Motivational and Educational Outcomes Associated with Solo, Competitive, and Collaborative Game Play

Jan L. Plass, Paul A. O'Keefe, Bruce D. Homer, Elizabeth O. Hayward, Murphy Stein & Ken Perlin

Paper submitted for presentation at the Annual Meeting of the American Educational Research Association (AERA), New Orleans, LA (April, 2011).

Results are presented from an experimental investigation of the effect of mode of play on motivational and educational outcomes. A computer-based arithmetic game was adapted to allow for solo, competitive, or collaborative game play. Participants (n = 54) from seven urban middle schools were randomly assigned to each experimental condition. Results suggest that solo play was found to be less situationally interesting than competitive or collaborative play. Participants in the competitive condition were found to endorse a stronger mastery goal orientation and a stronger performance-approach goal orientation, and perform better overall, than those in the solo condition. In contrast, those in the solo play condition scored higher on post-test measures of math fluency.

Introduction

The past decade has seen great interest in the educational potential of computer-based games and simulations. Computer-based games are highly engaging and motivating for players, and educators have suggested taking advantage of this engagement and motivation to support learning (Gee, 2007; Prensky, 2001; Squire, 2003). Furthermore, a number of influential books and articles have argued that well-designed games embody educational theory and are inline with some of the "best practices" of education (e.g., Collins & Halverson, 2009; Gee, 2003; Mayo, 2007; Plass, Homer & Hayward, 2009).

Current efforts in research games are examining the effects of different design patterns on students' learning experiences and outcomes (Plass et al., 2009). The current study examined the effects of manipulating the social context of playing an educational game. Middle-school students were randomly assigned to play a math game, *Factor Reactor,* either on their own (*solo*), against another student (*competitive*), or with another student (*collaborative*). Learning outcomes, situational interest, and game-specific achievement goal orientation were dependent variables.

Method

Participants and Design. Participants were 54 students from seven urban schools in a major Northeastern city. There were 35 female participants (65%). Each participant was randomly assigned to one of three modes of play: *solo*, *competitive*, and *collaborative*. In the *solo* condition, participants played the game independently, whereas in the *competitive* and *collaborative* conditions they played the game in pairs.

Procedure. After being randomly assigned to an experimental condition, participants were administered a pre-test of math fluency. Participants then watched an instructional video providing an overview of the rules and goals of the game, as well as how to use the controller to play the game. Participants then individually played a practice round of an educational math game, *Factor Reactor*, for 5 minutes at a laptop station with one XBox controller. They were provided with a controller schematic sheet to assist in learning the operation of the controller. An experimenter was available during this time for questions about game play. The controller schematic sheet was taken away at the close of the practice session.

All participants independently engaged in a pre-test play session, lasting 3 minutes. At this point, participants in the solo condition were situated in front of a laptop computer with a single controller, whereas the competitive and collaborative conditions joined with a partner in front of a laptop computer with two controllers. An experimenter provided instructions for each condition. Those in the solo condition were told: “When playing the game, get the best score you can.” Those in the competitive condition were told: “When playing the game, compete against each other for the better score.” Those in the collaborative condition were told: “When playing the game, work together to get the best score.” Participants were given 15 minutes to play, at which point the game automatically stopped.

Participants were independently administered surveys assessing their situational interest in the game and game-specific achievement goal orientations. They played the game independently for a 3-minute post-test play session, which was followed by a post-test of math fluency.

Materials. Factor Reactor, a multiplayer game focusing on arithmetic skills, was designed and adapted to investigate mode of play. The game was run on 13” and 15” laptops using wired XBox controllers. The object of the game was to transform the center number into one of the surrounding goal numbers by adding, subtracting, multiplying, or dividing it by one of the numbers from the inner ring. This was conducted by picking one of the operators (+, -, ×, ÷) and one of the inner numbers and hitting the fire button. The level ended when all goal numbers were computed. Levels increased in difficulty, such that the operations needed to reach the goal number became more complex. The number of problems completed was used as an indicator of game performance. See Figure 1 for a screen shot of each mode of play.

