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What is This?
Game-based Learning: The Impact of Flow State and Videogame Self-efficacy

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The science of serious games is growing at a substantial pace, providing new insights into the nature of game-based learning. Recently, research has begun to focus on the elements that comprise serious games and how these elements relate to learning (Wilson et al., 2009; Pavlas et al., 2009). As part of an effort to understand how these attributes impact learning outcomes, a study manipulating a number of game attributes in an immune system game was conducted. From this effort, two psychological constructs initially considered as mere covariates — video game self-efficacy and flow state — emerged as significant and highly explanatory predictors of learning. This article provides an overview of these constructs, describes the research that led to this finding, presents the results of this research, and offers implications and suggestions for future work.

INTRODUCTION

Game-based learning, a relative newcomer to the field of training, has seen a significant surge in research interest in the past decade. Serious games, the primary medium through which game-based learning is investigated, are games that work to provide learning, meaning, or similar outcomes rather than pure leisure experience. While serious games are superficially similar to training simulations, their focus on conveying knowledge, skills, and attitudes via play differentiates them from traditional computer-based training. This play-based approach to training necessitates focused research into the unique strengths, weaknesses, and requirements of serious games.

For researchers and practitioners seeking to investigate and apply new training strategies, serious games have provided a rich vein for investigation and discovery. Research has flourished, and advances in attribute-based manipulation of serious games (Malone, 1981; Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009), understanding the inherent motivational benefit of games (Garris, Ahlers, & Driskell, 2002), and qualifying the nature of a game experience (Squire, 2006) have provided numerous theoretical and practical implications.

As part of an effort to understand how serious games convey knowledge to learners, InnerCell – a health-oriented serious game platform – was developed. The basic framework of this game was designed to be flexible and allow for the manipulation of a number of game attributes (Pavlas et al., 2009). The game and the manipulated attributes will be discussed in greater detail later in this article. While this attribute-oriented research provided a number of insights into the nature of game-based learning, an overarching influence on game-based learning was uncovered during attempts to quantify attribute-related learning differences. Across the various manipulations conducted as part of the InnerCell research, the constructs of flow and videogame self-efficacy were found to have significant and strong effects on the acquisition of knowledge.

In order to illuminate the impact of these two constructs on game-based learning, this article presents findings on flow and videogame self-efficacy based on studies conducted with the InnerCell platform. First, some history on the constructs of flow and videogame self-efficacy is presented, followed by a description of the InnerCell game. Then, the experiments conducted with the InnerCall game platform are described, followed by a listing and discussion of the results of these studies. Implications for serious games research and practice are discussed alongside recommendations for future research in the field of game-based training.

SERIOUS GAMES, SELF-EFFICACY, & FLOW

While serious games are relatively well researched, the impact of flow and self-efficacy on game-based learning are not mainstream topics. Thus, these constructs are examined after a brief overview of serious games research.

Serious games

As previously noted, serious games are platforms that harness game interactions for learning outcomes (e.g., declarative knowledge, attitudinal change, etc.). While they are similar to computer-based simulations, the core element of a serious game is play (Baranauskas, Neto, & Borges, 1999). This focus on play as a key component of interaction has been reflected in a sizable body of research on the motivational impact of serious games (e.g., Malone & Lepper, 1987; Garris, Ahlers, & Driskell, 2002). The relationship between games, motivation, and learning is a popular topic of serious games research, with empirical studies and theoretical works identifying motivation as a key outcome and element of serious games (Doyle & Brown, 2000; Paras & Bizzochi, 2005).

However, motivation cannot be the only element that makes a serious game useful for learning. After all, if a learner
is highly motivated to use an ineffective tool, any increased effort on the learner’s part may not lead to actual increases in desired learning outcomes as the relative learning utility of the system is low. Research on serious games efficacy is steadily filling outcome-related gaps in the literature. Studies on specific games have indicated a wide range of potential learning outcomes, such as civil engineering skills (Ebner & Holzinger, 2007), economics (Blunt, 2007), math (Habgood, Ainsworth, & Benford, 2005), and military training (Fong, 2004). These applied outcomes are, in turn, indicative of a number of the learning outcomes in Bloom’s taxonomy of educational objectives, such as declarative knowledge, application, and knowledge organization (Bloom, 1956).

Finally, concurrent with this research focus on serious game efficacy, a growing body of work is examining what aspects of serious games make them “games”. Early work identified curiosity, fantasy, challenge, and control as the most basic elements of a game (Malone, 1981; Malone & Lepper, 1987), while later work identified control, conflict, rules and goals, context, and feedback (Gredler, 1996; Thagard, 1999; Leemtkv de Jong & Ootes, 2000; Juul, 2003). While the identification of these elements has illuminated serious games from a theoretical standpoint, the disparate and overlapping descriptions are experimentally problematic. More recently, these various elements have been combined to create a comprehensive taxonomy of game attributes and related learning outcomes (Wilson et al., 2009).

