A Model of Flow and Play in Game-based Learning: The Impact of Game Characteristics, Player Traits, and Player States

by

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Abstract

In this dissertation, the relationship between flow state, serious games, and learning was examined. Serious games, which are games that convey something other than enjoyment (e.g., learning), are increasingly popular platforms for research, training, and advertisement. The elements that make serious games useful to researchers, trainers, and practitioners are closely linked to those that make up the positive psychology construct of flow state. Flow state describes an optimum experience that is encountered when a variety of factors are met, and is characterized by high focus, engagement, motivation, and immersion. While flow state is often discussed in the serious games literature, in-depth empirical examinations of flow state remain elusive. In this dissertation I addressed this need by conducting a thorough literature review of flow, serious games, and game-based learning in order to propose a new model of flow in games. Two studies were conducted in support of this model. The first experiment consisted of the creation and validation of a play experience scale. Based on the data from 203 Study 1 participants, the Play Experience Scale was validated for use with video games. The 14-item version of the Play Experience Scale was composed of the components of freedom, lack of extrinsic motivation, autotelic experience, and direct assessment of play. The scale was reliable, with a calculated α of .86. In the second study, the newly developed scale was used alongside an immune system serious game to examine the impact of play, in-game performance, and emotional experience on flow in games. In an effort to provide a more symmetrical version of the scale, two items were added to the scale, resulting in a 16-item revision. Based on the empirical results obtained from Study 2's 77 participants, the proposed model of flow in games was revised slightly. Though Study 2 only examined a subset of the overall model of flow in games, the evidence suggested the model was a good theoretical match. Further, the two added items of the Play Experience Scale were valid, providing a final 16-item version of the scale. Play and in-game performance were key predictors of game-based learning. Additionally, play, video game self-efficacy, and emotional experience exhibited a reciprocal relationship with flow state. Implications for serious game development, scientific research into games and learning, and industry testing of game playability were provided. Following these implications, conclusions were presented alongside suggestions for further research.

Ad Astra

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This dissertation would not have been possible without the help of the many important people in my life. Though the popular perception is one of the graduate student slaving away alone, the reality is that the work isa collaboration between the student and their colleagues and mentors.

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CHAPTER 1
INTRODUCTION

1.1 Problem Statement

The intersection of learning sciences and digital entertainment has produced a new tool for training: the serious game. Serious games are games that move beyond simply providing enjoyment and into the realm of education and attitudinal change. Like simulations, serious games present a virtual reality of varying fidelity that allows learners to explore, experiment, or simply engage in learning. Successful implementations of serious games span a variety of contexts, from military training (Barlow, Morrison, & Easton, 2002), to health education (Lieberman, 1997), to humanitarian crisis awareness raising (Thompson, 2006). These kinds of games are increasingly used for a wide range of purposes, and gaining attention from researchers due to their ability to increase the attention and motivation of learners while continuing to produce effective learning. Given the growing prominence of these tools, it would be expected that the theoretical underpinnings of serious games are well-understood. Unfortunately, the appropriate design of serious games remains more art than science. Beyond the general lessons and guidelines the science of training provides (e.g., Salas & Cannon-Bowers, 2001), there is only a limited base of empirical findings to guide the development of serious games.

Though a number of research efforts have examined serious games, understanding these tools requires a thorough analysis of what makes them function as learning environments. The efficacy of serious games has been established, but the theory underlying them must still be built. Understanding the methods by which serious games are effective represents a new frontier of games research. Beyond merely understanding whether serious games are effective or not, theory-based explanations of game efficacy are required for scientific advances in serious games to continue. Recent literature has examined game-based learning with greater scrutiny, empirically testing the attribute-level explanations that were theorized over 20 years ago (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009). One construct that has garnered considerable theoretical discussion but surprisingly little empirical investigation is flow. A particularly useful theoretical explanation for serious game effectiveness, flow represents the optimum experience that can be anecdotally described as "being in the zone" (Chen, 2007).

First discussed within the context of work enjoyment (Csikszentmihalyi, 1975), the construct of flow is one of the most prominent elements of the positive psychology movement (Csikszentmihalyi, 1990). When an individual experiences flow they are said to be in flow state, a subjective experience characterized by increased focus, intrinsic motivation, a lack of concern for the self, an altered sense of time, and effortless involvement (Csikszentmihalyi, 1990). As a method by which to achieve high levels of immersion and motivation, flow has received significant attention from the scientific and gaming communities. Given the inherent motivational benefits of game-based learning technologies, this theoretical overlap creates a natural fit between flow theory and serious games. This scientific interest has even branched out of the realm of research and education and into the commercial domain. A game built from the ground up to focus on flow – flOw – made the transition from an online thesis to a successful commercial product (Chen, 2007). While such recent developments in research and practice have made the concept of flow more salient to the gaming community, the theory of flow is neither new nor untested. However, though flow has been studied empirically in other contexts, the discussion of flow within the context of games is largely theoretical. The notion of using flow for entertainment only scratches the surface of what flow offers the serious games community.

While the notion of flow state is appealing from the perspective of enjoyment, it is more broadly applicable to the human factors community. Far from being a simple component of immersion, flow describes and alters the entire experience underlying serious gameplay. In the case of serious games, gameplay is intrinsically tied to learning – suggesting that flow state may influence learning in serious games. Indeed, research has indicated that flow state is characterized by higher learning outcomes in a variety of contexts (Sorensen, 2007). If flow state is useful in general learning contexts, then it follows that flow will impact learning with serious games. Past efforts examining flow in games have provided considerable theoretical contributions that have led to this conceptualization of flow. Various theoretical models of flow have been proposed (e.g., Ghani, 1995; Guo, 2005; Cowley, Charles, Black, & Hickey, 2008), and guidelines for creating flow in games can be found throughout the literature (e.g., Jones, 1998; Sweetser & Wyeth, 2005). However, an examination of flow for serious games must move beyond simply describing flow and its anecdotal effects and move toward empirically illuminating the underlying construct and its relationship to games and learning.

Similarly, the core game construct of play is under-discussed and not appropriately measured. Though definitions of play are abundant in the literature (O'Connor & LaPoint, 1980), these definitions have not resulted in the development of validated measures of play experience outside the context of childhood development. The flow literature discusses the importance of play (Mathwick & Rigdon, 2004), but few empirical studies examine play at all. Further complicating this issue, the construct of playfulness as a trait has been confused with play experience as a state (e.g., Hoffman & Novak, 1997). The only context in which play has been effectively measured involves physiological measurement of a variety of internal neurological processes and physiological states (Mandryk & Atkins, 2007). A focused measure of play as a state would resolve this ambiguity while providing a new tool for research.

Given this state of the science, the problem is evident: flow state is purported to be useful for game-based learning, but empirical evidence for this relationship is largely derived from studies that have not been conducted with games. While flow is intuitively linked to serious games and learning, proper science demands a more rigorous explanation. To advance the science of serious games, critical studies into the effects of flow on game-based learning must be conducted. With this need in mind, this dissertation seeks to advance the science of game-based learning by focusing empirical efforts on flow in games and creating a measure of play to support these investigations.

1.2 Purpose of Study

The purpose of this dissertation, then, is to provide empirical evidence for a new model of flow in game-based learning. Through the formulation and testing of this new model, this dissertation works to provide the empirical evidence necessary to understand the relationship between flow, games, and learning. While numerous models of flow in games have been proposed, these efforts are fragmented and almost entirely without empirical validation.

Toward this end, a thorough review of the literature is provided. The topics of serious games, flow, learning, play, and motivation are investigated in order to establish where the field stands – and what hypotheses must be investigated to expand the science of flow in games. After this review of the literature is complete, extant models of flow in game are examined in light of the overall literature base. Based on these models and the literature, a new model of flow, games, and learning is proposed.

Once this model's theoretical basis is established, it is subsequently used as the guiding structure for two empirical efforts. The first effort involves a new measure of play experience, and a pilot study examining the psychometric properties thereof. In the second effort, an established immune system training game is used to examine part of this new model. Based on the insights gathered from these efforts, the proposed model of flow and game-based learning is revised. Finally, implications for practice and guidance for further research are presented.

CHAPTER 2
LITERATURE REVIEW

Before a new model of flow in game-based learning can be presented, it is necessary to examine the extant literature base and determine what aspects of serious games and flow can be empirically linked, what relationships exist solely based on theory, and what insights related psychological theories can provide. This section examines a variety of topics, including the three elements most pertinent to the discussion: serious games, flow, and learning. Given the subject matter's focus on play and motivation, the constructs of play and motivation are investigated in-depth. For each of these five topics, a brief conceptual introduction is followed by a review of extant theoretical and empirical literature. Following this review, the gathered information is synthesized into a new model of flow, games, and learning.

2.1 Serious Games

Serious games exist at the intersection of simulations, the science of training, video games, and general electronic learning environments. The use of games for training is nothing new to society. In the early 1800s, the Prussian army used a tabletop Kriegsspiel (literally, "war game") to train officers (Castronova, 2003). While this effort represented perhaps the first formalized training game for adult professionals, games have been used across human history and culture to convey values and knowledge (Roberts & Sutton-Smith, 1962). Today's game-based learning applications represent a scientifically driven avenue of education, informed through a broad range of interdisciplinary research and practice.

2.1.1 Defining Serious Games

Unfortunately, the exact parameters of what constitute a serious game are still debated by the serious game research community. Zyda's (2005, p. 26) formal definition makes for a useful starting point in defining serious games: "Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."

However, this definition excludes affective learning outcomes and serious games that are not video games. For the purposes of this discussion, the majority of the games referenced are in fact computer games, but this is not the only way in which serious games are instantiated. Similarly, learning outcomes targeted by serious games may be more affective in nature, as in the case of political serious games that seek to indirectly affect public policy via awareness raising (e.g., Darfur is Dying, a game focusing on the humanitarian crisis in Darfur; Thompson, 2006).

One of the distinguishing characteristics that separates serious games from simulations is the focus on fun. While many applications described as serious games are deficient in this element, one of the inherent goals of a game is to induce enjoyment. When fun is not an element of a serious game, it is more likely that the "game" could be more appropriately described as a low-fidelity simulation or electronic learning environment.

Thus, the definition of serious games used in this dissertation is more general and inclusive. A serious game is a representative task that harnesses play to convey knowledge, skills, or attitudes to one or more learners.

2.1.2 The Language of Games

The field of game-based learning has already progressed to encompass its own niche in training research. Naturally, this field is described and discussed through the language of its own evolving lexicon. While many of the aspects of serious games may be familiar to human factors professionals, the terms used to describe these elements are less universal. To allow this dissertation to progress without terminological ambiguity, some definitions for commonly used words and phrases are provided here.

Gameplay describes two potential elements: the act of an individual playing a game, and the interactions that are afforded by a game's design. In the former, gameplay is easy to understand, as it is simply the act of interacting with a game system. The latter definition is more meaningful to this discussion, as it carries with it a number of potential nuances. A more formal definition of gameplay is offered by Ang (2006, p. 306), who describes gameplay in video games as "activities conducted within a framework of agreed rules that directly or indirectly contribute to achieving goals."

This notion of gameplay is the driving element behind one of the earliest debates in the games literature: ludology versus narratology. These two terms describe different viewpoints from which the study and discussion of games can be conducted. Ludology examines video games by viewing them as play-based game activities, while narratology casts video games as interactive stories (Ang, 2006). From a ludological viewpoint, the pleasure that comes from playing a game is due to the actual gameplay. To narratologists, however, it is the narrative (i.e., the fiction, whether participatory or not) of a game that provides a pleasurable experience.

The intersection of a game's gameplay and its fiction can be described through the lens of endogeny and exogeny. An endogenous game is one that is designed so that the context (e.g., the game's fiction, visual representations, etc.) is linked directly to the gameplay (Squire, 2006). In other words, an endogenous game's gameplay is consistent with its narrative and appearance. An exogenous game's fantasy is not integrated with the gameplay provided by the game. In an exogenous game, the game's fiction is an additional layer of the game, and is not reflected in the interactions the player engages in. For example, the physics serious game Electromagnetism: Supercharged! allows players to interact with subatomic particles to teach electromagnetic principles (Squire, 2006). In this game, the gameplay (e.g., interacting with particles, moving using electric fields, etc.) is closely tied to the narrative (i.e., a miniaturized craft moving through the microcosm) and the external learning goals of the game. In an exogenous serious game, the gameplay does not reinforce the narrative and learning goals, as in the case of "edutainment" games such as Math Blaster, which allows young students to learn mathematical concepts via various space-themed games.

Immersion is a popular term in the games literature, and is related to the ideas of engagement and presence. Together, these three terms describe the game player's subjective acceptance of a game's reality, as well as their degree of involvement and focus on this reality (McMahan, 2003). Presence refers to the temporary acceptance of a game's reality over the real world, and is characterized by the feeling of "being there" (McMahan, 2003). This sensation is described in different contexts in the human factors literature, as in the case of telepresence in synthetic environments (Steuer, Biocca, & Levy, 1995). Immersion is often discussed within similar terms, representing the player's degree of involvement with the game environment (Calleja, 2007). Like presence and immersion, engagement refers to deep involvement with a game. However, engagement stems from gameplay rather than narrative or sensory stimuli (McMahan, 2003).

2.1.3 A Review of Serious Games Research

Though the formalized use of computer-based serious games is relatively new to the human factors and training community, empirical and theoretical research examining serious games for a variety of contexts is extant and flourishing. In this section, a brief history of serious games research is provided.

As noted, the use of games and play for learning is nothing new to human society. Video games are a newer mode of play, but their application for learning are similar to those of established training techniques (e.g., simulation, role play, etc.). While games have been used for learning for ages, serious video games are a relatively new topic in the scientific literature. The earliest discussions of digital games for training do not arise in the literature until the 1970s, with the discussion of games as potential learning simulations (Parry, 1971) and examples of successful game-based learning applications (e.g., Counselor; Sharan & Colodner, 1976). Parry noted that games are an active, dynamic activity that can serve a role similar to learning simulations (1971), while Sharan & Colodner (1976) actually used a learning game to study decision making. The Simulation & Gaming journal began its print run in March of 1970, signaling the emergence of a formal scientific discourse on games, simulations, and learning. In the early 1980s, the theoretical discussion of serious games reached a new level of scientific integration, as game-based training was examined from the context of cognitive psychology (Malone, 1981). Malone (1981) approached games for learning from the standpoint of cognition and motivation, noting the features of games that contribute to a learner's (or player's) motivation. From this point on, the discussion of serious games became closely tied with the notion of intrinsic motivation.

With the emergence of inexpensive computer technology and rapidly modifiable video games, the serious game research base flourished. Simultaneously, successes of game-based training in high-profile human factors domains (e.g., aviation and crew resource management; Baker, Prince, Shrestha, Oser, & Salas, 1993) led to the human factors community embracing serious games directly, with publications appearing in the primary journal of the field, Human Factors (e.g., Gopher, Weil, & Bareket, 1994; Washburn & Raby, 1998). Baker et al. (1993) examined air crews training via an off-the-shelf flight simulator game (Microsoft Flight Simulator 4.0) and found that both student pilots and experienced pilots reacted positively to the training, highlighting its potential use as a training tool. Gopher, Weil, & Bareket's 1994 study showcased the potential of low-fidelity games for training applied skills. Using the game Space Fortress to train pilots showed promising results, with actual flight skills increasing after training with the game.

While the first thirty years of serious game literature focused primarily on overarching theoretical concepts and the efficacy of individual game-based training platforms, the 21st century saw the emergence of more focused theoretical discussion and empirical examination of serious games. One thread of research focused on the fiction that defines games (Seegert, 2009), including the notion of fantasy and reality in game contexts (Habgood, Ainsworth, & Benford, 2005). Seegert (2009) posited that interactive fiction showcases the need for presence in electronic environments. Habgood, Ainsworth, & Benford (2005) proposed that the fantasy component of games is key to the their motivational enhancement, and that the proper matching of game content to gameplay produces more effective learning outcomes This notion grew in importance over the course of its development: the fit between a game's content and context, described as endogenous (fitted) and exogenous (not fitted), was introduced as a useful way to describe the layer of fiction surrounding a game's gameplay (Squire, 2006). In general, the literature identified endogeny as the more advantageous state for game fiction (Squire, 2006; Van Eck, 2006), and noted that fantasy was beneficial to creating learning outcomes (Habgood, Ainsworth, & Benford, 2005). However, much of this discussion was based on theoretical discussion rather than empirical research.

