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Cognitive consequences of making computer-based learning activities more game-like

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ABSTRACT

Some students (base group) played the Circuit Game, a 10-level computer-based learning activity intended to help students learn how electrical circuits work. Other students (competition group) played the same game but with competition features added – including a score bar showing performance on each level, the opportunity to earn one ticket per level if a performance criterion is met, and the opportunity to win a prize based on the number of tickets earned. On a retention test given after the game, the competition group remembered significantly more than the base group ($d = 0.47$). On an embedded transfer test constituting the final level of the game, the groups did not differ significantly. However, on the transfer test there was a significant gender by group interaction in which men performed worse in the competition group than the base group ($d = -0.54$) and women performed better in the competition group than the base group ($d = 0.24$). Overall, adding game-like features to a computer-based learning activity caused students to pay attention to game details but did not motivate students – particularly men – to learn more deeply.

1. Introduction

When the goal is to make learning more fun, students can be invited to engage in computer-based learning activities that include game-like features (such as competition). An important research question concerns the degree to which adding a particular game-like feature improves student learning. Mayer (2011) refers to this approach to games research as the *value-added approach*, because the goal is to determine whether adding a particular feature to a game will improve player learning. In particular, competition is a game feature that is thought to foster deeper learning from educational games by increasing motivation, that is, by challenging the player to work harder (Lepper & Malone, 1987). The goal of the present study is to use the value-added approach to test the effects of adding competitiveness to a computer-based learning activity. The rationale for studying the role of competitiveness is that it has been implicated as a key motivational component in games (Lepper & Malone, 1987; Malone, 1981).

Reviewers of game research have decried the lack of scientifically rigorous studies aimed at pinpointing instructional design features that improve the instructional effectiveness of games (Clark, Yates, Early, & Moulton, 2010; Hannifin & Vermillion, 2008; O'Neil & Perez, 2008; O'Neil, Wainess, & Baker, 2005; Tobias & Fletcher, 2011). For example, in a recent review of game research, O'Neil and Perez (2008, p. ix) concluded that "there is almost no guidance for game designers on how to design games that facilitate learning." In another review of game research, Hannafin and Vermillion (2008, p. 215) concluded that games "have tremendous potential in education, but . . . there is yet insufficient evidence to draw definitive conclusions." In a broad review of game research, O'Neil, Wainess, and Baker (2005) started with 4000 published papers on games but of those found only 19 that used sufficient measures of learning outcome. These observations support the need for a value-added approach to games research aimed at identifying the instructional design features that make games effective.

In the present study, we begin with a computer-based activity called the Circuit Game (Johnson & Mayer, 2010; Mayer & Johnson, 2010), which is intended to help students learn how electrical circuits work. The Circuit Game consists of 10 progressively more difficult levels, each containing a series of challenging problems – such as determining which of two circuits carries more current or deciding which circuit component could increase or decrease the speed of the current. After responding, the student receives visual feedback for correct and incorrect answers, and on to the next problem. Although Mayer and Johnson (2010) showed that explanative feedback improves game performance, this version of the game includes only feedback of correctness of answers, in order to look specifically at how adding competition affects learning. The tenth level is an embedded transfer test consisting of 22 novel

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problems that require students to apply what they have learned about basic circuits to circuits involving light bulbs. The rationale for using the Circuit Game is that it is a computer-based learning activity that has a clear instructional objective but appears to have only minimal amount of game-like feel, based on pilot testing.

How can we spice up this learning activity to make it more game-like? In the present study, we added competitiveness by (a) adding a graphic showing the student's score on the current level, (b) telling students that they could earn one ticket for each level they won by reaching a threshold level on the score bar, (c) showing the current number of tickets on the screen before each level, and (d) providing one entry into a $50 prize raffle for every ticket they earned across the entire game. In other words, the more levels each student won across the whole game compared to other participants, the better their chances were for winning the raffle. Our use of competitiveness in the Circuit Game involves competition against oneself – by trying to get increasingly higher numbers of points (or maintain perfect performance) on each level – as well as competition against others – by trying to accumulate enough tickets to beat everyone else in the upcoming raffle.

A rationale for investigating the instructional effects of adding competitiveness to games is that it has been found to be one of the preferred game characteristics of children (Rieber, 2005). The importance of competitiveness is indicated by Rieber's (2005, pp. 563–564) inclusion of competitiveness in the following definition of an educational game: "Competitive rule-based environment involving one or more players with an expressed goal of performing or meeting a goal at a superior level (i.e., winning) either in relation to a previous performance level (one player game) or in relation to the performance of other players. Success in the activity requires use of subject matter in some way."

