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The effect of uncertainty on learning in game-like environments

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A B S T R A C T

Considering the role of games for educational purposes, there has an increase in interest among educators in applying strategies used in popular games to create more engaging learning environments. Learning is more fun and appealing in digital educational games and, as a result, it may become more effective. However, few research studies have been conducted to establish principles based on empirical research for designing engaging and entertaining games so as to improve learning. One of the essential characteristics of games that has been unexplored in the literature is the concept of uncertainty. This study examines the effect of uncertainty on learning outcomes. In order to better understand this effect on learning, a game-like learning tool was developed to teach a database concept in higher education programs of software engineering. The tool is designed in two versions: one including uncertainty and the other including no uncertainty. The experimental results of this study reveal that uncertainty enhances learning. Uncertainty is found to be positively associated with motivation. As motivation increases, participants tend to spend more time on answering the questions and to have higher accuracy in these questions.

1. Introduction

One of the serious problems in education is the failure of schools to motivate students (Lepper, Sethi, Dialdin, & Drake, 1997). Learning tasks in schools have been criticized to be boring, too easy, or decontextualized (Miller & Backman, 2004; Salomon & Perkins, 1998). In order to motivate students, serious games have been used for educational purposes for decades. Considering this potential of games, educators have been keen on creating more game-based learning environments (Dickey, 2005). In addition, computer and video games are suggested to increase the motivation and engagement of players because they include elements such as play, fantasy, curiosity, challenge, competition, cooperation, and learner-control (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Cordova & Lepper, 1996; Malone, 1981). However, insufficient research has been conducted to examine the effect of these individual elements on motivation and learning. One of the features of games that has yet remained unexplored is uncertainty (Howard-Jones & Demetriou, 2009). Studies in the literature show that uncertainty increases the level of engagement (Howard-Jones & Demetriou, 2009). Nevertheless, to our knowledge, no study has examined the impact of uncertainty on learning and the causal relationship between uncertainty and learning outcomes. For this reason, this study attempts to better understand this effect on learning in game-based environments. In the following section, literature review on games, flow theory, motivation, indicators of motivation in game-based learning, and uncertainty are covered.

2. Literature review

A game is defined as a rule-based system having quantifiable outcomes which are assigned to specific values (Juul, 2005). The player spends effort to influence the outcomes in the game, and as a result, the player will be happy with positive outcomes or unhappy with negative outcomes (Juul, 2003). Meaningful learning occurs when the relationships between actions of a player and the outcomes of the system in a game are "discernable and integrated into the larger context of the game" (Salen & Zimmerman, 2004, p. 34).

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Many studies in the literature have shown that games can increase motivation (e.g., Kebritchi, Hirumi, & Bai, 2010; Papastergiou, 2009; Prensky, 2003; Randel, Morris, Wetzel, & Whitehill, 1992; Rosas et al., 2003; Schwabe & Göth, 2005), engagement (e.g., Barab, Pettyjohn, Gresalfi, Volk, & Solomou, 2012; Parker & Lepper, 1992), and learning (e.g., Terrell & Rendulic, 1996). Games have been proposed to provide a more effective learning by bringing about more fun, appealing, and learner-centered environments (Ebner & Holzinger, 2007; Prensky, 2001). Several reasons have been suggested to account for the positive effect of games on learning. One is that, in order to move to higher levels of play, games require individuals to use prior knowledge, transfer new information into new situations, apply information in correct contexts, and learn from immediate feedback (Oblinger, 2004). Studies have shown that games help learners apply, synthesize, and think critically about what they learn through active and social participation (Colby & Colby, 2008; Fu, Su, & Yu, 2009; Koster, 2005). Game-based environments afford activities for experiential, situated, problem-based, and active learning (Boyle, Connolly, & Hainey, 2011).

One of the reasons for individuals preferring to learn through games may be their optimal flow experiences and their motivation on playing games (Squire, 2003). While playing games people usually spend considerably longer time-periods on the subject of the game. They tend to enjoy the environment and have higher levels of motivation to remain in such environments. This concept has been elaborated by researchers of the flow theory. Csikszentmihalyi (1993) defines flow as 'a state of consciousness that is sometimes experienced by individuals who are deeply involved in an enjoyable activity'. When people are in the optimal flow experience, they are in such a psychological state that, during the activity, they do not care about their environment (Inal & Cagiltay, 2007; Kiili, 2005). Players also temporarily lose track of time, surroundings, and the actual environment that they are in. Studies show that participants perceive higher levels of flow, and apply in-depth problem solving strategies with computer games (Liu, Cheng, & Huang, 2011). In order to put players in the flow zone during games, game designers and developers mainly focus on improving the motivation and the attention level required for games (Csikszentmihalyi, 1993). Several studies propose guidelines for creating flow in games (Andresen & Ahdell, 2002; Colby & Colby, 2008; Csikszentmihalyi, 1975, 1993; Ellis, Voelkl, & Morris, 1994; Hong et al., 2009; Kiili, 2005; Koster, 2005; Northrup, 2001; Pilke, 2004; Price, Rogers, Scaife, Stanton, & Neale, 2003; Sweetser & Wyeth, 2005). These studies suggest that there exists a relationship between learning and excitement or flow in games.