Flow

The current research builds upon this contemporary effort to understand serious games from an attribute standpoint (Pavlas et al., 2009). In addition to investigating these elements, two constructs less commonly studied by the gaming literature are examined. The first of these constructs, flow state, describes an optimal experience that is characterized by clear goals, concentration, the merging of action and awareness, a distorted sense of time, the presence of feedback, balance between skill and challenge, a sense of control, and intrinsic motivation (Csikszentmihalyi, 1990). Flow is commonly linked with engagement and learning (Whitson & Consoli, 2009), which makes it of particular interest to the serious games community, for whom engagement and learning are key concepts.

However, the gaming community has approached flow from a primarily theoretical standpoint. While much has been written about the potential utility of flow for game-based learning (e.g., Chen, 2007; Cowley, Charles, Black, & Hickey, 2008; Lemay, 2008), little empirical research has been conducted on its actual utility. Though flow has been shown to influence learning in general (Whitson & Consoli, 2009), research on flow and learning within the context of games remains insufficient. It can be theorized that the effect on learning will be similar, but the preferred approach would be to support this claim with empirical evidence. Merging the literatures on flow in games and games for learning will allow specific examination of how flow in serious games aids learning. To provide more insight into this potential link, the research effort described in this article measures flow state alongside learning outcomes.

Videogame self-efficacy

Self-efficacy is a construct that is well understood within the training literature. Unlike flow, self-efficacy is a mainstream term for many psychologists, describing an individual’s personal belief in their ability to perform tasks and behaviors (Bandura, 1977). Videogame self-efficacy, then, describes an individual’s confidence in their ability to interact with videogame systems. The general self-efficacy construct is a powerful predictor of both performance and training success (Salas & Cannon-Bowers, 2001), but is of particular interest because it may dictate whether trainees will engage with computer-based training technology (Christoph et al., 1998).

Despite empirical evidence for the usefulness of self-efficacy in predicting learning (Schunk, 2006), self-efficacy is not commonly discussed in serious games research. This is unfortunate, as self-efficacy is a relatively easy construct to examine within specific contexts, by converting the General Perceived Self-Efficacy Scale (Schwarzer & Jerusalem, 1995) to more focused self-efficacy constructs (Schwarzer, 2008). Some research on analogous constructs, such as prior videogame experience, has indicated that an individual’s pre-existing videogame ability and general self-efficacy impact how successful their training with a game will be (Orvis, Horn, & Belanich, 2007). Similarly, success in e-learning environments is affected by technology self-efficacy (Johnson, Hornik, & Salas, 2008; Ho & Kuo, 2010). It follows, then, that videogame self-efficacy is likely to predict success in game-based learning environments. Thus, the research described herein includes videogame self-efficacy in an attempt to examine this potential link.

METHOD

The study described in this section is part of a larger effort to understand the impact of game attributes on learning. As an extension of Pavlas, et al., 2009, the primary hypotheses of this study relate to individual game attributes and learning outcomes. For the purposes of this article only those elements pertaining to flow, videogame self-efficacy, and learning are discussed in detail.

InnerCell

The InnerCell game provides an experimental platform with which to investigate game-based learning. In this game, the player is tasked with defending the body from infection. A simple strategy game akin to popular commercial real-time strategy games, InnerCell allows players to interact with the immune system across three levels, each containing a planning stage and an infection stage. In the planning stage, players are introduced to the various cells they will use for defense and the infections they will be combating in the level’s upcoming infection stage. In the infection stage, players create and command different immune cells to defend the body. InnerCell provides players with interactions that semantically mirror common processes of the immune system. For example, the immune system is able to use Neutrophil to destroy bacterial pathogens, but killer T-cells are ineffective against bacteria.
The InnerCell game is useful from an experimental standpoint due to its modifiability – in order to investigate the effects of different gaming attributes on learning, a number of versions of the game were produced. Past efforts have included creating differing levels of feedback and dynamic adaptation (Pavlas et al., 2009). In the present study, four versions of the game were employed alongside a traditional e-learning environment containing the same learning content. These game versions included a fantasy story version, a realistic story version, a version requiring interaction with a second player, and a version involving proactive rather than reactive conflict. The fantasy story version allows the player to take the role of a future medical technician whose actions via nanomachines allow them to assist the immune system. In the realistic story version, the players take the role of a contemporary physician. In the human interaction version of the game, participants rely on a confederate to identify unlabeled pathogens. Finally, in the proactive conflict version of the game, the participant actively hunts down pathogens rather than simply defending the host from invading pathogens. A traditional e-learning environment was also included as non-game comparison condition. However, for the purpose of this article, comparisons are only made between the game conditions, as the constructs of interest lie within the context of serious games rather than between game and non-game learning environments.