Continuing the trend of past game research, the topics of motivation and enjoyment drew considerable interest in the literature. More integrated models of motivation in games were developed, including frameworks of flow and motivation (Sweetser & Wyeth, 2005), adaptations of the input-process-output model to motivation and game-based learning (Garris, Ahlers, & Driskell, 2002), and discussions of game motivation in the context of industrial-organizational psychology theories such as self-determination theory (Ryan, Rigby, & Przbylski, 2006). Though the discussion of the motivational effects of serious games was not new at this point, the increased breadth of discussion and renewed focus on enjoyment as a factor of game-based training motivation (Smith, 2006) ensured that this new track of motivation-oriented research was useful to the field as a whole.

Another track of game-based research, the modeling of player characteristics and gameplay experiences, showed considerable advancement in the 21st century. Whereas previous investigations of serious games focused on the games and technology themselves, these efforts examined how players respond to game challenges (Cowley, Charles, Black, & Hickey,

2006) and what characteristics of players (e.g., self-efficacy, prior exposure to games, etc.) influence serious game efficacy (Orvis, Belanich, & Horn, 2006). Orvis, Belanich, & Horn (2006) empirically examined how self-efficacy and prior exposure to video games influenced training processes and outcomes (e.g., motivation, satisfaction, team cohesion, metacognition, etc.) in the America's Army game. Cowley, Charles, Black, & Hickey (2006) introduced a person-artifact-task model of virtual interactive entertainment. This model drew on the concept of flow in order to explain the interactions that occur as part of gameplay. Similarly, models of gameplay experience such as the experiential gaming model (Kiili, 2005) began to explain the processes of game-based learning from the point of view of the players themselves. Like the person-artifact-task model of Cowley, Charles, Black, & Hickey (2006), Kiili's experiential gaming model (2005) describes how individuals respond to game challenges and learning objectives. In Kiili's model, this occurs through the individual's experimentation, observation, reflection, idea generation, and schemata construction.

As the field's understanding of game players increased, so too did its conceptualization of how games are created to address the needs of players. Wilson et al's integration of game attributes (Wilson, Bedwell, Lazzara, Salas, Burke, Estock, Orvis, & Conkey, 2009) provided the starting point for further attribute-based research, describing how individual game attributes (e.g., game fiction, challenge, feedback) influence learning outcomes. Research following up on these theoretical propositions examined how game attributes such as challenge, fiction, and feedback influence gameplay and learning (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009), providing a bottom-up view of serious game technology. For example, Pavlas et al. (2009) found that, within the same serious game, an endogenous and fantastical fiction was more effective in producing learning outcomes (e.g., declarative knowledge) than an endogenous and realistic fiction.

While the theoretical and empirical advances in the science of games amassed throughout the past forty years are impressive, too many of these theoretical advances are yet untested. Much remains to be understood about how games provide learning, and how serious games can be improved as learning platforms. With this overview of the serious games literature in mind, this dissertation now turns to its primary topic of interest: flow.

2.2 Flow

The studies on human experience conducted by Csikszentmihalyi revealed a remarkably flexible and useful classification of human experience: flow. Described simply, flow is an optimal experience resulting in intense engagement, heightened motivation, receptiveness to information, and diminished perception of time (Csikszentmihalyi, 1990; Nakamura & Csikszentmihalyi, 2002). This state is encountered during tasks with clear goals, a need for concentration, feedback, a merging of action and awareness, matched challenge and skill, personal control, and intrinsic reward. While this appears simple enough at first glance, it is in fact somewhat troublesome: this definition of flow consists both of the necessary precursors to flow as well as the results of flow state. Another definition provided by Csikszentmihalyi (1990) enumerates the eight necessary conditions for flow to arise, though even in this definition outcomes are mixed with necessary states: 1) A task to accomplish, 2) The ability to concentrate on the task, 3) Clear task goals, 4) Immediate feedback, 5) A sense of control over actions, 6) Deep but effortless involvement, 7) Loss of concern for self, and 8) An altered sense of time. Of these, only one through six can actually be considered to contribute to creating flow. The last two are better categorized as flow outcomes. To address flow from a theoretical standpoint without introducing further ambiguity, these definitions will be separated into those items that work to create flow and the actual consequences of flow state.

From the eight items offered by Csikszentmihalyi as necessary for the creation of flow, the first six are evident as actual components that create flow. The first, “a task to accomplish,” is logical enough: flow state can only arise during a task; thus, a task is a necessary precursor to flow. Further, “the ability to concentrate on the task” suggests that the task need not be automatic by nature, but require actual cognitive effort on the part of the performer. This, in turn, relates to the requirement of “a sense of control over actions.” It is not merely enough for a person to be performing a task actively, they must feel that their actions have some sort of impact that is within their power. Finally, the performance of the task should be produced via “deep but effortless involvement.” This is the most vague precondition, as depth of involvement is highly subjective (and can be viewed as an outcome). However, understanding this point as a skill-challenge pairing issue makes it fairly easy to digest: the interaction should challenge the performer without overwhelming them. This skill-challenge pairing concept is best explained by graphically examining the relationship between a person’s skill and the challenge of the task (see Figure 1). If an individual’s skill does not match the challenge provided to them, anxiety results. Conversely, if their skills exceed the challenge, the individual becomes bored. It is when skill and challenge are appropriately paired and the individual is challenged without being overwhelmed that flow is reached.

Together, these four items are the task-specific precursors to flow. The last two components that work to create flow deal with feedback available to the task performer. First, the task requires “clear task goals.” This means that the desired end state of the task should

Table 1: Flow factors, adapted from Csikszentmihalyi, 1990 and Nakamura & Csikszentmihalyi, 2002

Flow Requirements & Outcomes	
A task to accomplish	Intense engagement
Ability to concentrate on a task	Intrinsic motivation
A sense of control over actions	Receptiveness to information
Deep but effortless involvement	Merging of action and awareness
Clear task goals	Loss of concern for the self
Immediate feedback	Altered sense of time
Matched challenge and skill	

be clear to the task performer. The "immediate feedback" mentioned by Csikszentmihalyi provides performers with insight into the completion of these goals. When combined, these two items provide the feedback and context for the task defined by the previous four components.

From the two definitions offered by Csikszentmihalyi, multiple outcomes of flow are evident: intense engagement, intrinsic motivation, receptiveness to information, merging of action and awareness, loss of concern for the self, and an altered sense of time (see Table 1). The engagement and motivation that are a result of flow are perhaps the most meaningful outcomes, as they are drivers for many of the other flow effects. Based on a cursory look at these outcomes, it is immediately apparent why flow and games are a logical pair – engagement, motivation, and focus define almost all of flow's outcomes. As the goal of games is to entertain, and the goal of serious games is to engage, the fit between flow and games is definitional.

2.2.1 Flow and Learning

While flow is a fairly new construct for the field of serious games, efforts to harness flow for learning have been furthered by recent research. Beyond merely theorizing about

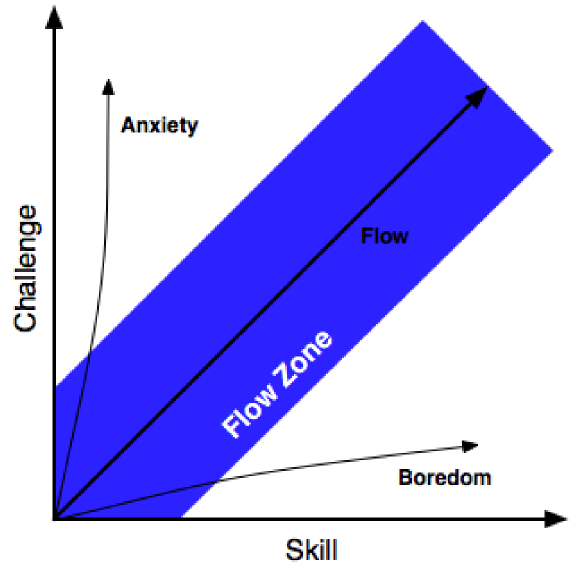

Figure 1: Skill-challenge relationship (adapted from Chen, 2007)

the potential for flow to assist in producing learning outcomes, empirical work has been performed on linking flow and learning. To further guide the use of flow in serious games, examples of such research and applications are provided here.

Many studies of flow in learning environments presuppose the usefulness of flow without examining its effects on learning (see Sorensen, 2007; Huang, 2007). Instead, such studies focus on flow as a potential outcome of a learning environment, and do not provide evidence for flow's effects on learning. Sorensen (2007), for example, simply measured flow during an engineering competition without tying flow to learning. Similarly, Huang (2007) measured the flow experiences of students in an English class, and suggested that flow might be useful for learning, but did not actually measure learning or test flow's effects upon learning outcomes. While these studies provide information on determining how to establish flow and assist in building an understanding of the construct in general, they do little to empirically demonstrate why flow should be considered for use in an educational context. Thankfully, a growing amount of research is targeting flow's actual effects, providing an expanding scientific rationale for flow's integration with learning environments. For example, in a field study of flow experience of students in a 5th and 6th grade Australian school, Harley (2003) found that the students experienced flow as a result of a curriculum that provided meaningful learning and an educational environment that facilitated flow.

Other examples of flow's utility to the learning sciences abound. Within the context of electronic environments (e.g., games, web-based learning tools, electronic tutoring), a number of studies have been conducted pairing flow with learning. The usefulness of flow in providing positive learning outcomes within a web-based electronic learning system was demonstrated in a study that found significant correlation between flow experience, learning outcomes, and attitudes towards e-learning (Choi, Kim, & Kim, 2007). This has strong implications for flow in serious games, as the primary indicators of flow state within the electronic environment were the interface, content, and interactions provided by the tools (Choi, Kim, & Kim, 2007). Not only was flow successful in creating positive learning outcomes, but flow was largely created through aspects of the e-learning tool's design. The findings of this study are bolstered by similar results encountered during an analysis of flow in an online learning environment, where it was found that flow state was experienced most often by high-achieving learners (Pearce, Ainley, & Howard, 2005). A similarly situated study determined that the presence of flow within e-learning environments was positively correlated with an intent to use that technology for learning purposes (i.e., motivation; Liu, Liao, & Pratt, 2009). Finally, the relationship between flow, electronic environments, and playfulness was found to benefit learning outcomes (Webster, Trevino, & Ryan, 1993). The usefulness of flow within the context of play and electronic environments provides an especially salient reason for the inclusion of flow in serious games.

These examples lend credence to the notion of using flow for learning. Though the practice of pairing flow with learning is still fairly new, its successes in digital environments are promising for the serious games community. As more studies on the relationship between flow, learning, and games are conducted, similar successes are likely.

2.2.2 Parallel Theories

The factors of flow discussed herein are thus far not defined specifically enough for scientific purposes. While it is possible to identify components of flow when examining a task or game using these factors, their theoretical basis requires further explanation. The psychological theories that support these components provide a necessary scientific basis for flow state. In this section, theories that relate to flow state, its outcomes, and its antecedents are discussed.

2.2.2.1 Task Complexity and Task Difficulty

Task complexity arises as a result of the cognitive demands imposed by a task onto the task performer or task performers (Kim, 2009). When task complexity is paired with the task performer's individual characteristics, task difficulty – the degree of challenge encountered when performing a task – emerges (Orvis, Horn, & Belanich, 2007). Unfortunately, the literature has treated the terms task difficulty and task complexity somewhat interchangeably (Kim, 2009). However, modern conceptualizations of these constructs have divided them into cognitive task factors (complexity) and task-learner pairing characteristics (difficulty; Robinson, 2001). Another way to consider these ideas is as absolute difficulty and relative difficulty, where absolute difficulty describes the task characteristics and relative difficulty describes the discrepancy between the task performer's capabilities and the task's demands. This conceptualization of complexity and difficulty is similar to the concept of the challenge/skill relationship in flow state (Csikszentmihalyi, 1990), as it is based on the relationship between the individual and the task.

Research on the relationship between task complexity and learning has shown that adaptation to task complexity leads to learning success, as learners who do not successfully recognize the discrepancy between their ability and the task's complexity do not learn as ably as those who do (Pieschl, Bromme, Porsch, & Stahl, 2009). When task difficulty is too high (i.e., the task complexity exceeds the learner's abilities), cognitive resources are strained and learning outcomes are reduced (Pomplun, Reingold, & Shen, 2001). This lends further credence to flow state's emphasis on matched skill-challenge pairings, as these pairings represent states where difficulty is present but not overwhelmingly so, allowing for effective learning and performance (Csikszentmihalyi, 1990).

2.2.2.2 Intrinsic Motivation

One of the most noticeable effects of flow is the motivational enhancement that occurs during flow state. When experiencing flow, an individual continues to work on a task simply for that task's sake (Csikszentmihalyi, 1990). A task experience with these characteristics is best described as autotelic. An autotelic task is performed solely for its own sake, requiring no extrinsic reward. While this motivational effect is easy to subjectively identify, explaining this motivation in a theoretical context is more complicated. A number of theories of motivation have arisen in the field of psychology, and examination of these theories helps to explain how this autotelic experience functions during flow. In particular, intrinsic motivation provides key insight into the theoretical link between flow and motivation, as it addresses the autotelic nature of a task during flow state. Intrinsic motivation is discussed in greater detail when the topic of motivation is addressed as a whole.

2.2.2.3 Interestingness, Immersion, and Engagement

The intense focus that individuals experience when they reach flow is one of its most recognizable characteristics. Their perception of "self" merges with their execution of actions, and their understanding of the passage of time is distorted (Csikszentmihalyi, 1990). Within the realm of computer games, several concepts have emerged that have been used to describe this aspect of flow: interestingness, immersion, and engagement. Interestingness is the degree to which a game affords the user allocating attentional resources to it (Yannakakis & Hallam, 2004), and is influenced by the challenges that players experience during gameplay. In the case of adversarial games, this presents a complicated balancing act, as completely optimal adversary behavior quickly leads to games where the player simply cannot win. An interesting game, then, is one where players are challenged by opponents (or artificial circumstances) without being overwhelmed. Beume et al. (2008) posit that interestingness as defined by adversary behavior must relate to flow, and it is reasonable to connect this notion of interesting behavior to optimal skill-challenge pairing. This requirement for interestingness may relate to the need for interesting information in general (Hidi, 1990), as more complex interactions between the player and the game represent a more interesting unit of information than a predictable scripted interaction. In this way, interestingness relates to the curiosity component of games (Malone, 1981) as well as the pairing between task demands and player skill necessary for creating flow.

Engagement is a concept that garners much attention in the games literature, often being discussed as a component of – or synonym for – the experience of immersion (Brown

& Cairns, 2004). A player is engaged with a game when they experience an emotional investment with the game and are interested in continuing to play as a result (McMahan, 2003; Brown & Cairns, 2004). Like flow, immersion and engagement are easy to subjectively identify, but difficult to empirically pin down. However, theoretical examination of these constructs has identified paths and barriers to engagement that are produced by game design aspects. For example, immersion requires an "invisibility of the controls" (Brown & Cairns, 2004) to take place, which immediately evokes the effortless involvement component of flow. This effortlessness can be confounded by complicated physical controls (e.g., multi-button input on a traditional controller), or aided by immediately meaningful interaction metaphors (e.g., swinging the Wii's remote like a baseball bat, using trigger buttons on a controller for shooting, etc.).

As explanations of the focus experienced during flow, the concepts of interestingness and engagement are especially useful for the specific application of flow in games, as they are terms familiar to game players and designers. It is likely that this immersion effect is a result of an interplay between motivation, engagement, and factors such as interestingness. Understanding how to bring users through the barriers to engagement (Brown & Cairns, 2004) and into an immersed state will enhance the ability of designers to create flow in games, as these same barriers detract from the focus that is inherent and necessary to flow. However, more empirical work is needed to understand the nature of engagement and interestingness in relation to flow.

2.2.2.4 Zone of Proximal Development

The zone of proximal development (ZPD; Vygotsky, 1978) is typically discussed in a developmental education context, and deals with how learners can learn most effectively.

In the context of ZPD, the "zone" represents what the learner can do with assistance from another individual, and the "core" comprises those actions a learner can perform without assistance (Borthick, Jones, & Wakai, 2003). Within the zone, learners acquire knowledge not by rote instruction but by collaboration with another party. This instruction by non-instruction is accomplished by bridging the gap between what an individual can perform and what they cannot perform within a collaborative task. By working with another individual or system, this gap becomes a useful tool for learning. This necessity to push the capabilities of the individual slightly past their normal range bears similarities to the skill-challenge matching requirements of flow. Similarly, the goal-oriented assistance provided by a second party in ZPD mirrors flow's requirement of clear goals (Strobel & Idan, 2006). In flow theory, there is an optimum zone of performance (see Figure 1) that creates the favorable outcome of flow state. Similarly, in terms of ZPD, the range of potential performance bounded by an individual's skills combined with potential cooperators is analogous to this flow zone. In both cases, the task performer or learner can only reach the optimum state when kept within this zone. For ZPD, this optimal state simply represents the highest level of performance an individual can exhibit.