According to researchers, motivation is a preliminary step in the instructional process (Chan & Ahern, 1999). As an important factor for increasing level of flow and learning in games, the Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation identifies these four aspects to be addressed in order to increase motivation (Keller, 1987). To begin with, and, as the first element of motivation, attention should be drawn to the relevant stimuli and sustained during the course of instruction. Interesting animations or graphics, events that present conflict or incongruity, or unresolved problems can build curiosity and attract attention (Keller, 2008). "After gaining attention and building curiosity, a challenge is to sustain them, which can be done by applying the principle of variability. People adapt to routine stimuli; no matter how interesting a given technique or strategy is, they will lose interest over time" (Keller, 2008, p.177). The second element, relevance, is associated with whether learning activities are perceived to be related to the students' goals, learning styles, and prior experiences. To this end, teachers should discover their learners' interests and needs and incorporate them into their instructions (Keller, 1987). The third factor, confidence, is the level of the students' confidence and expectancy to be successful. For this, instruction should be designed so that success is attainable with realistic effort and ability. Satisfaction, as the last element, refers students' anticipation and experience of positive feelings about the outcomes of the current learning task (Keller, 2008). To accomplish this, intrinsic and extrinsic reinforcements should be provided in learning environments.

In addition, some measures have been used in the related literature to assess motivation in game-based learning. For instance, learners' performance while playing a game is an essential indicator of the players' engagement during a game. When players get higher scores, their post-test scores also increase, which shows that scores of players in games (accuracy) may be used as a predictor for their learning (Shin, Arbor, & Soloway, 2006). As Garris, Ahlers, and Driskell (2002) report, performance feedbacks and scores in games allow players to track their own progress toward the desired goals. Anecdotal evidence by Toups, Kerne, and Hamilton (2009) suggests that there is a relation between game score and motivation. They propose that game scores intrinsically motivate, engage, reward the player and direct action.

Furthermore, players' on-task time (i.e., the time spent on the learning material) during the game is another indicator of motivation (Beck, 2004). Studies show that there is a relationship between individuals' response time and their motivation or engagement in learning. When participants spend a reasonable amount of time to response a question, this indicates that they are feeling more responsible for their own learning and that they are more motivated. Whereas, when their responses are quick, this is a sign of disengagement in learning and lack of motivation (Beck, 2004).

One of the factors that have a potential impact in increasing level of flow and motivation in games and as such, improving learning progress is uncertainty. Uncertainty is determined by the probability P, that an event will occur, "being maximal at $P = 0.5$ and decreasing at higher and lower probabilities" (Fiorillo, Tobler, & Wolfram Schultz, 2003, p. 1898). Anselme (2010) has shown that uncertain events can motivate individuals. The release of dopamine, a neurotransmitter which is associated with reward-seeking behavior (Arias-Carrión & Pöppel, 2007) increases as the uncertainty of stimulus–reward relationship is increased. Dopamine neurons in the brain are activated by rewarding stimuli, such as food, sex, music, and video games (Cannon & Bseikri, 2004). Howard-Jones and Demetriou (2009) investigated the effect of gaming uncertainty on learning and discovered that players preferred the uncertain, rather than the certain option of the game. Moreover, they found that participants in the uncertain condition experienced higher arousal as measured by electrodermal activity. In addition, Howard-Jones, Demetriou, Bogacz, Yoo, and Leonards (2011) showed that a reward-based model of dopaminergic activity could predict the recall performance of subjects. Howard-Jones and Demetriou (2009) also report that gaming uncertainty may improve engagement and may also improve encoding and later recall. It has been suggested that uncertainty deepens the players' interest in a game (Hong et al., 2009), hence, it may play an important role in learning through playing. Whitehall and McDonald (1993) showed that varying payoff in a game increases the persistence of learners in choosing more difficult levels and game performance. Hence, uncertainty (Hong et al., 2009) is an important factor that may affect the flow in games and which has not been studied in detail as far as the available literature is concerned.

Although several studies have shown that games improve learning, there do not exist many examples of such games in higher education, especially in the field of computer engineering. Additionally, the guidelines for developing such educational games are very limited. On the other hand, students in higher education prefer to use computer simulations and games in their lessons (Cagiltay, 2007; Tao, Cheng, & Sun, 2009). Accordingly, this study aims to better understand the effect of uncertainty on learning through games. In order to examine this, a