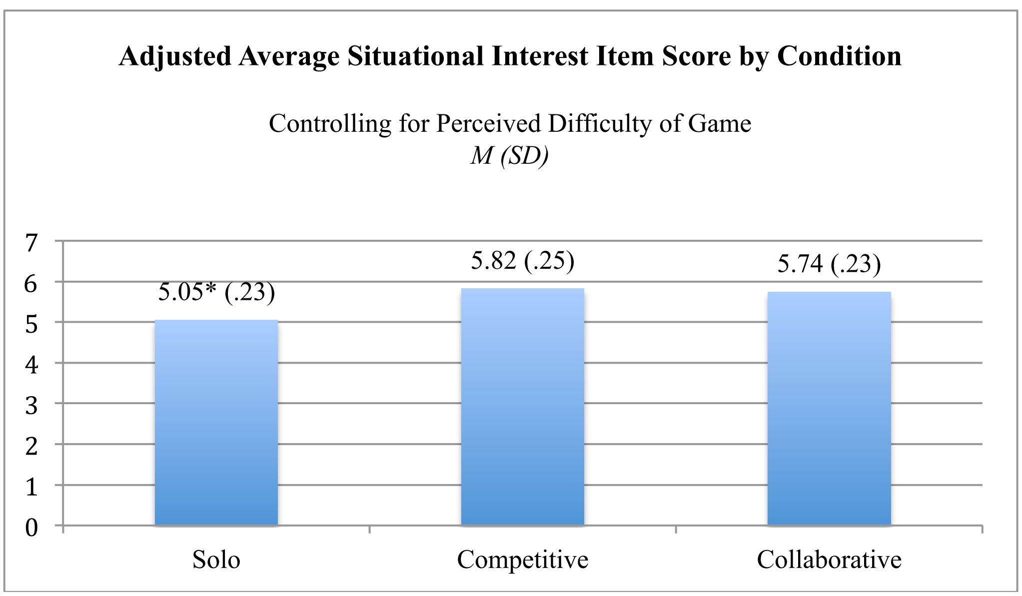
Measures. Participants were first given a pre- and post-test of math fluency. The measure included 160 simple arithmetic problems for which participants were given 3 minutes to complete as many problems as possible. The measure of math fluency was adapted from the *Woodcock Johnson – III Math Fluency subtest* (McGrew & Woodcock, 2001), modified by randomizing the presentation of problems and by including simple division problems as well as addition, subtraction, and multiplication problems. The post-test of math fluency was identical to the pre-test, though the problems were presented in a different, randomized order to diminish practice effects.

Participants were also given the *Situational Interest Survey* (Linnenbrink-Garcia et al., in press) and the achievement goal orientation subscale from the *Patterns of Adaptive Learning Scales* (PALS; Midgley et al., 2000). The language in the scales was simplified to ensure comprehension in our middle school sample. These scales were also adapted to be relevant for game play. The *Situational Interest Survey* asked participants to use a 7-point Likert scale to indicate their level of agreement with twelve statements, such as “The game was exciting,” “The things I learned from the game are important to me,” and “I thought the game was interesting.” The 14-item goal achievement scale asked students to indicate their level agreement using a 7-point Likert scale in response to items such as “One of my goals was to learn as much as I could about the game” (mastery), “One of my goals was to show others that the game was easy for me” (performance-approach), and “It was important to me that my performance on the game didn’t make me look stupid” (performance-avoidance). Lastly, participants were asked to indicate how difficult they found the game (rated on a 5-point Likert scale, from “Too Hard” to “Too Easy”), as well as their level of experience with videogame controllers like the ones presented (rated on a 5-point Likert scale, from “None” to “A lot”).

Results

Situational interest. Our first question concerned the extent to which mode of play (solo vs. competitive vs. collaborative) influenced situational interest ($M = 5.50$, $SD = 1.05$) in the game. One participant reported situational interest more than 2.5 *SD*s below the mean, and was, therefore, omitted from the analysis. Controlling for perceived difficulty, a between-subjects ANCOVA yielded a significant main effect for mode of play, $F(2, 49) = 3.27$, $p = .046$. Planned contrasts suggested that solo play ($M_{adjusted} = 5.05$, $SE = .23$) was significantly less situationally interesting than the competitive ($p = .026$; $M_{adjusted} = 5.83$, $SE = .25$) or collaborative ($p = .039$; $M_{adjusted} = 5.74$, $SE = .23$) conditions. The competitive and collaborative conditions, however, did not differ in their situational interest ($p = .810$).

Figure 2.