Though ZPD is primarily considered in the context of development and education (Dunn & Lantolf, 1998), it is nonetheless interesting to note the similarities between it and flow. The major theoretical difference to consider is that ZPD, by definition, relies on an external collaborator. It may be possible, however, to view this collaborator in a more abstract light – for example, as the system or game that the learner is using. Viewed in this way, ZPD becomes quite relevant to the concept of flow state in serious games. Though ZPD is not integral to flow theory, it is useful to examine such interdisciplinary constructs that mirror flow to expand understanding of flow.

2.2.3 Theoretical Models of Flow

The initial models of flow provided by Csikszentmihalyi primarily focused on the skill-challenge aspect of flow rather than the broader range of antecedents and outcomes. Originally, the model-based conceptualization of flow closely resembled Figure 1, with challenge and skill predicting flow, anxiety, or boredom (Csikszentmihalyi, 1975). However, this model was soon revised into two further versions: a four channel model of flow (see Figure 2) and an eight channel model of flow (see Figure 3; Csikszentmihalyi, 1990; Ellis & Voelkl, 1994). In the four channel model, an additional element of apathy is added, occurring when both challenge and skill are low (Csikszentmihalyi, 1988). The eight channel model further details the potential outcomes of a challenge-skill pairing, providing the outcomes of flow, arousal, control, boredom, relaxation, apathy, worry, and anxiety (Csikszentmihalyi & Nakamura, 1989). These models, while useful in explaining how the relationship between skill and challenge can lead to flow, suffer from a major flaw: they do not explain any of the other elements that Csikszentmihalyi proposed as leading to flow. While the skill-challenge relationship is certainly important for applying flow in games, there is much more to flow than this.

As flow has been examined in applied contexts, a number of models that address the individual factors, components, or dimensions of flow have been proposed. Within the context of electronic learning, several models and frameworks of flow have arisen that help to create a more complete understanding of the construct. A model of flow and exploratory use within hypermedia environments, though only using two factors to predict flow experience, added the notion of perceived control to challenge (i.e., skill-challenge pairing) to create a short but predictive model of flow experience (Hoffman & Novak, 1996). Perceived control

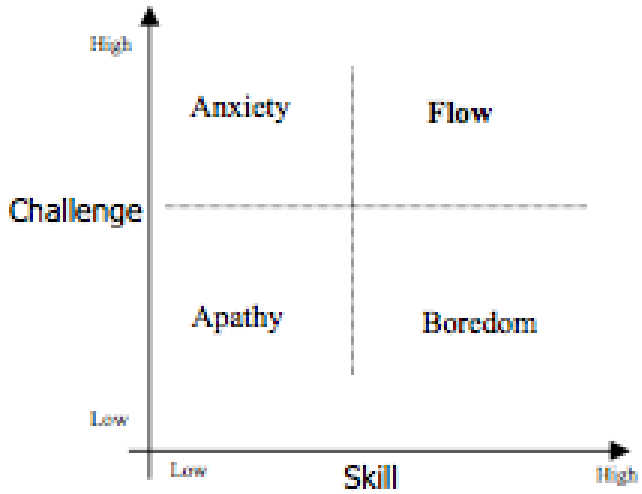

Figure 2: Four channel model of flow (reproduced from Guo, 2005)

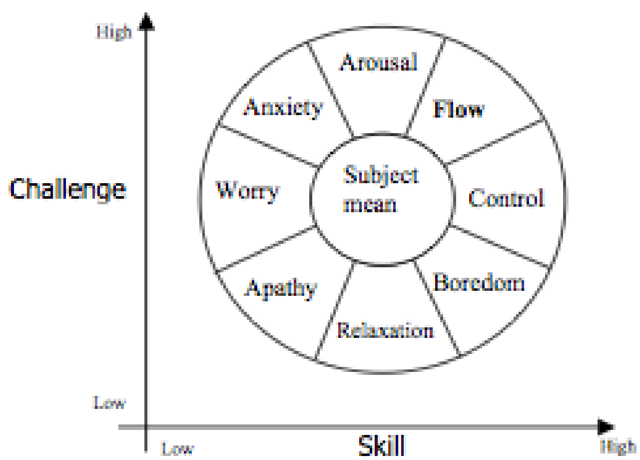

Figure 3: Eight channel model of flow (reproduced from Guo, 2005)

shares elements of the concentration and control requirements previously discussed herein, as it deals with the user's perception of their ability to manipulate the learning environment (Hoffman & Novak, 1996). This model was further developed in an empirical study in web use, with a focus on the skill-challenge pairing as a continuous variable (Novak & Hoffman, 1997). Flow has also been examined within computer-based communication, with researchers producing a model predicting flow as resulting from ease of use, computer skill, and type of technology (Trevino & Webster, 1992). In this model, skill combined with type of technology is analogous to the skill-challenge pairing of flow, while ease of use relates to a number of flow requirements (i.e., concentration and control, clear goals, and immediate feedback). Unlike other models, this model also provides outcomes of flow within a computer environment: attitude (toward the technology), effectiveness, quantity of communication, and barrier reduction (Trevino & Webster, 1992). With the exception of effectiveness, each of these outcomes essentially deals with the user's engagement and motivation to use the technology, which recalls Csikszentmihalyi's original definition of flow.

Within the context of electronic environments, additional theoretical models of flow have been proposed. Kiili's (2005) model of flow in computer-mediated environments indicates that flow results out of a three-way pairing between person, task, and artifact, with the previously identified flow antecedents controlling whether flow state emerges (see Figure 4). This model is similar to the Finneran and Zhang (2003) model of flow, which states that flow antecedents are contingent upon person, task, and artifact pairings. In Paras and Bizzocchi's (2005) model of flow in games, play is the key element that lies between games and flow. Similarly, Reid's (2004) model of flow in virtual reality interactions casts flow and playfulness as reciprocal factors in user experience. These models share the common advancement of an explanation of flow that stems from the interaction between the task and the individual.

The most comprehensive model for flow state in an electronic environment is, like the previous model, based in hypermedia (specifically, an online learning tool). Hoffman and Novak (1996) proposed a model of flow state for users navigating online environments.

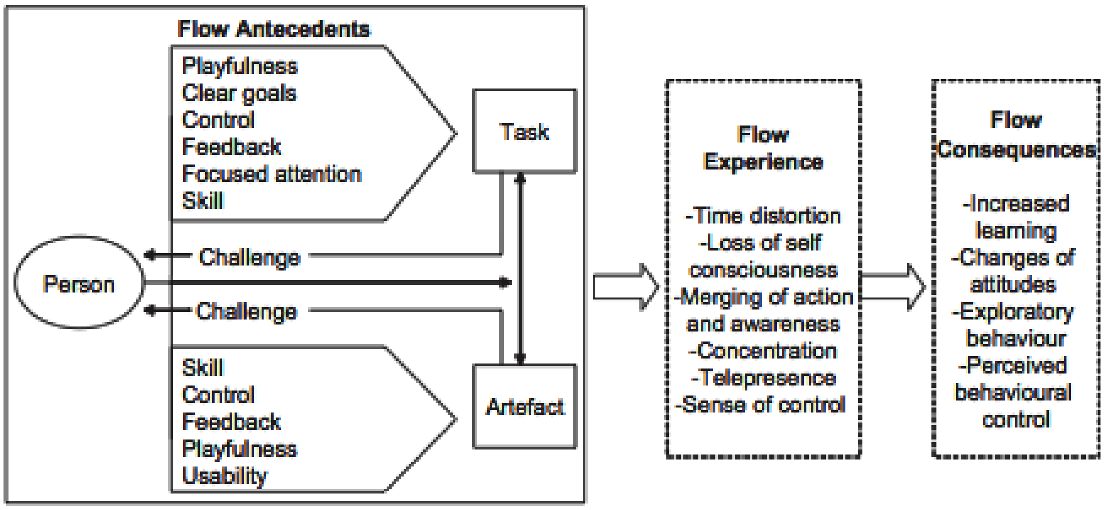

Figure 4: Flow model (reproduced from Kiili, 2005)

This model includes a number of factors as preconditions for flow, including the traditional skill-challenge pairing, interactivity, focused attention, and process characteristics such as goal orientations. Of particular note is the inclusion of increased learning as an outcome of flow in addition to traditional outcomes such as enjoyment, altered sense of time, and focus (Hoffman & Novak, 1996). While this model is unique in providing a broad look at a number of requirements and outcomes for flow, it is organized into a flowchart style that does not make it particularly useful from an experimental standpoint. The second iteration of this model is unique in its contribution of the element of an empirically measured play construct (Hoffman & Novak, 1997). While this model is organized in a more useful fashion, the construct of play is severely misinterpreted in the study. By using Webster & Martocchio's Computer Playfulness Scale (1992), the authors measured the trait of playfulness rather than the state of play, resulting in a theoretically suspect model. In the games literature, other frameworks and organizing models of flow have been proposed (e.g., Jones, 1998; Sweetser & Wyeth, 2005), though these were not created as causal models of flow and flow outcomes.

This lack of testability makes these models informative but ultimately limited in applicability to research.

While Hoffman and Novak's (1996; 1997) model of flow is perhaps the most theoretically complete model of flow in an electronic environment, Guo's (2005) model of flow in web shopping provides a rare model of flow that is empirically qualified with path coefficients that indicate the strength of relationship between various factors in flow state. Unfortunately, this model of flow is based on interactions performed in the presence of significant extrinsic consequences (i.e., online shopping), and is thus of reduced usefulness for the study of flow in games. Nonetheless, the comprehensive empirical examination is useful in providing a data-driven model of flow.

Clearly, flow has been discussed from a variety of theoretical standpoints. Though each of the models and frameworks discussed above reflect some of the factors and outcomes of flow, none satisfactorily draw on empirical data to illustrate how to create flow and understand the consequences thereof. The early models focus too much on the skill-challenge relationship at the expense of other antecedents and outcomes, while the models specific to electronic environments are more explanatory than causal. To guide creators of serious games as well as researchers looking to establish empirical links between flow factors and learning outcomes, a comprehensive and causal model of flow in games is required. The first step in creating such a model is providing a clear set of definitions of the factors of flow in games.

2.2.4 Conceptualizing Flow in Games

To empirically investigate flow's effects on game-based learning and create this new model, it is necessary to outline the factors of flow within the context of games. This enumeration of factors is based not only on the factors of flow identified in the section on Csikszentmihalyi's basic definition of flow, but also on past attempts to integrate the theories of flow and games. Csikszentmihalyi's factors of flow, as previously discussed, are best grouped into requirements and outcomes of flow. The requirements of flow as introduced by Csikszentmihalyi (1990) are a task to accomplish, the ability to concentrate on the task, clear task goals, immediate feedback, a sense of control over actions, and deep but effortless involvement. The outcomes of reaching flow state include a loss of concern for the self, an altered sense of time, increased engagement, intrinsic motivation, receptiveness to information, and a merging of action and awareness.

Attempts to integrate flow and games have worked to match these initial factors with elements of games. Sweetser and Wyeth's (2005) GameFlow model adapts Csikszentmihalyi's eight elements of flow into elements of game design. The requirement of a task to accomplish, for example, becomes "the game" in the GameFlow model. Similarly, Jones (1998) and Cowley, Charles, Black, and Hickey (2008) worked to create one-to-one pairings between the elements of flow described by Csikszentmihalyi and elements of games evident from literature. However, included in these taxonomies are flow outcomes such as engagement or motivation. For the purposes of examining how games create flow, only the flow requirements are meaningful. Thus, when comparing these efforts, the "loss of concern for the self" and "altered sense of time" outcomes are not included, though they were in each of the original works. A comparison of these three taxonomies is provided in Table 2.

A look across these pairings paints a somewhat jumbled picture. Some elements are fairly concrete and clear, while others are thoroughly vague. Some elements, like the basic task, are simple to identify in games. Others, such as sense of control over actions, are not

Table 2: Flow requirements linked to game elements

Flow Requirement	Sweetser & Wyeth (2005) Game Element	Cowley et al. (2008) Game Element	Jones (1998) Game Element
A task to accomplish	The game itself.	The complete gaming experience.	Levels provide sub-tasks that lead to completion of whole task.
Ability to concentrate on task	Game provides interesting stimuli & workload.	Presence; Dedicated gaming environment	Creation of convincing worlds to draw users in.
Clear task goals	Primary and intermediate goals are presented.	Missions, plot lines, and levels.	Survival, collection of points, gathering of items, solving puzzles.
Immediate feedback	Feedback is provided via status, score, progress indicators.	Rewards and penalties.	Actions have immediate consequences. Shooting an NPC causes a result, picking up an item moves in.
Sense of control over actions	Player is able to move their avatar(s) and feel control over input devices.	Familiarity or skill with controls, knowledge of game conventions.	Mastering physical inputs such as keyboard or mouse.
Deep but effortless involvement	Game environment should transport player emotionally/viscerally.	High motivation to play, emotional draw to content.	Fantastic environments remove suspension of disbelief and engage players.

consistently identified across these three approaches. Thus, to guide the framework creation that will occur in the next section, a game-oriented list of flow's prerequisite factors must be created (see Table 2).

2.2.4.1 A Task to Accomplish

The task to accomplish in a game is the least complex flow element to define. It is, as Cowley et al. (2008) and Sweeter and Wyeth (2005) identify, simply the game itself. However, the game's tasks are likely split into sub-tasks based on the user's own perceptions toward the game. In a game of *Tetris*, for example, the player may conceptualize the task as either attempting to get the highest number of lines cleared, or they may try to clear lines the fastest. While the task remains fairly similar, their conceptualization thereof changes. Thus, as an element of establishing flow, "a task to accomplish" becomes the game and the player's perception thereof.

2.2.4.2 Ability to Concentrate on a Task

The ability to concentrate on a task, by its phrasing, requires two preconditions: 1) a need to concentrate and 2) a freedom to do so. Each of the definitions in the previous taxonomies covers the need to concentrate, but does not discuss the removal of any barriers to concentration. Such waylays may include difficult controls, confusing interfaces, or distracting information. Thus, in a game, the ability to concentrate on a task is manifested in both a task requiring concentration as well as an interface that does not impede it. This need for concentration can be created through challenging tasks, akin to the challenge component of GameFlow (Sweetser & Wyeth, 2005). Without a task that produces challenges, problems, or conflicts, there is no impetus for concentration. This concentration requirement effectively demands cognitive focus from the user as they attend to tasks and solve problems. Any interference from a confusing interface or difficult control scheme will detract from this focus and require the player to allocate resources toward a meta-task (i.e., grappling with manipulating the game rather than playing it).

2.2.4.3 Clear Task Goals

The need for clear goals is echoed by the training community, as a principle of instructional design (Anderson & Krathwohl, 2001). Similarly, the need for explicit goals and support structures toward those goals is raised by the serious games community (Strobel & Idan, 2006). Coupled with the need for clear goals in flow state, it is wholly evident that the intersection of flow and games for learning demands effective goal presentation. One method by which to explain goals in the game is to make them clear from an interaction-affordance standpoint. This method relies on prior knowledge to guide the player towards the goals of the task. For example, if presented with a ball and a circular hoop, the obvious affordance for the player is to get the ball through the hoop. A more direct method of presenting task goals is to quite literally present them. Many games provide a sort of goal listing (e.g., the "quest log" in many online role playing games) that guides players through their tasks. Regardless of the mode of presentation, understanding goals is necessary for a player to move toward flow state.

2.2.4.4 Immediate Feedback

Immediate feedback is provided in a game when the results of a user's actions are immediately apparent to them. For example, changing the amount of funds placed toward a government policy or program in the game *Democracy 2* provides feedback as to the effects of that change on various constituents. On a more visceral level, feedback can take the form of a cause-effect relationship: when the player shoots at an enemy, the enemy is damaged. The important aspect of this requirement is that the effects of the player's actions are transparent to the user. While long-term effects of an action may be difficult to ascertain, short-term effects of player performance should be evident. Without this feedback, the game becomes an open loop where the user must guess as to the efficacy of their actions. Note that immediate feedback can also be provided via the traditional notion of feedback in games (Malone, 1981), where information on action success or failure is provided in a quite literal sense.

2.2.4.5 Sense of Control over Actions

The sense of control over actions required for flow state describes the need to feel the "impact" of performed actions. The ability to concentrate on a task describes control in the basic physical sense (i.e., the controls not obstructing interaction); thus, the sense of control that is required for flow does not describe control over the game, but rather control in the game. A sense of control is created when the player has a feeling of agency. For this to occur, the player's actions must have a salient effect upon the game environment. This element is similar to the notion of control (Garris, Ahlers, & Driskell, 2002) identified in the games literature. Without this agency, a player is less of an active member of the game fiction and more of a passive viewer. For example, a game with many choices that provide lasting effects both in the short and long term such as *Fable 2* provides a high amount of agency. Conversely, a highly linear role playing game or visual novel game provides little agency, and thus the user experiences less sense of control over their actions.