Preliminary research shows that under some circumstances adding competitive features to a game can affect student beliefs and perceptions (Cheng, Wu, Liao, & Chan, 2009; Yu, 2003) as well as learning outcomes (Fisher, 1976; van Eck & Dempsey, 2002). A recent study shows that when players almost win a game, the reward areas of the brain are activated, indicating motivational prompts to continue playing (Clark, Lawrence, Astley-Jones, & Gray, 2009). The present study contributes to this research base by focusing on the issue of whether students learn to solve circuit problems better from a computer-based learning activity when the game-like feature of competitiveness is added.

1.1. The theoretical case for adding competitive features

The main theoretical argument for incorporating competitive features is the theoretical proposal that competition increases the learner's motivation to engage in the learning activity, to persist in the learning activity, and to achieve success in the learning activity (Lepper & Malone, 1987; Malone, 1981). The increase in engagement in the learning activity is proposed to result in a better learning outcome (Moreno & Mayer, 2007). Thus, according to this competition-fosters-motivation theory, students who play the competitive version of the Circuit Game will learn more deeply and therefore perform better on the embedded transfer test in level 10 and on a retention question than will students who play the base version of the Circuit Game.

1.2. The theoretical case against adding competitive features

The main theoretical argument against incorporating competitive features is based on the theoretical proposal that the learner's working memory capacity is quite limited, as specified in cognitive load theory (Sweller, 2010) and the cognitive theory of multimedia learning (Mayer, 2009). In particular, the argument is that competition is a distraction that increases extraneous cognitive processing – cognitive processing that does not support the instructional goal (Mayer, 2009; Sweller, 2010). With the increase in extraneous processing, there is less remaining cognitive capacity available for learning the subject matter. Thus, according to this competition-fosters-distraction theory, students who play the competitive version of the Circuit Game will learn less deeply than students who play the base version, and will therefore perform worse on the embedded transfer test (in level 10) and on a retention test. Alternatively, a compromise between the two competing theories is that the motivational advantages of adding competitive features may be offset by the distraction disadvantages, resulting in no differences in learning outcomes between students who learn with the competitive version versus the base version of the Circuit Game.

1.3. Gender differences in gaming

As a final issue in this study, we were interested in how gender might affect adding competition to an educational game. On the one hand, men tend to be more competitive than women, especially when competing to win (e.g., Hibbard & Buhrmester, 2010), suggesting that adding competition to an educational game might help men more than women. On the other hand, men tend to play more video games (e.g., Lucas & Sherry, 2004) and might not benefit from adding competitive features to the game, since they may be generally more motivated to play the game than women.

2. Method

2.1. Participants

The participants were 137 college students recruited from the Psychology Subject Pool at the University of California, Santa Barbara, who fulfilled a course requirement by participating.

2.2. Design

The design of this study consisted of two main groups: the base group ($n = 48$, 18 men and 30 women) and the competition group ($n = 86$, 40 men and 46 women). Because there were several ways to implement the points and ticket scoring system in the game, the competition group was composed of four subgroups in which we manipulated whether students earned or avoided losing points with each correct answer, and whether they earned or avoided losing tickets on each level in which they scored above the 50% threshold.[1] These four subgroups, however, were collapsed for analysis purposes, as they did not differ significantly from one another on any dependent measures and because they all involved a similar approach to inducing competition.

2.3. Materials and apparatus

The materials consisted of a participant questionnaire, two major versions of the Circuit Game, cognitive load questions, and a

[1] Within the competition group, a 2 (points: earn or avoid losing) × 2 (points: earn or avoid losing) design was implemented (Markman, Baldwin, & Maddox, 2005). In the Earn conditions, students started the game with zero points and zero tickets, and earned them as they played the game. In the Avoid conditions, students started the game with 10 tickets and full points on each level, and avoided losing them as they played the game. In the Earn Tickets/Earn Points condition ($n = 22$), students played to earn tickets on each level and earned points on each problem. In the Earn Tickets/Keep Points condition ($n = 23$), students played to earn tickets on each level but avoided losing points on each problem. In the Keep Tickets/Keep Points condition ($n = 23$), students played to keep tickets on each level and avoided losing points on each problem. In the Keep Tickets/Earn Points condition ($n = 20$), students played to keep tickets on each level but earned points on each problem.