Achievement goal orientations

Our second set of analyses examined the effect mode of play had on students’ achievement goal orientations (see Table 1). To control for familywise error rate, a MANOVA was conducted with all three achievement goal orientations as dependent variables, which suggested that mode of play had a significant effect, $F(3, 50) = 3.46$, $p = .023$. Next, a series of follow-up analyses were performed to better understand the influence of the game play conditions on each achievement goal orientation. First, a between-subjects ANOVA examining mastery goal orientation yielded statistical significance ($F(2, 51) = 4.21$, $p = .036$). Planned contrasts suggested that there was only a significant difference between solo play and competitive play ($p = .011$), such that the competitive condition ($M = 6.18$, $SD = .91$) caused students to endorse a stronger mastery goal orientation than the solo condition ($M = 5.20$, $SD = 1.20$).

Next, a between-subjects ANOVA examining the effect of game play condition on performance-approach goal orientations reached marginal significance, $F(2, 51) = 2.75$, $p = .07$. Planned contrasts suggested that only the solo condition was significantly different than competitive condition ($p = .026$), suggesting that competitive play ($M = 4.99$, $SD = 1.65$) caused students to endorse a stronger performance-approach goal orientation than the solo game play ($M = 3.83$, $SD = 1.20$). Finally, a between-subjects ANOVA examined the effect of game play condition on performance-avoidance goal orientations, which did not reach significance ($F(2, 51) = 1.14$, $p = .328$).

Table 1

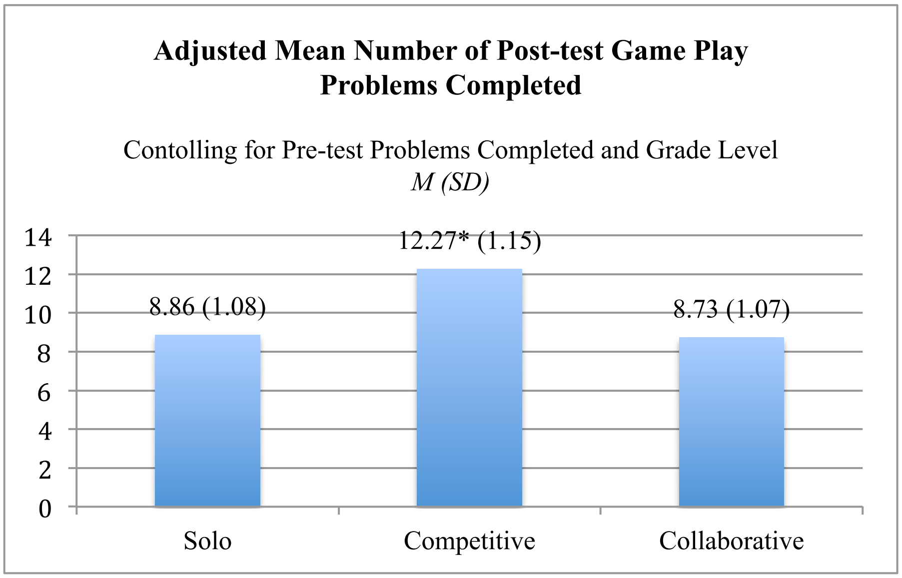
Mean Scores for PALS Subscales by Group

PALS Subscale	Solo *n* = 18		Competitive *n* = 17		Collaborative *n* = 19	
	M	*SD*	*M*	*SD*	*M*	*SD*
Mastery-Approach	5.20	1.20	6.17	.90	5.59	1.14
Performance-Approach	3.83	1.22	4.99	1.65	4.18	1.57
Performance-Avoidance	3.83	1.20	4.59	1.69	4.21	1.51

Game Performance

In order to examine the effect mode of play had on actual performance, an ANCOVA was performed on the total number of problems solved in the post-test, with pre-test game performance, grade level, and level of experience with the videogame controller added to the model as covariates. The analysis yielded a significant main effect for condition, $F(2, 46) = 3.12$, $p = .05$. Planned contrasts suggested that competitive game play ($M_{adjusted} = 12.27$, $SE = 1.15$) resulted in better performance than solo game play ($p = .039$; $M_{adjusted} = 8.87$, $SE = 1.09$), and also collaborative game play ($p = .029$; $M_{adjusted} = 8.73$, $SE = 1.07$; see Figure 3).