2.2.4.6 Skill-challenge Pairing

Though it is not introduced as part of the original elements of Csikszentmihalyi's flow description, the relationship between skill and challenge is key to understanding flow. Despite not listing it as a requirement for flow, Csikszentmihalyi's original model focuses almost entirely on this construct (Csikszentmihalyi, 1990). The relationship between skill and challenge can result in flow, anxiety, or boredom (see Figure 1), with flow arising when the skills of an individual are sufficient to complete the challenges provided, rather than too high or too low. In the context of games, technologies such as adaptation or dynamic difficulty adjustment (Chen, 2007) can ensure that this skill-challenge pairing remains appropriate for inducing flow.

2.2.4.7 Deep but Effortless Involvement

The final requirement for flow state in games is perhaps the most nebulous. Though it is easily interpreted as being part of the outcome of immersion, the concept of effortless involvement is closely related to the requirement for control. Deep but effortless involvement draws on each of the previous requirements to create the immersion that is prized in games. Effortless involvement requires a task to accomplish, and an unimpeded ability to concentrate on this task. Once these requirements are met, as long as the controls and interface do not hinder the player (as per the concentration & control game requirement), the performance of a player is “effortless.” The depth of interaction is a result of the availability of meaningful choices. A game is, at its core, “a series of interesting choices” (Sid Meier; in Dickey, 2005, p. 67). Interesting choices arise when the skill-challenge pairing is appropriate and multiple solutions are present for a given problem. Thus, deep but effortless involvement is a result of unimpeded interaction with a skill-challenged tuned system that provides interesting choices. Because this element of flow is somewhat split across antecedent and outcome, the proposed model of flow will divide this element's aspects into the other elements of control (for the antecedent portion) and immersion (for the outcome portion).

2.3 Play

Play is one of the most recognizable characteristics of the human experience. Play can be found in the make-believe fantasies of children, in the pick-up sports games of adolescents and adults, and in the myriad leisure activities found around the world. From childhood to adolescence to adulthood, human beings engage in play (Anderson, 1998; Umek, Musek, Pecjak, & Kranjc, 1999). The pursuit of play is something that defines humanity, but it is not unique to homo sapiens as a species. Animal play is well-documented, serving similar non-functional (i.e., not essential for survival) roles in humans and animals (Van Leeuwen & Westwood, 2008). In this section, the notion of play and its relation to learning and games is discussed.

2.3.1 Defining Play

While play is intuitively easy to recognize, it is remarkably difficult to define: "We seem to intuitively know what play is, but we still have difficulty defining exactly what factors are involved in the play process" (Lentz, in Codone, 2001). A simple definition of play might cast it as an intrinsically motivated activity free of extrinsic goals or consequences (O'Connor & LaPoint, 1980). Huizingia (in O'Connor & LaPoint, 1980) defines play as an activity that is: voluntary, different from ordinary life, regulated by rules, has only intrinsic value, and has fixed limits in time and space. However, this definition is somewhat outdated, and though useful in initially growing the science of play, has since been supplanted by new theory and evidence. A modern definition of play by Gordon (2008) offers a fairly complex view of the construct:

> "Play is the voluntary movement across boundaries, opening with total absorption into a highly flexible field, releasing tension in ways that are pleasurable, exposing players to the unexpected, and making transformation possible. Transformations occur as frames bisociate and the parts and the whole interpenetrate,

> increasing the differentiation of the part, the integration of the whole, and the range, coordination, and spontaneity of movement between and among them." (p. 12)

While this definition is rather in-depth, it is also unwieldy and largely philosophical. To clearly define play for this dissertation, it must be possible to discretely categorize behaviors as play or non-play. Other definitions of play have described it in terms of the characteristics that must be present in the activity, such as surprisingness, novelty, incongruence, randomness, suspension of reality, and variety (Levy, 1978). However, such definitions focus overly much on the task itself, and thus may be better suited to describing how a task engenders play rather than the measurable experiences of a human engaging in play.

More recent definitions of play invoke the ideas of freedom within rules. Zimmerman describes play as "the free space of movement within a more rigid structure," noting that, "play exists because of and also despite the more rigid structures of a system." (Zimmerman, in Esposito, 2005, p. 3). This interpretation of play is somewhat similar to that of Caillois (2006), who describes play as an activity that is free, separate, uncertain, unproductive, governed by rules, and make-believe. However, the most applicable modern definition of play may be the one offered by O'Connor and LaPoint (1980), who cast play as "any voluntary human activity aimed at intrinsic satisfaction which is initiated and completed by the player(s), requiring mental awareness" (p. 7). This definition becomes especially pertinent when taking into account Millar's (1968) note on how play should be considered: "perhaps play is best used as an adverb; not as a name of a class of activities, nor as distinguished by the accompanying mood, but to describe how and under what conditions an action is performed" (p. 21). Thus, play is used as a modifier for behavior. To engage in play is to engage in behavior that is performed as play. Under such a definition, enjoyment is not definitive evidence of play. Rather, the context and process of a behavior determines whether it is play.

The characteristic that makes it possible for an individual to engage in play behavior is playfulness. Playfulness enables an individual to "step outside of and manipulate interpretive frames from the perspective of another frame" (Gordon, 2008, p. 7). In other words, playfulness allows an individual to make an activity meaningful in an abstract sense.

2.3.2 Play as Learning

One of the reasons play is so pervasive in human behavior is that it is a kind of learning. Specifically, play represents not only recreation, but also a "preparation for maturity" (Sutton-Smith, 1997, p. 47) in children. When children are between two and six years of age, it is common for them to engage in activities that are both playful and developmental. For example, locomotor play, which is play that involves large body movements, allows children to learn physical skills and develop their endurance and musculature (Smith & Pellegrini, 1998). In social play, such as "playing house", children acquire social skills, learn scripts for acceptable behavior, and begin to develop an understanding of social coordination (Smith & Pellegrini, 1998). Even solitary play activities, such as children talking to themselves before sleep, can reinforce skills. In the case of language play, children repeating phrases to themselves in a humorous fashion assists in the development of phonology, vocabulary, syntax, and grammar (Smith & Pellegrini, 1998). On a more global scale, the activity of play in children may be a necessary aid to the development of their minds (Dunn & Cutting, 1999), as friendly interactions lead to the development of a model of the world and the individuals in it.

The examples of children learning through play highlight how play functions as a learning process. Imitative play allows children to "practice" skills that will be required when they are members of society – for example, in agricultural groups, children pretend-perform the jobs that adults are tasked with (e.g., cooking, cleaning, planting, building; Smith, 1982). While play-based learning is surprisingly under-explored in the literature, the notion of a "blended" activity that mixes learning and education is similar to the model of game-based learning proposed by Garris, Ahlers, and Driskell (2002). In the same way that a game with learning content provides an integrated experience that leads to learning, play activity that contains material that is being reinforced to children may be the mechanism by which early childhood play functions as learning.

Today, the evolutionary advantage of learning through play has been largely supplanted by formalized education (Smith, 1982). Play is largely viewed as an outlet for energy rather than a method by which knowledge can be conveyed. However, serious games highlight how play can be used for a direct purpose by humans of all ages. The emergence of a new ludological (i.e., game study) movement shows this shift in the conceptualization of play (Malaby, 2007). Similarly, the emerging concept of playful learning highlights the utility of directed play in fostering meaningful learning (Resnick, 2006).

2.3.3 Play in Games

It seems natural that play is an inherent part of a game. However, recalling Millar's (1968) warning on identifying play based on outcome rather than process, it is not a simple rule that a game invokes play behavior in its players. Intrinsic motivation and freedom are hallmarks of play behavior, and it is all too easy to invoke examples of games that do not contain either of these elements, as in the case of habitual gambling (Gordon, 2008) or compulsive MMORPG (Massively Multiplayer Online Role-Playing Game) play (Lee, Yu, & Lin, 2007). Similarly, when play is viewed as a behavior rather than a type of behavior, it can be seen as being inherently at odds with the rule-oriented nature of games (Smith & Pellegrini, 1998). If play is defined by freedom, and games require the imposition of rules, how can the two coexist?

Because this dissertation views play as a type of behavior rather than a behavior in and of itself, this seemingly irreconcilable paradox is easily circumvented. While a game may impose a rule-based structure in which behavior takes place, the actual behavior the player can exhibit within that space can still be free (i.e., unrestrained beyond the base rules of the game). Similarly, if the rules of the game do not specify an extrinsic motivator or consequence for gameplay, then the driving force underlying gameplay can be intrinsic. Recalling the Zimmerman definition of play, play exists "because of and also despite the more rigid structures of a system" (Zimmerman, in Esposito, 2005, p. 3). Indeed, the definition provided by O'Connor and LaPoint (1980) illustrates how the play aspect of behavior functions across four levels: spontaneous activity, recreation, games, and sport. These types of play behavior display varying levels of structure and goals, with spontaneous activity being largely unregulated and sport being relatively formalized. Though the latter categories of play may restrict freedom, activity within their rule space is still free. Indeed, without the presence of rules, the formalized play of sport may be unachievable. Thus, though games are defined by their application of rules, this is not incongruous with play.

2.3.4 Adults and Play

The topic of play is strongly represented in the childhood development literature, but theoretical discussions and empirical examinations of play behavior by adults are relatively rare. With the increased human factors focus on hedonomics (i.e., pleasurable design) and serious games, this lack of research presents a significant theoretical gap. Though play has been embraced as part of the process of human development (Sutton-Smith, 1997), adult play must be studied by the psychological community if the construct is to be understood as a whole (Cohen, 1993).

In general, adult play fills a number of roles, providing a strategy for informal hypothesis testing, a creative outlet, a means of communication, and a reinforcer of social and relational bonds (Baxter, 1992). The play that adults engage in, like the play of children, is characterized by pleasure, leisure, freedom from extrinsic goals, and engagement (Gitlin-Weiner, 1998). Adult play can take a number of forms, including gossip, role-playing, physical play, public performance, and games (Aune & Wong, 2002). In the investigation of serious games, it is primarily the game version of play that draws attention. Indeed, one theoretical development that helps to explain adult play is the differentiation between toyplay and gameplay. Gameplay is performance-oriented, whereas toyplay is unorganized stimulation (Van Leeuwen & Westwood, 2008). As the purpose of this dissertation is to investigate flow, play, and learning, gameplay is a more appropriate avenue for investigation than toyplay.

While the research base for adult play is small (Brougre, 1999; Van Leeuwen & Westwood, 2008), it is nonetheless a known fact that adult humans engage in play. The science of play has provided the means by which to study playfulness in adults, with scales such as the Microcomputer Playfulness Scale and the Adult Cognitive Spontaneity Scale (Webster & Martocchio, 1992) allowing for examinations of individual differences in play. The surge of interest in serious games provides an avenue that allows for empirical examination of adult play. However, for such research to take place, measures of play experience will need to be developed. Observational scales of child play behavior exist, but no measure of adult play is present in the literature.

If games are contexts in which play can be experienced, and serious games are environments in which individuals can learn, it follows that serious games provide one method by which learning can be achieved by adult play. Investigations into the mechanisms by which gameplay provides learning will thus help grow the science of play, providing the field with much-needed expansion.

2.4 Learning

On a basic level, learning is the process of acquiring knowledge, skills, attitudes, and behaviors (Salas & Cannon-Bowers, 2001). Learning is a relatively complex topic, with the learning literature differentiating between various learning outcomes and processes, e.g., declarative knowledge, application, attitudinal change, etc. (Anderson & Krathwohl, 2001). As serious games are tools for learning, it is necessary to turn to the science of learning in order to appropriately examine the science of serious games. In this section, various factors that influence learning are discussed. As the goal of a serious game is to convey some sort of learning outcome, addressing these various factors is key to understanding how serious games can be effective.

2.4.1 Prior Knowledge

The prior domain knowledge held by learners is one element that affects how well they are able to integrate new information. In particular, learners who hold relevant domain knowledge are able to learn information more easily. In one study, learners who tested high on a pre-intervention knowledge test scored higher on post-intervention tests than those who scored low on the pr-test (Mitchell, Chen, & Macredie, 2005). However, their knowledge gains (i.e., delta) were lower than those learners who started with less knowledge (Mitchell, Chen, & Macredie, 2005). This result is intuitive – learners who already know some information have less to "gain" than those who are empty vessels. However, because learners with pre-existing knowledge can integrate new information more readily, their final scores are higher than learners who do not have pre-existing knowledge. This effect carries over into electronic learning environments, where knowledgeable users experience fewer disorientation problems and are more able to structure the content that is being presented to them (McDonald & Stevenson, 1998). In learning environments that involve abstract, confusing, or obtuse tasks or situations, high prior knowledge also leads to higher learning outcomes (McNamara & Kintsch, 1996).

2.4.2 Engagement

In studies of engagement in academic settings, cognitive engagement was shown to be positively related with learning outcomes (Miller, Greene, Montalvo, Ravindran, & Nichols, 1996). The engagement examined in this academic setting was characterized by use of deep cognitive strategies, i.e., a focus on solving problems or performing tasks. The immersion component of engagement is created through interactivity (Oblinger, 2004), making games a prime candidate for creating high levels of engagement. The mechanism for how engagement is useful to learning lies within its effects. Engagement is characterized by both increased attention and positive affect (Douglas & Hargadon, 2000), and these attributes are the key to how engagement affects learning.

Thankfully, there is a wealth of studies examining the effects of attention on learning. In the simplest sense, attention is necessary for learning by the simple need for information to reach an individual in order to be stored in memory. The relationship between attention and implicit learning is especially meaningful in the context of serious games. Implicit learning is learning that takes place on an unconscious level, i.e., learning that occurs simply as a result of exposure to information (Jiang & Chun, 2001). Generally, this learning is understood to take place without attention being necessary. However, it has been demonstrated that attention positively affects the amount of implicit learning that takes place (Jiang & Chun, 2001). This indicates that, although peripherally available information is learned without full attention, attention must still be given to units that are near the information that is to be learned implicitly. This is logical, as implicit learning cannot take place without that information somehow being transmitted to the learner. Information in serious games that is not directly tied to interactions (i.e., information that is simply "present" without being active) is most affected by this attentional requirement. Apart from implicit learning, attention also plays a role in building a working model of information that is tied to game interactions (i.e., associative learning). Associative learning is characterized by rapid shifts in attention, which is meaningful in the context of many styles of games. Moving attention from item to item works to facilitate learning (Kruschke, 2001), providing a reason why consistent attention toward several game objects works to promote learning.

2.4.3 Affect

Affect has thus far only been briefly touched on. However, as flow is a construct that emerged from positive psychology, and games are played in the pursuit of pleasure, this dissertation cannot neglect the relationship between flow, affect, and learning. As in the case of motivation or engagement, it is intuitively reasonable that positive affect should enhance learning. In fact, as affect is interrelated with motivation and engagement (Craig, Graesser, Sullins, & Gholson, 2004; Higgins, 2006), it is natural to find a relationship between affect and learning.

Positive emotion has long been known to be a meaningful contributor towards successful learning. Emotions such as satisfaction are associated with positive learning outcomes, and short exposure to positive memories can increase learning outcomes in students (Bryan & Bryan, 1991). Creating a sense of curiosity and interest in an individual is beneficial to producing meaningful learning outcomes (Hidi, 1990). Even the simple positive affect generated through receiving a small gift of candy can positively influence learning outcomes (Carnevale & Isen, 1986). A positive affective state is related to engagement and motivation (Fredrickson, 1998), which may explain some of this effect. Negative emotions are generally predictors of lower learning outcomes. For example, boredom has been shown to negatively correlate with learning outcomes in college students (Craig, Graesser, Sullins, & Gholson, 2004). Other negative affective states such as anxiety or frustration are also contributors to lower learning outcomes or even negative learning outcomes (i.e., learning the wrong information; Kort, Reilly, & Picard, 2001). Similarly, negative past experiences with training content or context may impair learning, while positive associations may enhance learning (Smith-Jentsch, Jentsch, Payne, & Salas, 1996). Surprisingly, positive emotions may counter the detrimental effects of negative emotions, making the quest for positive affect even more meaningful, especially in the context of learning (Fredrickson, 1998). If a learning application can produce positive emotions in an individual that approaches training from an initially negative standpoint, it may be possible to remedy the influence of these negative emotions on their training.

