in general, they are improving (or not). Second, we customized the game *Concentration* for this experiment. Future research could focus on games that gamers have chosen for themselves to play naturally outside of the experiment.

Third, we used a brain-training game which had potential applications outside the game world. Given that such a game may be different from other educational games or games for behavior change, future work should be replicated using other types of games to determine if a behavior-change framework itself has significant effects on player motivation. Specifically, given our negative effects of competence on play, future research should perhaps particularly examine the effect of competence on skill training games vs. non-skill training games, in order to see if the positive relationship between competence need satisfaction and free choice behavior that we predicted is only endemic to skill-training games or also applies to other game types.

Finally, we compared three different types of feedback (descriptive, comparative, evaluative) and feedback valence in a false feedback manipulation. Of course, other feedback variables that could be considered in future research include are clarity of the feedback (cf. Ogilvie & Haslett, 1985), and perceived reliability of (cf. Manser & Muchinsky, 1980) and trust in the feedback source (O'Reilly and Anderson, 1980). Additionally, using feedback that accurately reflects participants performance rather than experimental condition may be a better predictor of motivation and behavior. Although unlikely, it is possible that the false-feedback manipulation may have made participants suspicious or distrusting of the feedback if they did not agree with the assessment. Therefore, future research should consider participant performance as a casual variable in the feedback to motivation chain, and move away from the false-feedback paradigm towards feedback tailored to actual game play.

5. Conclusions

Our study shows the potential of extending the motivational framework of games as understood via CET (Deci & Ryan, 2000) by including the relevance of feedback (FIT; Kluger & DeNisi, 1996). We found that both negative and positive feedback can positively enhance willingness to engage in continued play of serious games. Players receiving negative feedback feel less competent and want to immediately repair their performance. This indicates that negative feedback may, counter-intuitively, be good in stimulating short-term and immediate gaming behavior. Gamers receiving positive feedback, on the other hand, felt more competent and autonomous and desirous of playing the future. This suggests that positive feedback may be good in sustaining long-term play. Studying the impact of theoretically relevant game elements such as feedback thus demonstrates the potential strengths and weakness of including these types of elements in serious games and gamified applications. Future research will do well to examine these elements and their subsequent effects in large field studies of player behavior outside the lab, in order to best understand how to motivate players of behavior-change games.

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