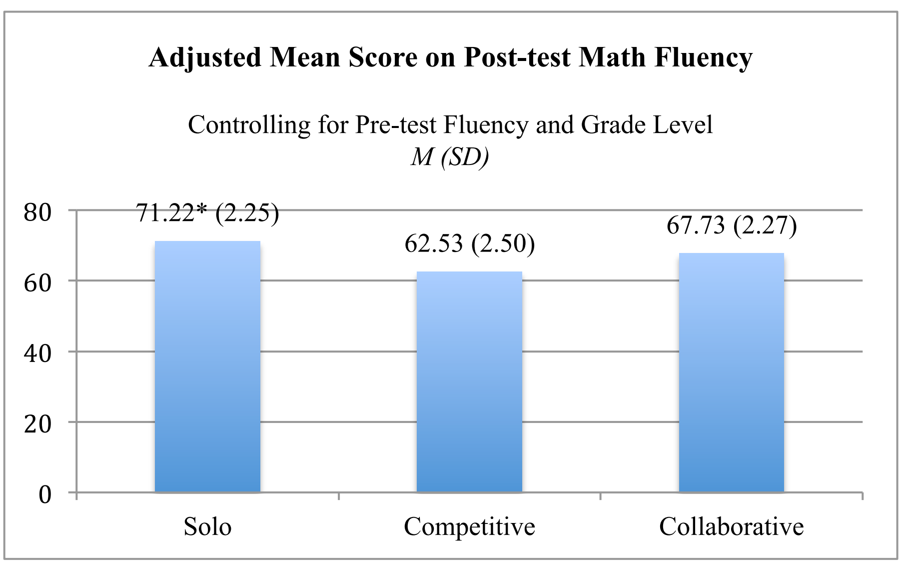
Figure 3.



Math fluency

To investigate the effect of game play condition on math fluency, an ANCOVA was performed on post-test math fluency scores, with pre-test math fluency performance and grade level added to the model as covariates. The analysis resulted in a significant main effect of condition, $F(2, 46) = 3.30$, $p = .046$. Planned contrasts suggested that only solo play ($M_{adjusted}$ = 71.22, $SE = 2.25$) was superior to competitive play ($p = .014$; $M_{adjusted}$ = 62.53, $SE = 2.51$; see Figure 4).

Figure 4.



Discussion

The current study investigated how mode of interactivity (solo, collaborative or competitive) affected situational interest, achievement goal orientation, and learning outcomes. Both collaborative and competitive play resulted in greater situational interest than solo play, suggesting that a social component of the game yields greater intrinsic interest. Competitive game play resulted in the strongest approach-related goal orientations (i.e., mastery and performance-approach), which are adaptive motivational orientations and associated with beneficial learning outcomes. Finally, despite the fact that participants in the competitive group completed more math problems in the game, the solo group demonstrated significantly greater math fluency in the posttest. Overall, the results suggest ways in which long-term educational goals should inform design for this type of game. For example, solo play may be better for short-term learning, but having a social element may result in greater long-term interest in playing and result in greater learning when the game is to be used over a longer period (e.g., a semester). Future work should examine the effects of other design factors, and also if the effects found in the current study are different for different types of games (e.g., do discussions that are enabled by collaborative play result in better learning of more complex concepts?).

References

Collins, A., & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and schooling in America*. NY: Teachers College.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York, NY: Palgrave Macmillan.

Gee, J.P. (2007). *Good video games + Good learning*. New York: Peter Lang.

Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., et al. (in press). *Situational interest survey (SIS): An instrument to assess the role of situational factors in interest development*.

Mayo, M. J. (2007) Games for science and engineering education. *Communications of the ACM, 50* (7), 30-35.

McGrew, K. S. & Woodcock, R. W. (2001). Technical Manual: Woodcock-Johnson III.

Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E., Anderman, L. H., Freeman, K. E., et al. (2000). *Manual for the Patterns of Adaptive Learning Scales (PALS)*. Ann Arbor, MI: University of Michigan.

Plass, J.L., Homer, B.D., & Hayward, E. (2009). Design Factors for Educationally Effective Animations and Simulations. *Journal of Computing in Higher Education, 21*(1), 31–61.

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9(5)*, 1-6.

Squire, K. (2003). Video Games in Education. *International Journal of Intelligent Simulations and Gaming (2)* 1.