Participants

120 undergraduates enrolled in psychology courses were recruited from a large southeastern university. Course credit was awarded for their participation in the study. 60.3% of the participants were female, 38.0% male, and 1.7% did not indicate gender. Participant ages ranged from 18 to 27 years ($M = 18.81$, $SD = 1.40$).

Measures

**Videogame self-efficacy.** The General Perceived Self-Efficacy Scale (Schwarzer & Jerusalem, 1995) was modified to serve as a measure of videogame self-efficacy. This modification was supported by prior research indicating the utility of modified measures of self-efficacy (Schwarzer, 2008). Thus, this measure focused on the individual’s sense of competence in interacting with video games. An example question was, “I can always manage to solve difficult problems within a video game if I try hard enough.” Participants responded along a 4-point Likert scale, with anchors at “not at all true” (1) and “exactly true” (4).

**Flow state.** A slightly modified version of the Flow State Scale (FSS; Jackson & Marsh, 1996) was used. This scale measures the flow subcomponents of challenge/skill balance, action-awareness merging, clear goals, unambiguous feedback, concentration, control, loss of consciousness, transformation of time, and autotelic experience. Participants responded to 36 questions along a 5-point Likert scale, with anchors at “strongly disagree” (1) and “strongly agree” (5). The FSS’s references to the individual’s control of their body were altered to refer to the individual’s control over their actions, as the interaction of interest was taking place within a game rather than a real-world environment.

**Declarative knowledge.** A multiple choice knowledge measure based on the provided immune content was presented to participants. This measure assessed the basic immune information inherent in the game as well as the more complicated interactions developed in the second and third levels of the game. A total of 43 questions were provided, with participants earning one point for each correct answer.

**Motivation.** The motivation outcome measure employed examined task-specific intrinsic motivation (McAuley, Duncan, & Tammen, 1989). Participants rated items on a 5-point Likert scale, with anchors at “strongly disagree” (1) and “strongly agree” (5).

**Knowledge organization.** An expert-scored card sort was used as a measure of knowledge organization. The webspot.net card sorting tool was seeded with key items from the immune system content (e.g., neutrophil, haemophilus). Participants were tasked with sorting these various items into categories of their creation.

**Application.** The final knowledge measure assessed how well participants applied the resource matching skills of the training game to a novel external task. A rule-based resource task was created wherein participants were charged with creating meals for restaurant patrons. Certain food characteristics were disliked or liked by different patrons, whose needs grew increasingly complex as the task progressed. Each participant was required to create eight meals with three components each, earning one point for each correct component (resulting in a total possible score of 24). Because participants were required to engage in behavior analogous to the game interactions (i.e., resource matching), their score on this task serves as an indicator of skill application.

Procedure

The experiment was conducted based on the procedure outlined in Pavlas et al., 2009. Upon entering the lab and providing informed consent, participants were randomly assigned to one of the game versions. After receiving training, being presented with the game story, and completing pre-measures, participants played the three levels of InnerCell. Following game play, post-measures were provided. All measures were provided in electronic form on a lab computer.

**RESULTS**

First, the data were analyzed for potential differences based on gender and age. No significant difference was found between male and female participants, nor was any effect for age detected. The data were then analyzed using the fantasy condition as the comparator or “baseline” condition, as it was most representative of the fantasy stories found in traditional video games (Pavlas et al., 2009). ANCOVAs were conducted comparing each of the three remaining conditions (reality, human interaction, and proactive conflict) to the fantasy condition, with videogame self-efficacy, flow state, self-report GPA, and class year used as covariates. Within the context of baseline vs. reality comparisons, no significant main effects were found for the attribute manipulation’s effect on declarative knowledge, knowledge organization, motivation,
or application. Similarly, for the baseline vs. proactive conflict and baseline vs. human interaction comparisons, no significant main effects were found. However, throughout these analyses, an interesting trend was found: the flow state and videogame self-efficacy covariates were repeatedly significant, with large F-values and large overall model effect sizes. Given this qualitative trend, further exploratory analyses on the role of videogame self-efficacy and flow state were conducted across the entire data set.