2.4.4 Motivation

Numerous studies on learning have found that motivation is a key determinant of training effectiveness (Salas & Cannon-Bowers, 2001; Gully & Chen, 2009). Motivation, whether intrinsic or extrinsic, has profound implications as both a pre-condition of the individual engaging in training and as an outcome of training. Motivation affects the learner's willingness to engage with the learning environment (Gully & Chen, 2009), their drive to succeed in learning (Button, Mathieu, & Zajac, 1996), and their eventual transfer of learned skills and knowledge to the real world (Baldwin & Ford, 1994). The importance of motivation to the process and science of learning cannot be understated. As motivation is a large topic deserving of considerable attention, the next section focuses entirely on this higher-order construct and its related theories.

2.5 Motivation

Motivation is the necessary pre-condition for action, whether that action is learning, performance, play, or any other behavior a human might engage in. In other words, motivation is the drive or incentive that spurs an individual toward performance (Paras & Bizzocchi, 2005). Numerous models of motivation exist, with many focusing on the distinction between extrinsic motivation and intrinsic motivation (Garris, Ahlers, & Driskell, 2002). Intrinsic motivation is the drive to perform that is born from the task itself (Malone, 1981), while extrinsic motivation is produced by external factors, with the task being a means to an end (Vallerand, Fortier, & Guay, 1997). Motivation is meaningful to this discussion because it is linked to both training outcome and training transfer (Cheng & Ho, 1998), and trainees who are forced to train instead of choosing to train generally perform more poorly (Mathieu, Tannenbaum, & Salas, 1992).

2.5.1 Intrinsic Motivation

Intrinsic motivation is derived from an inherent satisfaction with a specific task (Ryan & Deci, 2000). This type of motivation is especially meaningful to the games community, as it is the core motivating factor behind play (Deci & Ryan, 1985). Interestingly enough, intrinsic motivation is to some degree inherent in tasks that require manipulation, information processing, or exploration (Deci & Ryan, 1985). These task requirements should be familiar to those working in the field of games, as they are effectively analogous to components of a game (e.g., challenge, fantasy, curiosity; Malone, 1981). Indeed, intrinsic motivation has been identified as a key factor of why games are effective as teaching tools (Malone, 1981). The connection between flow, serious games, and intrinsic motivation is rich with potential. However, this potential cannot be truly tapped without a scientific understanding of each of these elements. To achieve this understanding, it is useful to examine how various theories of motivation explain intrinsic motivation.

2.5.2 Extrinsic Motivation

Extrinsic motivation forms the other half of the basic motivation taxonomy. As the name suggests, extrinsic motivation is motivation created through an external factor, reward, or incentive (Benabou & Tirole, 2003). For example, motivation stemming from mandated training or the promise of financial reimbursement is extrinsic. A simple way to determine if motivation is intrinsic or extrinsic is to consider whether the motivation originates from the task or individual. Generally, if the task itself is not providing the motivator, and the individual's own motivations are not creating the impetus for action, the motivation created is extrinsic. Extrinsic motivation is not as meaningful to flow as intrinsic motivation, as an examination of flow in games is especially focused on the intrinsically motivating factors of games and flow state. Further, extrinsic motivation can promote an awareness of the self (e.g., comparing to others, seeking approval) that is counter to flow's temporary removal of the self. Nonetheless, extrinsic motivation remains a key component in explaining motivation as a whole, and thus warrants mention from a theoretical perspective.

2.5.3 Engagement

One of the most salient motivating components of gameplay is engagement. Motivation is necessary to create the initial action for a task, and engagement works to maintain the intrinsic motivation inherent to the game task. Therefore, a task is engaging when it continues to produce intrinsic motivation for the task performer. While this may appear somewhat circular, it is possible to create engagement via other game factors. Immersion is one game element that works to provide engagement by transporting the player into the fiction of the game (Douglas & Hargadon, 2000). When a player is immersed in a game, their attention is consumed by the game task and the world inherent to the game. In the field of serious games, engagement and immersion are heavily linked, as one is created through the other. Engagement in games is created through the use of fiction (e.g., world, story, characters) and interaction characteristics of the game (Dickey, 2005). As engagement assists in creating intrinsic motivation, and intrinsic motivation is a key component of flow, the discussion of engagement is particularly meaningful to the understanding flow in games.

2.5.4 Goal Setting Theory

The goal setting theory of motivation focuses on a fairly straightforward concept: the object or aim that an individual is trying to reach or accomplish (Locke, Shaw, Saari, & Latham, 1981). Goal setting theory predicts that accepting a harder goal leads to better performance than choosing an easy goal (Locke, Shaw, Saari, & Latham, 1981). However, this effect is contingent upon an individual's ability to achieve a difficult goal. If high levels of anxiety arise as a result of insufficient abilities combined with a difficult goal, performance drops sharply (Locke, Shaw, Saari, & Latham, 1981). This anxiety effect has obvious parallels to the skill-challenge pairing concept of flow. Thus, it is important for a goal to be challenging but attainable (Latham & Locke, 1979). Goal setting theory is especially meaningful when matched with flow, as it recognizes that motivation is largely an internal force of an individual – in other words, its primary source is the individual themself (Latham & Locke, 1979). This focus on intrinsic motivation as resulting from the pairing between an individual's goals and his or her ability to achieve those goals is aligned with the conditions for eliciting flow state. However, a task (especially a game) may be completed entirely for the task's state. This type of intrinsic motivation is inconsistent with the notion of most goals (other than, for example, a goal of enjoyment), and thus goal setting theory may not completely capture the motivation inherent in flow.

2.5.5 Motivation and Learning

Within the context of serious games, motivation is interesting because of its potential effects on learning. It is natural to presume that a motivated learner is a more effective learner, as they are more likely to actually invest effort in learning. And, indeed, this is the case – it has been empirically demonstrated that motivation results in greater learning outcomes. Vansteenkiste, Simons, Lens, Sheldon, and Deci (2004) found that learner motivation created through intrinsic goal content was related to test performance and learning persistence. Further, the increased learning brought on by motivation occurs whether the motivation is intrinsic (Cordova & Lepper, 1996) or extrinsic (Vallerand, Fortier, & Guay, 1997). For example, a study on motivation in students found that students who were intrinsically motivated performed significantly better, and were more engaged in their tasks (Pintrich & DeGroot, 1990). There is some evidence to suggest that intrinsic and extrinsic motivation function separately (i.e., are not simply additive, but are related in more complex ways), however, it is clear that both are useful in increasing learning (Osterloh & Frey, 2000).

Though motivation has been shown to be useful for learning, it is useful to examine the mechanism by which motivation improves learning. In the context of self-regulated learning (i.e., learning driven by the individual), self-efficacy, task value beliefs, and goal orientation are prime examples of how motivation alters learning outcomes (Pintrich, 1999). Self-efficacy refers to whether an individual feels confident in their abilities to perform a task (Payne, Youngcourt, & Beaubien, 2007). When self-efficacy is high, individuals achieve greater learning and are more likely to engage in varied cognitive strategies and self-regulatory behavior (i.e., planning and being aware of learning) than those with low self-efficacy (Pintrich & DeGroot, 1990). This is important because motivation is related to self-efficacy, and can thus work through self-efficacy to increase learning (Gist, 1987). Task value beliefs refer to how an individual feels about a task's importance. Like self-efficacy, belief in task value is positively related to both learning outcomes and motivation (Bong, 2001), providing another route by which motivation may increase learning.

When examining learning, goal orientation is considerably more complex than self-efficacy or task value beliefs. An individual's goal orientation refers to their standards and approach toward learning (Payne, Youngcourt, & Beaubien, 2007). Beyond learning, prove-performance, and avoid-performance (VandeWalle, 1997), there are other goal orientations identified in the literature, but these three prominent examples are most relatable to learning outcomes. Interestingly, learning orientation is positively related to learning outcomes, while performance orientation is negatively related to learning outcomes and self-efficacy (Pintrich, 1999). This difference may account for why extrinsic motivation is generally considered to be secondary to intrinsic motivation in promoting learning, as it enhances the negative extrinsic orientation of individuals.

Given this knowledge, it is clear that motivation is useful in enhancing learning. Whether motivation is intrinsic or extrinsic, the presence thereof is typically (though not always) related to positive learning outcomes. Both flow and and the play-based nature of games (Paras & Bizzocchi, 2005) are able to create intrinsic motivation in learners. It is only natural, then, to work to create flow within serious games in order to increase motivation and learning.

CHAPTER 3
THEORETICAL FOUNDATION: A NEW MODEL OF FLOW

Keeping the previously discussed literature in mind, it is now possible to provide a conceptual model with which flow's relationship to learning and games can be empirically examined. The flow models examined thus far have several factors in common. In creating a new model for flow, it is necessary to cleanly divide these factors into flow inputs (i.e., precursors) and outcomes.

From the literature discussed thus far, a list of potential constructs to include in the new model of flow in games was created. This list was then organized into two tables: one defining the individual constructs that define the model (see Table 3) and one describing the variables that are not included as modeled elements, but are investigated as covariates or otherwise controlled during the studies used to test the model (see Table 29). The modeled constructs listed in Table 3 are further split into flow precursors and flow outcomes. These precursors can be further divided into elements describing the game or the player.

Before moving into a discussion of the studies that empirically examine this model (see Figure 5), each of these factors is briefly reviewed. Though the full model is discussed in this section, only a subset of the model is examined in these studies (see Figure 6). As these terms have been used throughout the literature review with occasionally disparate definitions, their definitions are provided alongside the hypotheses examined in these studies.

Table 3: Identified constructs

Construct Name	**Affects**	**Effect Size**	**Source(s)**
Flow State	Motivation	beta = .324	Guo, 2005
	Immersion	beta = .249	Guo, 2005
	Enjoyment	High	Csikszentmihalyi, 1990
	Play	beta = .686	Guo, 2005
	Learning	Medium	Csikszentmihalyi, 1990
	Flow State Subscales	(is defined by)	Jackson & Marsh, 1996
Intrinsic Motivation (Trait)	Learning (Multiple)	Medium	Winne & Nesbit, 2010 Weissinger & Bandalos, 1995
	Flow State	beta = .51	Kowal, 1998
	Playfulness	Medium	Weissinger & Bandalos, 1995
Challenge	Challenge/Skill Balance	Large	Csikszentmihalyi, 1990
Playfulness	Play	Medium	Webster & Martocchio, 1992
	Flow State	Medium	
Video Game Self-Efficacy	Flow State	Medium	Schwarzer & Jerusalem, 1995 Schwarzer, 2008
	Learning	Medium	Pavlas, Bedwell
Control	Flow State	Medium	Jackson & Marsh, 1996
Challenge/Skill Balance	Flow State	beta = .186 (non-game)	Csikszentmihalyi, 1990 Guo, 2005
Feedback	Flow State	beta = .724	Guo, 2005
Clear Goals	Flow State	Medium	Jackson & Marsh, 1996
Emotional Experience	Flow State	Medium	Bradley & Lang, 1994
Play	Enjoyment	Medium	McAuley, Duncan, & Tammen, 1989
Learning (DK)	Performance	Medium	Pavlas et al., 2009
Learning (KO)	Performance	Medium	Pavlas et al., 2009
Immersion	Enjoyment	Medium	Jennett et al., 2008
Enjoyment	Game Training Acceptance	Medium	Lin, Gregor, & Ewing, 2008
	Learning	Medium	Craig, Graesser, Sullins, & Gholson, 2004

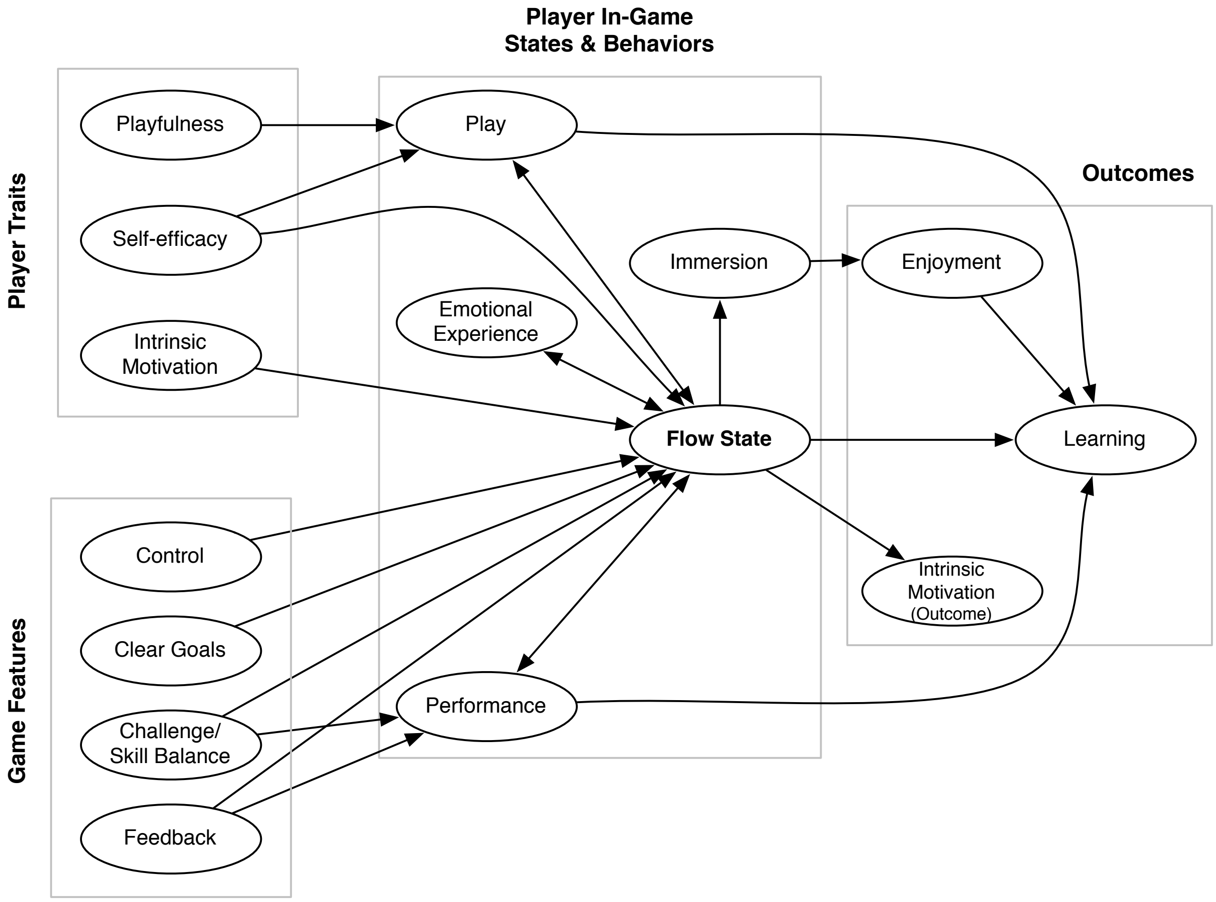

Figure 5: New model of flow

3.1 Game Characteristics

Based on the review conducted, it is clear that there are a number of key preconditions for an individual reaching flow state. First, there are those constructs that come from the task itself — in this case, the definitional elements of the gameplay. The relationship between player skill and task challenge (and, thus, the function of the game that adapts to player skill) is related to the player's ability to achieve flow state (Csikszentmihalyi, 1990; Sweetser & Wyeth, 2005; Chen, 2007). While at first this concept may appear to fall outside of the influence of the game's design, the method by which the game adapts to the player's skill (e.g., dynamic difficulty adjustment, adaptation, etc) is one of the most effective ways to ensure a game is appropriately challenging (Chen, 2007). Thus, this model casts the task's ability to support a balanced skill-challenge relationship as an element of the game. Other elements that define the structure of gameplay – the means by which the game conveys feedback, goals, and actions to the players – will hinder or aid the player in experiencing flow (Malone, 1981; Cowley et al., 2008). Control is another necessary element to allow players to reach flow state (Garris, Ahlers, & Driskell, 2002). In a game, control refers to the system's openness to manipulation by the player (Pavlas, Bedwell, Wooten, Heyne, & Salas, 2009), and is evidenced by subjective feelings of concentration and agency.

3.1.1 Challenge/Skill Balance

Challenge is one of the most basic elements of a game (Malone, 1981; Sweetser & Wyeth, 2005), and can be likened to constructs such as task complexity (Campbell, 1988). Challenge refers to the types of problems presented during the course of gameplay, with a focus on the degree of "absolute" challenge presented (i.e., independent of any player reaction or skill). As an element of the new model, challenge is subsumed by the challenge/skill balance. The balance between the game's challenge and the player's skill is the foundation of the two-channel model of flow (Csikszentmihalyi, 1975). The interaction between player skill and game challenge create the actual perceived difficulty of the game (and thus, the player's performance). Because it is such a definitional precursor to flow state, the degree of match between challenge and skill should have a strong and direct effect on the player's ability to reach flow state.

3.1.2 Feedback

Feedback is the element of a game that allows a player to understand how they are performing (Malone, 1981). In a no-feedback condition, performance is met with no knowledge of success or failure. Conversely, when feedback is tightly integrated with gameplay, the player is immediately aware of the outcome of their actions. Like challenge/skill balance, feedback is a central element of Csikszentmihalyi's original definition of flow (1990), and should thus show strong effects on the player's ability to reach flow state.

3.1.3 Clear goals

Without clear goals, the player is left without an effective means by which to judge their performance on a global scale. While the presence of feedback provides a local action-outcome loop, clear goals steer the overarching task performance of an individual (Sweester & Wyeth, 2005). An element of the original flow state definition (Csikszentimhalyi, 1990), the presence of clear goals should show a significant effect on flow state.

3.1.4 Control

Also known as agency, control is the degree to which an individual feels empowered to create changes in the game world (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009). In Csikszentmihalyi's original flow definition (1990), a "sense of control over actions" is provided as a necessary antecedent to flow state. Within this model, the concept of control includes the "effortless involvement" element. Extrapolated to a serious game task, control refers not only to the ability of the player to influence the game environment, but also their ability to literally control (i.e., manipulate) the game and make their intent manifest (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009). As with the other flow antecedents, control should show a strong effect on the player's ability to reach flow state.

3.2 Player Traits

The second set of flow antecedents is comprised of the static and dynamic characteristics of the player. While flow is itself a subjective experience, there are precursor states that impact the player's ability to reach flow. Prior empirical evidence suggests that the degree to which an individual feels confident in their ability to interact with video games in general impacts flow (Pavlas, Heyne, Bedwell, Lazzara, & Salas, 2010), as does the general (i.e., trait) intrinsic motivation of the player (Kowal, 1998; Engeser & Rheinberg, 2008). Finally, the attitude a learner holds toward play (i.e., their playfulness) is likely to influence their ability to reach play. Through play, this should influence player ability to reach flow state in a game, as the experience of flow overlaps with that of play (Petersson, 2006).

3.2.1 Intrinsic Motivation

Trait intrinsic motivation is the first flow antecedent of this model of flow not explicitly mentioned by Csikszentmihalyi's (1990) definition. Implicitly, intrinsic motivation is close to the concept of autotelic experience, as intrinsic motivation is a necessary element of a task that is completed for its own sake (Polaine, 2005). Unlike the previous antecedents, intrinsic motivation is not a characteristic of the game task, but a trait of the game player. Because of its conceptual link to autotelic experience, trait intrinsic motivation should show an effect on flow state.

3.2.2 Playfulness

Playfulness as a trait refers to an individual's disposition towards engaging in play (Webster & Martocchio, 1992). As play is intrinsically rewarding (O'Connor & LaPoint, 1980), it is conceptually similar to the experience of flow state's autotelic experience (Csikszentmihalyi, 1990). Thus, it is plausible to expect individuals who are playful will be more likely to experience play, and through play, potentially reach flow.

Hypothesis 1: Playfulness will be significantly and positively related to an individual experiencing play behavior.

3.2.3 Video Game Self-Efficacy

Self-efficacy refers to an individual's belief in their ability to successfully engage in behavior or complete a task (Payne, Youngcourt, & Beaubien, 2007). Video game self-efficacy, then, is an individual's confidence in their abilities to successfully play a video game. The construct of self-efficacy is often targeted towards specific tasks or contexts in order to grant it further specificity (Schwarzer & Jerusalem, 1995). The ability to concentrate and focus on a task is a core element of flow state (Csikszentmihalyi, 1990) – it follows that video game self-efficacy theoretically relates to the ability to achieve flow state in a serious game. Indeed, prior research has shown the importance of video game self-efficacy for learning in serious games (Orvis, Belanich, & Horn, 2006), and suggests that flow state may mediate the relationship between video game self-efficacy and learning (see the upcoming section of Flow State; Pavlas, Heyne, Bedwell, Lazzara, & Salas, 2010).

Hypothesis 2: Video game self-efficacy will be significantly and positively related to an individual experiencing play behavior and flow state.

3.3 Player States

Flow is a dynamic construct, arising out of the player's interactions with the game. Because of this, it is natural to expect that the player's gameplay states – their performance, their emotions, and their play experience – will influence (and be influenced by) flow state. For example, the nature of the learner's emotional response toward the game should serve as an indicator of flow state, as indicated in the four and eight channel models of flow (Csikszentmihalyi & Nakamura, 1989). Individuals who are experiencing anxiety, boredom, or apathy, are by definition not likely to experience flow state.

3.3.1 Play

As previously discussed, play is best defined as a qualifier for experience and behavior (Millar, 1968), with the defining characteristics of play being its free, intrinsically motivated nature (O'Connor & LaPoint, 1980). Because flow state is itself defined quite similarly, individuals who achieve flow state should also self-report having experienced play behavior. In the same vein, individuals who engage in play should be more likely to reach flow state (Bertozzi & Lee, 2007). Because of this relationship with flow, the impact of play on learning should be qualified by flow.

Hypothesis 3: Play will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.

3.3.2 Performance

In an endogenous serious game, performance is intrinsically related to learning, as the gameplay actions are directly tied to learning content (Squire, 2006). In-game performance should also affect the player's ability to reach flow state, as per the previously discussed challenge/skill relationship (Csikszentmihalyi, 1990). This relationship is complicated by the potential impact of flow state on in-game performance and learning. Because of flow's intermediary position between in-game performance and learning, the effects of performance on learning should be partially contingent upon flow state.

Hypothesis 4: In-game performance will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.

3.3.3 Emotional Experience

The pattern of emotions that individuals experience while playing a game may indicate their proximity to flow. The eight channel model of flow (see 3) describes flow state in terms of emotional states, with arousal and control being adjacent to flow state (Csikszentmihalyi & Nakamura, 1989). Arousal, control, and emotional valence (positive/negative, happy/sad) are three key indicators of emotional experience under the established Self-Assessment Manikin and Semantic Differential scales (Bradley & Lang, 1994). As flow state is a high-level emotional response, it is possible that patterns of lower-level emotional experiences will predict an individual's reaching flow state. In particular, individuals who experience arousal, control, and positive valence (i.e., happiness) should be more likely to experience flow than those who experience little arousal, no control, and negative valence, or those who experience high arousal, no control, and negative valence.

3.3.4 Flow State

The central element of the new model of flow in serious games – flow state – is directly linked to a number of outcomes and processes. Players who experience flow state are likely to represent their experience as positive (Helander, Tham, 2003). Because of this, it is expected that flow state will result in enjoyment. The immersive experience provided by flow state will also create enjoyment, though this should be separate and distinct from the individual effects of flow state. The free, exploratory nature of the flow state experience is closely linked to the experience of play (Csikszentmihalyi & Bennett, 1971), which should manifest itself in the player experiencing play behavior. Players who experience flow state should show higher learning outcomes due to their increased focus on game content (Starbuck & Webster, 1991). Finally, the intermediary position of flow state in this model should manifest itself by flow functioning as a mediator for the relationship between player characteristics, in-game processes, and gameplay outcomes.

> *Hypothesis 5: Play, emotional experience, and in-game performance during a game play session will be significantly and positively related to flow state in that session.*

> *Hypothesis 6: Prior levels of flow state will be significantly and positively related to later experiences of play, emotional experience, and in-game performance.*

> *Hypothesis 7: Patterns of performance during individual game play rounds that reflect matched challenge/skill will be predictive of flow outcomes.*

3.4 Outcomes

On the outcome side of the proposed model, flow state itself is characterized by a number of sub-scales (e.g., autotelic experience) that are captured by the Flow State Scale (Jackson & Marsh, 1996). Other direct outcomes of flow state include the oft-discussed construct of immersion (Brown & Cairns, 2004) as well as state intrinsic motivation. Naturally, learning is a key outcome of flow in a serious games. While this learning can be broken down into a variety of outcomes (e.g., declarative knowledge, application, knowledge organization; Anderson & Krathwohl, 2001), for the purposes of this initial model, learning is treated as a general outcome, though it is measured in several ways in the studies to follow. The experience of play is an outcome that is itself linked to one of flow state's most universal outcomes: enjoyment (O'Connor & LaPoint, 1980). Enjoyment, in turn, is helpful to learning, as positive affective experience can improve learning outcomes (Bryan & Bryan, 1991).

3.4.1 Learning

Learning is the process of acquiring knowledge, skills, attitudes, and behaviors (Salas & Cannon-Bowers, 2001). In a serious game, learning is the key outcome of gameplay. A successful serious game produces a learning outcome, whether the learning is manifested in declarative knowledge, change in mental models, change in attitude, or the acquisition of skills (Salas & Cannon-Bowers, 2001). In this model of flow in serious games, a number of factors contribute to the potential learning outcome, including intrinsic motivation (Garris, Ahlers, & Driskell, 2002), self-efficacy (Schunk, 1990), enjoyment (Fu, Su, & Yu, 2009), and flow state itself (Chan & Ahern, 1999). During the process of endogenous serious gameplay, learning should also affect the player's ultimate performance, as this performance is contingent upon the player's learning (Squire, 2006).

3.4.2 Immersion

One of the most commonly-referenced characteristics of video games is their ability to create an immersive experience (McMahan, 2003; Calleja, 2007). Immersion refers to the player's temporary acceptance of a game's reality, their focus on this reality, and their general degree of involvement with the game. One of the characteristics of flow state is engagement with the task (Csikszentmihalyi, 1990), which, as previously discussed, is effectively a part of the immersion construct. Immersion also describes the outcome portion of "deep but effortless involvement", which has been split into the aspects of control and immersion for this model. As an element of the model, immersion is an outcome of flow state that is linked to enjoyment, as the experience is affectively positive (McMahan, 2003).

3.4.3 Performance

Performance refers to the player's degree of success in the game task. As an element of the new model of flow in games, actual performance on the game task is the only outcome that does not have a causal link to another element. While game performance may have effects on other constructs (such as satisfaction with game experience; Malone, 1980), in this model, performance in a serious game is related primarily to learning (by the very nature of the player's interaction with the serious game) and flow state (as per the skill/challenge pairing; Csikszentmihalyi, 1990).

Hypothesis 6: The impact of in-game performance on learning will be partially mediated by flow state.

Hypothesis 7: Patterns of performance during individual game play rounds that reflect matched challenge/skill will be predictive of flow state.

3.4.4 Enjoyment

As this model seeks to explain the relationship of flow state to games and learning, enjoyment is a key component of the model. While not the primary outcome of serious

Table 4: Model hypotheses

	Hypotheses
H1	Playfulness will be significantly and positively related to an individual experiencing play behavior.
H2	Videogame Self-Efficacy will be significantly and positively related to an individual experiencing play behavior and flow state.
H3	Play will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.
H4	In-game performance will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.
H5	Play, emotional experience, and in-game performance during a game play session will be significantly and positively related to flow state in that session.
H6	Prior levels of flow state will be significantly and positively related to later experiences of play, emotional experience, and in-game performance.
H7	Patterns of performance during individual game play rounds that reflect matched challenge/skill will be predictive of flow state.

gameplay, enjoyment is nonetheless meaningful from a learning perspective (Bryan & Bryan, 1991). Additionally, the affectively positive experience of enjoyment is likely to serve as a prior experience (Smith-Jentsch, Jentsch, Payne, & Salas, 1996) that informs future interactions with serious games, leading to greater acceptance of training games in general. However, as this outcome is rather distal, it is not examined in this study.

3.4.5 Intrinsic Motivation

Intrinsic motivation, in the form of state intrinsic motivation, is also visible as an outcome of flow. State intrinsic motivation describes how motivated an individual is while engaging in a particular task, rather than how motivated they are in general. Because flow is so closely linked with the concept of intrinsic motivation, achieving flow state should be reflected by an increase in state intrinsic motivation.

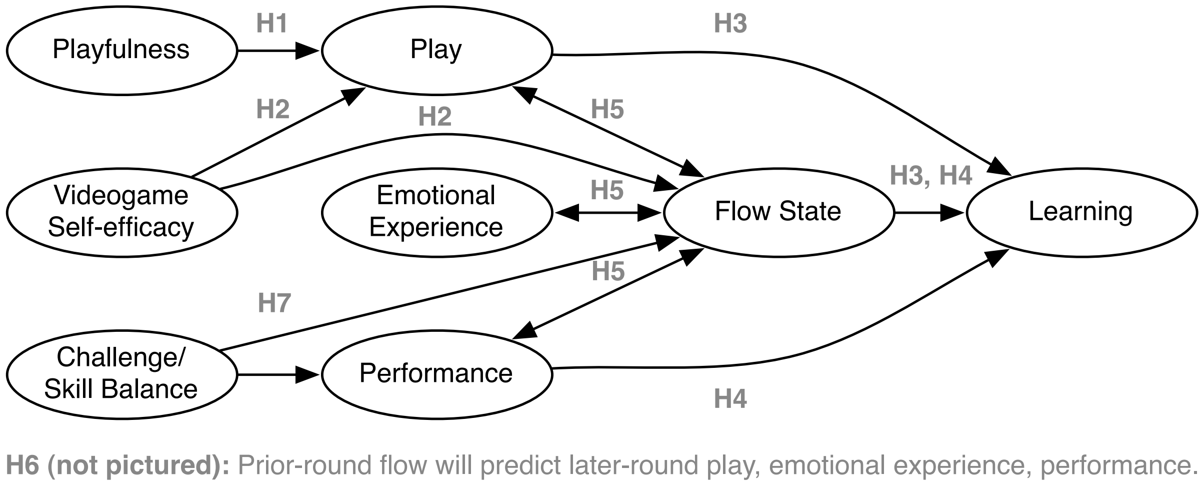

Figure 6: Examined subset of the model of flow in games

CHAPTER 4
EMPIRICAL STUDIES

To determine the feasibility of the new model of flow in serious games, a series of two studies was conducted. The first study was a pilot experiment to determine the psychometric properties of a new measure of play experience. In the second study, a serious game focusing on human immune system content was used to study a subset of the overall model of flow in games.

4.1 Study 1: Play Experience Scale

In this study, a play experience measure was created and examined for its psychometric properties. Because play is an important construct in the new model of flow in serious games, a reliable and valid measure of play was necessary for further research. Unfortunately, science had not yet produced such a measure. Thus, this experiment was conducted with the goal of creating a new measure to assess the experience of play.

4.1.1 Method

4.1.1.1 Participants

For the study, a sample of 226 undergraduate volunteers enrolled at a large southeastern metropolitan university was recruited. Of these, 35.40% were male and 65.60%

were female. Participants ranged in age from 18 to 58 years old, with a mean age of 21.02 ($SD = 4.95$).

A priori power analysis conduced in G*Power using ANOVA to detect group differences between the three groups at a power of .80, effect size of $f^2 = .25$, and α error probability of .05 indicated that a sample size of 159 participants was required. However, given that principal component analysis and structural equation modeling were planned for analysis, a minimum of 200 participants was decided upon.

4.1.1.2 Design

Participants were tasked with engaging in one of three games over the course of two performance periods. The experiment was conducted with a 3 × 2 mixed repeated measures design. The between-subjects independent variable of "game" constituted the primary manipulation of the experiment. The three games employed were *flOw*, *Tetris*, and a custom-created visual search task. Participants were randomly assigned to one of these three conditions. The within-subjects variable consisted of two performance periods, one immediately following the other after some brief measures. After each performance period, two dependent variables were collected: flow state and play experience. Additional measures were collected at the start of the experiment and after both performance periods were complete.

4.1.1.3 Measures

The primary measure employed in this study was the Play Experience Scale. Additionally, existing measures of playfulness, flow state, and motivation were used in the study. Full scale descriptions are available in Appendix A.

Play Experience Scale

The Play Experience Scale was developed based on the definitions of play encountered during the literature review. Items that focused on the shared elements of various play definitions were created, with O'Connor and LaPoint's (1980) definition of play as an intrinsically motivated, free activity used as the core guiding definition. Five categories of questions were represented: (a) items assessing the participant's perceptions of freedom in the task; (b) items assessing the degree to which performance on the task was not extrinsically motivated; (c) items assessing the intrinsically motivated, autotelic nature of the interaction with the task; (d) items assessing whether the participant was able to focus on task performance; and (e) items that directly asked if the participants would qualify their experience as "play." As these categories relate back to established constructs, other scales of intrinsic motivation (Weissinger & Bandalos, 1995), extrinsic motivation (Guay, Vallerand, & Blanchard, 2000), and immersion (Thompson, 2007) were referenced. Four items were created for each category. One of each set of 4 questions was reverse-coded (see Table 5). Finally, the scale's responses were represented via a six-point Likert-type scale ranging from "strongly disagree" (1) to "strongly agree" (6).