In order to test the impact of flow and videogame self-efficacy on the measured learning outcomes, each outcome was regressed onto flow and videogame self-efficacy. When declarative knowledge (DK) and motivation were separately regressed onto these two predictors, results were significant for all four comparisons: flow predicting DK ($\beta = .48, t(118) = 5.92, p < .001; F(1,118) = 34.99, p < .001$, adjusted $R^2 = .22$), flow predicting motivation ($\beta = .52, t(115) = 6.54, p < .001; F(1,115) = 42.76, p < .001$, adjusted $R^2 = .27$), videogame self-efficacy predicting DK ($\beta = .45, t(119) = 5.44, p < .001; F(1,119) = 29.58, p < .001$, adjusted $R^2 = .19$), and videogame self-efficacy predicting motivation ($\beta = .29, t(116) = 3.21, p < .01; F(1,116) = 10.30, p < .01$, adjusted $R^2 = .07$).

Given the potential link between self-efficacy, motivation, and flow (Whitson & Consoli, 2009), these data were further analyzed for a potential mediation effect of flow state. As videogame self-efficacy represented a pre-existing characteristic of the participant and flow state represented a state encountered during the experiment, the potential mediation effect of flow state on the relationship between videogame self-efficacy and declarative knowledge was examined. In consideration of the recent evidence suggesting the use of a bootstrap approach to test for mediation (Kenny, 2009), an established SPSS bootstrapping technique was used (Preacher & Hayes, 2008). In both analyses, videogame self-efficacy was a significant predictor of flow.

Based on 1000 bootstrap resamples, a significant indirect effect for flow state was found ($Z = 3.22, p < .01$, $effect = .20$, $SE = .07$). The direct effect of videogame self-efficacy remained significant but decreased ($\beta = .40, p < .001$), indicating partial mediation. The overall model showed a large effect size (based on adjusted $R^2$), explaining 29.06% of the variance in declarative knowledge ($F(2,117) = 25.38, p < .001$).

The same bootstrapping procedure was followed to test for a potential mediation effect of flow state on the relationship between videogame self-efficacy and motivation. In this case, an indirect effect for flow state was also found ($Z = 4.02, p < .001$, $effect = .56$, $SE = .15$). However, this effect also reduced the main effect of videogame self-efficacy to non-significance ($p = .60$), indicating full mediation. The overall model showed a similarly large effect size (based on adjusted $R^2$), explaining 26.01% of the variance in motivation ($F(2,114) = 21.39, p < .001$).

**DISCUSSION**

While the attribute variations did not produce significant differences in learning outcomes, exploratory analysis of the relationship between videogame self-efficacy, flow state, and learning outcomes revealed interesting effects. Specifically, flow and videogame self-efficacy predicted motivation and declarative knowledge outcomes. However, this relationship was not merely two factors accounting for unique variance. Rather, flow partially mediated the effects of videogame self-efficacy on declarative knowledge. Further, flow completely mediated the effects of videogame self-efficacy on intrinsic motivation.

Given the strong theoretical link between flow and intrinsic motivation (Csikszentmihalyi, 1990), results support current understanding of flow in games. More surprising, however, is the relationship between videogame self-efficacy, flow, and motivation. Though videogame self-efficacy appears to predict motivation, it actually does so via flow state. Videogame self-efficacy predicts flow, which predicts motivation; consequently, videogame self-efficacy is actually a key component for ensuring motivation in games because of its significant relationship to flow state.

Similarly, the findings regarding flow, videogame self-efficacy, and declarative knowledge is important because it expands the current understanding of flow, games, and learning. Though flow is often referenced in the games literature as a desirable state (e.g., Sweetser & Wyeth, 2005; Chen, 2007; Nackete & Lindley, 2008), its utility in serious games is still in need of empirical investigation. The results of this study represent a first step in this research, indicating that flow state is positively related not only to motivation, but also to quantifiable learning outcomes.

**CONCLUSION**

While the hypothesized effects of the present study did not reveal significant learning differences due to changes in game attributes, a far more meaningful result was obtained: videogame self-efficacy and flow state was shown to influence declarative knowledge and intrinsic motivation. Given the significant interest the game research community has shown in flow state (Chen, 2007), this result is gratifying. Though flow has been linked to learning in other contexts, its utility in serious games applications has been largely theoretical. To date, the relationship between self-efficacy and flow state has not been sufficiently examined, especially within the context of games. Future research on flow in games should measure videogame self-efficacy in order to see if this effect holds across a variety of settings.

The results of this study indicate that flow is not only useful from a game-based learning standpoint, but also that videogame self-efficacy plays an important role in this relationship. As the results discussed in this article are from exploratory analysis of an empirical study, future research should engage in experimental manipulation specifically targeting these constructs. By expanding upon the knowledge gained from this study, the serious games field stands to gain significant insight into how flow, self-efficacy, and learning are related — and through this, enhance the ability of serious games to function as learning environments.
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