Enjoyment Scale

To measure enjoyment, the web enjoyment survey (Lin, Gregor, & Ewing, 2008) was modified to refer to a gameplay experience rather than a web browsing experience. This 12-item scale employs three subscales (engagement, affect, and fulfillment) to measure participant enjoyment. Participants respond to items along a 6-point Likert-type scale anchored from "strongly disagree" (1) to "strongly agree" (6). Previous experiments with the original scale established it as highly reliable, with a Cronbach's alpha of 0.97 (Lin, et al., 2008).

Table 5: Initial play experience scale items

	Item	Dimension and Coding
1.	I felt that I was free to use whatever strategy I wanted to while I was using the game	Freedom
2.	I was able to make the game do what I wanted it to	Freedom
3.	The game gave me the freedom to act how I wanted to	Freedom
4.	The game made it difficult to do what I wanted to do	Freedom (R)
5.	I was not worried about someone judging how I performed in the game	No extrinsic
6.	Regardless of how I performed in the game, I knew there wouldnt be a real-world consequence	No extrinsic
7.	My performance in the game was not going to matter outside of the game	No extrinsic
8.	I felt like I had to do well, or the experimenter would judge me	No extrinsic (R)
9.	When I was using the game, it felt like I was playing rather than working	Play-direct
10.	I would characterize my experience with the game as playing	Play-direct
11.	I was playing a game rather than working	Play-direct
12.	Using the game felt like work	Play-direct (R)
13.	When I was using the game, I didnt worry about anything in the real world	Focus
14.	I was able to concentrate on the game without thinking about other things	Focus
15.	When I was using the game, I was focused on the task at hand	Focus
16.	I had a hard time concentrating on the game	Focus (R)
17.	I wanted to do well in the game, "just because"	Autotelic
18.	When I was using the game, I wanted to do as well as possible	Autotelic
19.	I tried to succeed in the game because I felt like it	Autotelic
20.	During the game, my performance didnt matter to me	Autotelic (R)

Note: Responses ranged from 1 (Strongly Disagree) to 6 (Strongly Agree). Items were presented in random order.

Flow State Scale

The Flow State Scale measures the degree to which respondents feel a particular experience could be characterized as flow state (Jackson & Marsh, 1996). The scale includes a number of subscales based on the definition of flow state, namely: (a) challenge/skill balance, (b) action-awareness merging, (c) clear goals, (d) unambiguous feedback, (e) concentration, (f) control, (g) loss of consciousness, (h) transformation of time, and (i) autotelic experience. Responses to the measure are provided on a Likert-type scale from "strongly disagree" (1) to "strongly agree" (6). A validated 9-item short form version of the scale (Jackson, Martin, & Eklund, 2008) was used instead of the 36-item version to prevent survey fatigue.

Computer Playfulness Scale

The Computer Playfulness Scale was developed to assess playfulness as a trait, rather than play as a task-specific behavioral state (Webster & Martocchio, 1992). The scale consists of seven self-description items (e.g., "I am…") that respondents rate on a seven-point Likert scale ranging from strongly disagree to strongly agree. Though the name of the scale suggests its application is limited to computer environments, neither the scale's directions nor its items mention computers.

Intrinsic Motivation Scale

An outcome (i.e., state-based) intrinsic motivation scale (McAuley, Duncan & Tammen, 1989) was used to serve as a potential indicator of the play experience scale's convergent validity. The scale measures participant reaction to a number of items along a 6-point Likert-type scale anchored from "strongly disagree" (1) to "strongly agree" (1), with subscales indicating interest, tension, effort, and competence.

Situational Motivation Scale

The 16-item Situational Motivation Scale (SIMS) measures task-referent intrinsic motivation, identified regulation, external regulation, and amotivation (Guay, Vallerand, & Blanchard, 2000). Participants respond to the measure along a 6-point Likert-type scale, anchored from "strongly disagree" (1) to "strongly agree" (2).

4.1.1.4 Procedure

The study tasks and measures were presented via a web site designed to record participant responses. Upon entering the web site, each participant's informed consent was obtained. If the participant consented to the study, pre-study measures (i.e, demographics, playfulness scale) were provided, followed by instructions for their task.

Three tasks were employed during this study. The first group engaged in a task that was designed to create as little subjective feelings of play as possible. A block of random upper and lower case letters was displayed on the screen, and participants were asked to count the instances of particular letters in the text (e.g., "L" and "l"). The text was displayed via an image file to avoid participants using electronic aids to count the letters. Participants engaged in this task for five minutes. New blocks and new target letters were provided after each time the participants provided their letter count.

The second group's task was a game known as *flOw* (Chen, 2006). This game tasked players with steering a microscopic organism through a primordial sea. Based on player choices, the game was made easier or more difficult. If players wished to seek more dangerous prey, they could dive deeper into the primordial sea. To reduce game difficulty, they may return to a more shallow level. Participants played this game for five minutes, working to grow their organism while avoiding predators.

The third group's task was a browser-based version of the popular game *Tetris*. In this game, players must arrange shapes created through the contiguous combination of four squares to create complete lines. Participants played the game for five minutes.

After the participant's first task round was completed, the flow state scale, play experience scale, intrinsic motivation scale, and situational motivation scale were administered through the web site. Following this, participants were once again presented with instructions for their task. Participants engaged in their tasks a second time and were then provided with the flow state scale, play experience scale, intrinsic motivation scale, and situational motivation scale. After they completed these scales for the second time, participants completed the enjoyment scale. Finally, participants were thanked for their participation and provided with an electronic post-experiment statement.

4.1.2 Results

Of the 226 participants that took part in the study, 203 provided complete data sets (i.e., completed both runs of the game and all surveys). These 203 cases were used in the following analyses. Means, standard deviations, and correlations are presented in Table 27. The analyses presented below were conducted based on the following goals. First, the suitability of the data was examined to determine whether a factor analytic approach could be used to test the data. Second, the underlying factor structure of the scale was determined. After the factor structure was determined, the convergent, discriminant, and construct validities of the scale were examined (see Table 13). Finally, the resulting scale's psychometric properties were tested.

4.1.2.1 Data Suitability

Initial analyses of the new Play Experience Scale included examination of its component structure. To ensure factor analysis was appropriate for the data, the factorability of the items was first established by examining the inter-correlations between the 20 items of the second-round play experience scale administration (see Table 28). Of the 20 items, 19 were significantly correlated at least .25 with another item. The Kaiser-Meyer-Olkin measure of sampling adequacy was .88, well above the recommended value of .60. This result indicates that the partial correlations between items were suitable for factor analysis. Bartlett's test of sphericity was significant ($\chi^2(190)= 2256.83, p <.001$), suggesting the variables were sufficiently correlated for factor analysis. Based on these indicators, the data were appropriate for factor analysis.

4.1.2.2 Scale Structure

After the suitability of the data was assessed, the underlying structure of the scale was examined. To test whether the subscales of the Play Experience Scale conformed to the theory-driven definitions used to create them, a principal component analysis (PCA) with manual five-component truncation and Promax rotation was performed on the original 20-item scale using data from the second administration of the test. Because this factor analysis was intended to test the hypothesized five-component structure of the PES, truncation was forced to five components. Given the potentially correlated nature of the Play Experience Scale's subscales, oblique rotation was achieved using the Promax function. Results from the principal component analysis are presented in Table 6. Of the five components that were extracted, the first four are recognizable as subscales of the PES, with the first component merging the Focus and Autotelic Experience subscales. The fifth component was comprised of the reverse-coded items of the scale.

Based on this initial analysis, four items of the scale were pruned. Item 16 failed to load strongly onto any of the extracted components and was subsequently removed. Given the goal of a symmetrical scale, the three low-loading items of component 1 (item 13, item 14, and item 20) were also removed before further analysis. The resulting 16-item play experience scale was again examined via principal component analysis using Promax rotation. Components with an eigenvalue greater than 1 were retained. Results from this component analysis are presented in Table 7.

This second component analysis indicated that item 4 was not loading onto the same component as items 1, 2, and 3, suggesting it for pruning. After removing item 4, linear regression was conducted using each of the items as an individual predictor of the "game"

Table 6: Principal Component Analysis: 20-item PES

Item	C1	C2	C3	C4	C5	Communality
Item 1	.40	-.34	.20	.57	.06	0.61
Item 2	-.04	.24	-.09	.76	.03	0.72
Item 3	-.04	.01	-.07	.88	.08	0.75
Item 4	-.27	.22	.05	.38	.64	0.72
Item 5	.10	-.02	.75	.15	.04	0.67
Item 6	-.02	.18	.69	-.20	-.02	0.46
Item 7	.31	-.14	.65	.05	-.19	0.54
Item 8	-.18	-.06	.68	-.10	.57	0.78
Item 9	.19	.85	.02	-.04	-.09	0.82
Item 10	.15	.83	.02	.04	-.04	0.83
Item 11	.17	.78	-.01	.13	-.08	0.82
Item 12	-.03	.72	.04	-.10	.38	0.77
Item 13	.54	-.02	.00	.22	-.01	0.41
Item 14	.55	.21	-.09	.12	.12	0.59
Item 15	.71	.13	.00	.09	.03	0.68
Item 16	.34	.36	-.02	-.03	.43	0.65
Item 17	.77	.15	.16	-.04	-.05	0.71
Item 18	.88	.07	.02	-.07	.01	0.80
Item 19	.82	.13	.11	-.14	-.01	0.70
Item 20	.53	-.27	-.34	-.11	.65	0.75

Note: Factor loadings >.40 shaded. Oblique rotation conducted using the Promax function. The five components accounted for 68.85% of the total variance in the 20 items.

variable (i.e., whether the data provide further insight into the diagnosticity of individual items). Results from the linear regressions are presented in Table 8. Based on these results, items 5 through 9 (the hypothesized no-extrinsic motivator subscale) were fairly low in diagnosticity. However, they were retained due to experimental constraints that will be further explained in the Discussion section. Additionally, item 1 was dropped based on its lack of diagnosticity. With items 1 and 4 removed from the scale, a final PCA with Promax was conducted on the 14-item version of the scale. Results from this analysis are presented in Table 9. The component loading items 2 and 3 was no longer symmetrical with the other four-item components, as it only contained two items rather than four. However, the scale

Table 7: Principal Component Analysis: 16-item PES

Item	C1	C2	C3	C4	Communality
Item 1	.29	-.27	.60	.17	0.58
Item 2	.00	.20	.78	-.12	0.72
Item 3	-.06	.03	.91	-.09	0.77
Item 4	-.39	.60	.38	.17	0.62
Item 5	.10	-.02	.14	.74	0.66
Item 6	.04	.11	-.02	.69	0.45
Item 7	.35	-.31	.09	.58	0.52
Item 8	-.29	.27	-.08	.78	0.68
Item 9	.37	.72	-.08	-.03	0.78
Item 10	.33	.72	.02	-.02	0.80
Item 11	.34	.67	.10	-.07	0.79
Item 12	.03	.87	-.10	.10	0.74
Item 15	.71	.09	.17	-.06	0.68
Item 17	.79	.11	-.01	.10	0.72
Item 18	.87	.07	-.01	-.03	0.79
Item 19	.84	.10	-.09	.04	0.72

Note: Factor loadings >.40 shaded. Oblique rotation conducted using the Promax function. The four components accounted for 68.81% of the total variance in the 16 items.

cleanly loaded onto four theory-aligned components, suggesting its use as a candidate scale for further analysis.

The subscales of the 14-item version of the PES were summed and examined for their diagnosticity of game condition via linear regression, with the four subscale variables used as a predictor of the "game" variable. The four subscales were also examined for their reliability. The results of this analysis are presented in Table 10. As only the direct play assessment subscale was individually predictive of game condition, a second candidate scale consisting of only the four direct play assessment items was formed for further analysis.

4.1.2.3 Scale Selection

With these two candidate scales in hand, the next step in determining which of the two scales to examine in-depth required an examination of the correlations between the

Table 8: PES individual item regression

Item	*B*	*SE*	β	*t*	*Sig.*
Item 1	0.01	0.03	0.02	0.29	0.77
Item 2	0.15	0.02	0.42	6.64	0.00***
Item 3	0.10	0.03	0.27	3.99	0.00***
Item 5	0.06	0.02	0.17	2.47	0.01*
Item 6	0.03	0.03	0.07	1.00	0.32
Item 7	0.02	0.03	0.04	0.52	0.61
Item 8	0.05	0.02	0.13	1.84	0.07
Item 9	0.17	0.02	0.58	10.01	0.00***
Item 10	0.18	0.02	0.59	10.40	0.00***
Item 11	0.18	0.02	0.58	10.17	0.00***
Item 12	0.17	0.02	0.57	9.87	0.00***
Item 15	0.13	0.02	0.36	5.43	0.00***
Item 17	0.11	0.03	0.29	4.24	0.00***
Item 18	0.11	0.03	0.29	4.24	0.00***
Item 19	0.09	0.02	0.25	3.70	0.00***

* p <.05, *** p <.001
Note: All regressions run individually in order to determine univariate impact.
For all cases, df = 1,201.

candidate scales and other theoretically related scales. First, the correlation between the two scales and the Computer Playfulness Scale was examined. The 4-item version of the PES was somewhat, but not statistically significantly correlated with playfulness ($r(201) = .12, p = .09$). The 14-item version of the scale was significantly and positively correlated with playfulness ($r(201) = .20, p <.001$). Given the strong theoretical link between playfulness and play, the 14-item version of the scale was used for further validity analysis.

As an additional test of the suitability of the 14-item version of the Play Experience Scale, confirmatory factor analysis was conducted using structural equation modeling with the four-factor model suggested by the previous analyses. Though there were experimental issues that prevented the external regulation factor from being fully tested, the 14-item version of the PES showed reasonably good fit ($\chi^2(71)$=158, p<.001; $GFI = .90; SRMR = .06$). A more parsimonious 10-item, 3-factor version of the scale that dropped the external

Table 9: Principal Component Analysis: 14-item PES

Item	C1	C2	C3	C4	Communality
Item 2	-.07	.14	-.03	.87	0.81
Item 3	-.10	-.01	.01	.94	0.80
Item 5	.08	-.03	.76	.16	0.67
Item 6	.01	.07	.67	-.12	0.43
Item 7	.36	-.36	.57	.15	0.55
Item 8	-.30	.27	.79	-.12	0.67
Item 9	.20	.79	-.02	-.01	0.81
Item 10	.17	.76	-.01	.10	0.82
Item 11	.18	.75	-.04	.11	0.82
Item 12	-.12	.90	.11	-.03	0.73
Item 15	.72	.03	-.05	.20	0.71
Item 17	.83	.12	.08	-.12	0.74
Item 18	.91	.04	-.05	-.06	0.81
Item 19	.90	.06	.01	-.14	0.76

Note: Factor loadings >.40 shaded. Oblique rotation conducted using the Promax function. The four components accounted for 72.41% of the total variance in the 14 items.

regulation subscale showed improved fit ($\chi^2(32) = 56.44$, $p<.01$; $GFI = .95$; $SRMR = .039$). This improvement in fit was significant, as indicated by a chi-square difference test ($\chi^2(39) = 101.56$, $p<.001$). This 10-item version of the PES showed higher reliability than the 14-item version of the test ($\alpha = .90$). However, given the lack of extrinsic motivation factors in the study, this may have been an artifact of study conditions rather than an indication of the play construct's structure. Further implications from these results are provided in the Discussion section. For the remaining validity examinations, the 14-item version of the scale was used.

4.1.2.4 Convergent Validity

With the structure of the 14-item version of scale established, it was possible to examine the scale's validity. As the construct of play is conceptually similar to that of state-based intrinsic motivation, correlations between the Play Experience Scale and the McAuley,

Table 10: PES subscales predicting game condition

Variable	*B*	*SE*	β	*t*	*Sig.*
(Constant)	−0.33	0.16		−2.11	0.04
Subscale 1	0.02	0.01	0.11	1.72	0.09
Subscale 2	0.01	0.01	0.06	1.04	0.30
Subscale 3	0.06	0.01	0.67	9.54	0.00
Subscale 4	−0.01	0.01	−0.11	−1.68	0.09

Adjusted R^2 = .436. Overall test of model F(4,198) = 39.97. p <.000.
Subscale 1 = Items 2, 3. Alpha = 0.78
Subscale 2 = Items 5, 6, 7, 8. Alpha = 0.67
Subscale 3 = Items 9, 10, 11, 12. Alpha = 0.91
Subscale 4 = Items 15, 17, 18, 19. Alpha = 0.90

Duncan, and Tammen (1989) scale of state intrinsic motivation were calculated (see Table 11). The correlation between the scales was high ($r(201) = .79, p < .001$) supporting the convergent validity of the scale. To further establish convergent validity, the correlation between the Play Experience Scale and the state-based amotivation subscale of the SIMS (Guay, Vallerand, & Blanchard, 2000) was calculated (see Table 11). The two scales were negatively correlated ($r(201) = -.35, p < .001$). The scale's relationship to the state-based external regulation (e.g., extrinsic motivation) subscale of the SIMS was similarly examined. State-based extrinsic motivation was negatively correlated with play experience ($r(201) = -.20, p < .01$), as had been suggested by the definition of play (O'Connor & LaPoint, 1980).

4.1.2.5 Discriminant Validity

The discriminant validity of the PES was assessed by comparing the average variance extracted (AVE; Fornell & Larcker, 1981) to the squared correlation of the PES and intrinsic motivation. AVE values were calculated using Construct Validity Calculator 2.0 (Md-Basir, Mahzan, Jaafar, Mokhtar, Abdl-Aziz, Abdul-Rahman, & Daud, 2010). The 14-item PES had an AVE of 0.68, which was higher than 0.62, the squared correlation of PES and intrinsic motivation (see Table 11 for scale correlations). Similarly, the average variance extracted of the intrinsic motivation scale was calculated at 0.77, which was also higher than 0.62. Thus, though the two scales were highly correlated, the PES and intrinsic motivation scales showed discriminant validity.

4.1.2.6 Construct Validity

Due to the scale's unique position as the first measure of play experience, concurrent validity could not be established. However, construct validity was assessed by comparing aggregated means of the two game conditions to the means of the non-game condition. ANOVA was used to compare the game and non-game conditions on post-task play experience scores. Mean scores for the game conditions ($M = 4.56, SD = 0.73$) were significantly higher than mean scores for the non-game condition ($M = 3.57, SD = 0.57; F(1, 201) = 96.94$, $\eta^2 = .32, p$ <.001). Construct validity was also assessed by testing whether playfulness was positively correlated with play. As previously noted, the Computer Playfulness Scale and Play Experience Scale were significantly and positively correlated ($r(201) = .20, p <.001$), as had been suggested by theory. Test-retest reliability was established by examining correlations between the first and second administration of the Play Experience Scale ($r(201) = .73, p$ <.001). Correlations between the two Play Experience Scales, the state-based measure of intrinsic motivation, the SIMS subscales, and the Computer Playfulness Scale for each of the two administrations are presented in Tables 11 and 12.

4.1.2.7 Psychometric Properties

Finally, the distribution of responses to the scale items were examined to further determine the Play Experience Scale's psychometric properties. The mean response to the scale for all three conditions was 4.22 ($SD = 1.01$). Responses ranged from a minimum of 2.07

Table 11: Scale correlations - second administration

	PES-14	PES-4	Playfulness	IMS	SIMS External
PES-14					
PES-4	0.76***				
Playfulness	0.20**	0.12			
IMS	0.79***	0.63***	0.10		
SIMS External	−0.20**	−0.12	−0.09	−0.27***	
SIMS Amotivation	−0.35***	−0.33***	−0.04	−0.40***	0.58***

PES-14 = Play Experience Scale 14 item, PES-4 = Play Experience Scale 4 item, IMS = Intrinsic Motivation Scale, SIMS = Situational Motivation Scale
** $p < .01$, *** $p < .001$
N = 203, two-tailed significance values reported.

Table 12: Scale correlations - first administration

	PES-14	PES-4	Playfulness	IMS	SIMS External
PES-14					
PES-4	0.70***				
Playfulness	0.09	−0.01			
IMS	0.67***	0.51***	0.05		
SIMS External	−0.23***	−0.06	−0.07	−0.27***	
SIMS Amotivation	−0.31***	−0.15*	−0.06	−0.43***	0.60***

PES-14 = Play Experience Scale 14 item, PES-4 = Play Experience Scale 4 item, IMS = Intrinsic Motivation Scale, SIMS = Situational Motivation Scale
** $p < .01$, *** $p < .001$
N = 203, two-tailed significance values reported.

to a maximum of 6. The scale's absolute minimum and maximum was 1 and 6, respectively. Responses to the scale were very slightly skewed ($skew = -.05$) and mildly platykurtic ($kurtosis = -.57$). The reliability of the 14-item version of the PES was calculated based on Cronbach's alpha, with the second administration of the test showing high reliability ($\alpha = .86$) and the first administration showing slightly reduced reliability compared to the second ($\alpha = .83$).

4.1.3 Discussion

Based on these data, I concluded that the Play Experience Scale is appropriate for further use in this dissertation – and for wider use by the scientific community. The scale

Table 13: Summary of PES validity

Validity Type	**Indicated**	**Reason**
Convergent	Yes	Correlation with intrinsic motivation scale, negative correlation with SIMS amotivation and external subscales.
Discriminant	Yes	Average Variance Extracted was higher than the squared correlation of the PES and intrinsic motivation scales.
Construct	Yes	Correlation with the Computer Playfulness Scale.
Concurrent	No	No other scale of play available.

showed high reliability, and it correlated with existing measures of theoretically related constructs as expected. Discriminant, convergent, and predictive validity were established by examining the relationships of the resultant post-pruning PES with established scales of motivation, playfulness, and the study manipulation itself. As expected, the PES was positively correlated with intrinsic motivation and playfulness. The PES was also negatively correlated with the amotivation and external regulation components of the Situational Motivation Scale, which was in line with theory. The 14-item version of the consists of 4 subscales: freedom, no extrinsic motivation, play-direct, and autotelic-focus (see Table 14).

Of four subscales, play-direct was the most effective in predicting whether an experience was the result of a game or non-game interaction. However, on its own, the play-direct subscale did not correlate with playfulness. This is problematic from a theoretical perspective, as playfulness should be related to the expression of play behavior. This lack of correlation is likely due to one of two reasons. First, it is possible that the Computer Playfulness Scale (Webster & Martocchio, 1992) does not adequately measure the construct of playfulness. This potential issue cannot be addressed by the present study. Instead, future research should continue to investigate the validity of this measure, as some concerns over the validity of the related Adult Playfulness Scale have been raised (Kruger, 1995).

The second possible cause for the lack of correlation between the PES and play is that the PES's play-direct items do not sufficiently measure all aspect of play behavior. This is reasonable to presume — the addition of items that ascertain play behavior based on other elements of the play definition (i.e., autotelic experience, ability to focus, lack of extrinsic motivation, and freedom) resulted in a scale that appropriately correlated with playfulness. Nonetheless, the direct-play subscale's lack of correlation with the Computer Playfulness Scale raises some concerns for future play researchers. However, given that the composite score derived from the 14-item version of the PES correlated with playfulness (and other measures) as expected, the Play Experience Scale should be useful for play research. Future research using the PES should investigate its relationship with other measures of playfulness and conceptually similar constructs.

The PES's pattern of correlations with the intrinsic motivation scale revealed another potential issue. Specifically, the Play Experience Scale was very highly correlated with intrinsic motivation. However, evidence from theory suggests that playfulness should predict play. If the scales of play behavior and intrinsic motivation were theoretically equivalent, playfulness would predict both intrinsic motivation and play behavior. This was not the case, as playfulness was only predictive of scores on the Play Experience Scale, and not of scores on the measure of intrinsic motivation. As additional evidence of the PES's discriminant validity, its average variance extracted was higher than its squared correlation with intrinsic motivation. Thus, though the two scales were highly correlated, it is likely that this is due to the inherent relationship between play and intrinsic motivation. Nonetheless, this high correlation should be examined in future research.

Of the five play definition factors initially used to "seed" the Play Experience Scale with items, four remained after principal component analysis. The autotelic experience and focus items collapsed onto one component, and were thus integrated into an autotelic-focus subscale. While the "no extrinsic motivation" items of the scale were not satisfactorily correlated with game condition, it is likely that this is an artifact of the experimental tasks rather than an implication for external regulation and play. The tasks employed were already free from any external consequence. Without any external consequences present, it is thoroughly reasonable to expect little variation in perceptions of external consequences. Indeed, the theoretical meaning of external regulation is maintained through the scale's negative correlation with the external regulation component of the Situational Motivation Scale. Because of this, the items comprising the "no extrinsic motivation" subscale were retained for use in Study 2, which features a higher degree of external outcome.

Based on this study alone, the 14-item version of the PES serves as an adequate and meaningful measure of overall play experience. However, based on the confirmatory factor analysis results, it may be appropriate to drop the extrinsic motivation items in contexts where researchers expect little variation due to external regulation (as was the case in study 1). In the following study, the suitability of the extrinsic motivation / external regulation factors was re-assessed to resolve this ambiguity and provide further validation of the PES.

4.2 Study 2: Immune Game

In this study, an immune system training game was used to examine the new model for flow in serious games. Specifically, the hypothesized impact of play, in-game performance, and emotional experience on flow state was examined (see Figure 6). These hypotheses target

Table 14: Subscales of the Play Experience Scale: 14-Item

	Item	Dimension and Coding
1	I was able to make the game do what I wanted it to	Freedom
2	The game gave me the freedom to act how I wanted to	Freedom
3	I was not worried about someone judging how I performed in the game	No extrinsic
4	Regardless of how I performed in the game, I knew there wouldn't be a real-world consequence	No extrinsic
5	My performance in the game was not going to matter outside of the game	No extrinsic
6	I felt like I had to do well, or the experimenter would judge me	No extrinsic (R)
7	When I was using the game, it felt like I was playing rather than working	Play-direct
8	I would characterize my experience with the game as "playing"	Play-direct
9	I was playing a game rather than working.	Play-direct
10	Using the game felt like work	Play-direct (R)
11	When I was using the game, I was focused on the task at hand	Autotelic-Focus
12	I wanted to do well in the game, "just because"	Autotelic-Focus
13	When I was using the game, I wanted to do as well as possible	Autotelic-Focus
14	I tried to succeed in the game because I felt like it	Autotelic-Focus

Note: Item numbers do not correspond to original item numbers, due to removal of original items.

a subset of the overall model of flow in games. Additionally, the study served to provide further validation of the newly established Play Experience Scale.

4.2.1 Method

4.2.1.1 Participants

A sample of 77 undergraduate volunteers enrolled at a southeastern metropolitan university was recruited for this study. In this sample, 46.8% of the participants were male and 53.2% were female, ranging in age from 18 to 27 years old. The majority of respondents were young adults; 90.9% of the participants ranged between 18 and 21 years old.

A priori power analysis conduced in G*Power using five predictors in linear regression at a power of .80, effect size of $f^2 = .25$, and α error probability of .05 indicated that a sample size of 58 participants was required. However, given the N-to-k heuristic suggested at least 70 participants, this higher number was used as the required sample size for the study.

4.2.1.2 Design

This study was conducted as a non-experimental empirical study of participant behavior within the flow-supporting serious game. There was no true manipulation, and thus no manipulated independent variable. Participants engaged in game play across three rounds, with the dependent variables of flow state, play experience, and emotional experience collected after each round of game play. Additional measures (e.g., video game self-efficacy, knowledge tests) were collected before and after the game play sessions.

4.2.1.3 Materials

The InnerCell training game is a strategy game that tasks players with defending a patient's body from infection by a variety of pathogens (Pavlas, Heyne, Bedwell, Lazzara, & Salas, 2010). Players must steer the body's immune cells to defeat the pathogens that the cells are best suited to engaging. For example, Neutrophil is effective in dealing with bacterial pathogens, but useless against viruses. Each of the three rounds of gameplay is comprised of two phases. In the planning phase (see Figure 7), players investigate the pathogens they will be facing and place static defenses such as chemical walls and helper t-cells. In the infection phase (see Figure 8), the patient's body is under assault by the pathogens identified during the planning phase. Players must allocate and command the body's natural defenses, spend resources (Tymosin points) to create immune cells, and administer external treatments (such as TamiFlu). After the infection phase is finished, the game presents feedback, followed by the next round's planning phase. Each round increases in difficulty compared to the last, with new pathogens and more complicated treatment options (e.g., Augmentin must be used to weaken the pathogen Haemophilus before it can be defeated by a Neutrophil cell).

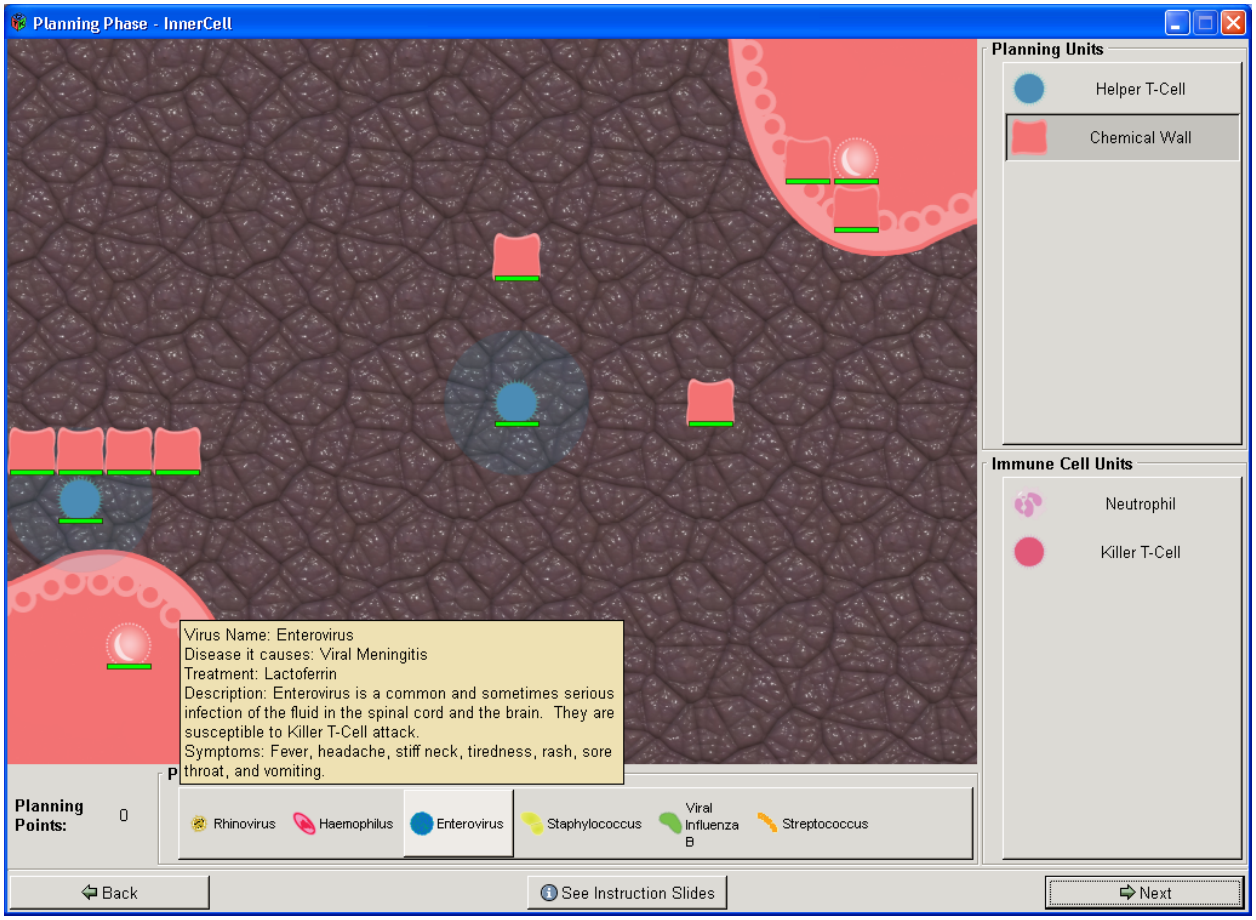

Figure 7: InnerCell planning phase

The InnerCell game was used in previous research investigating the impact of different game attributes on learning (Pavlas, Heyne, Bedwell, Lazzara, & Salas, 2010). The modifiable nature of the game made it especially useful for the present study, as it was possible to create a flow-supporting version of the game. To provide the game players in this study with greater opportunities to reach flow state, the design of the game was iterated upon. Based on the flow literature, additional features were added to the game, including greater visual feedback in the form of combat animations, damage numbers appearing during combat, additional visual feedback for actions such as basophil use, a "panic" button for player-driven dynamic difficulty adjustment, and next-wave warning arrows (indicating incoming pathogens). Additionally, the adaptation algorithms from previous versions of the game were updated to provide players with more constant challenge, working to keep players from becoming bored or overwhelmed.

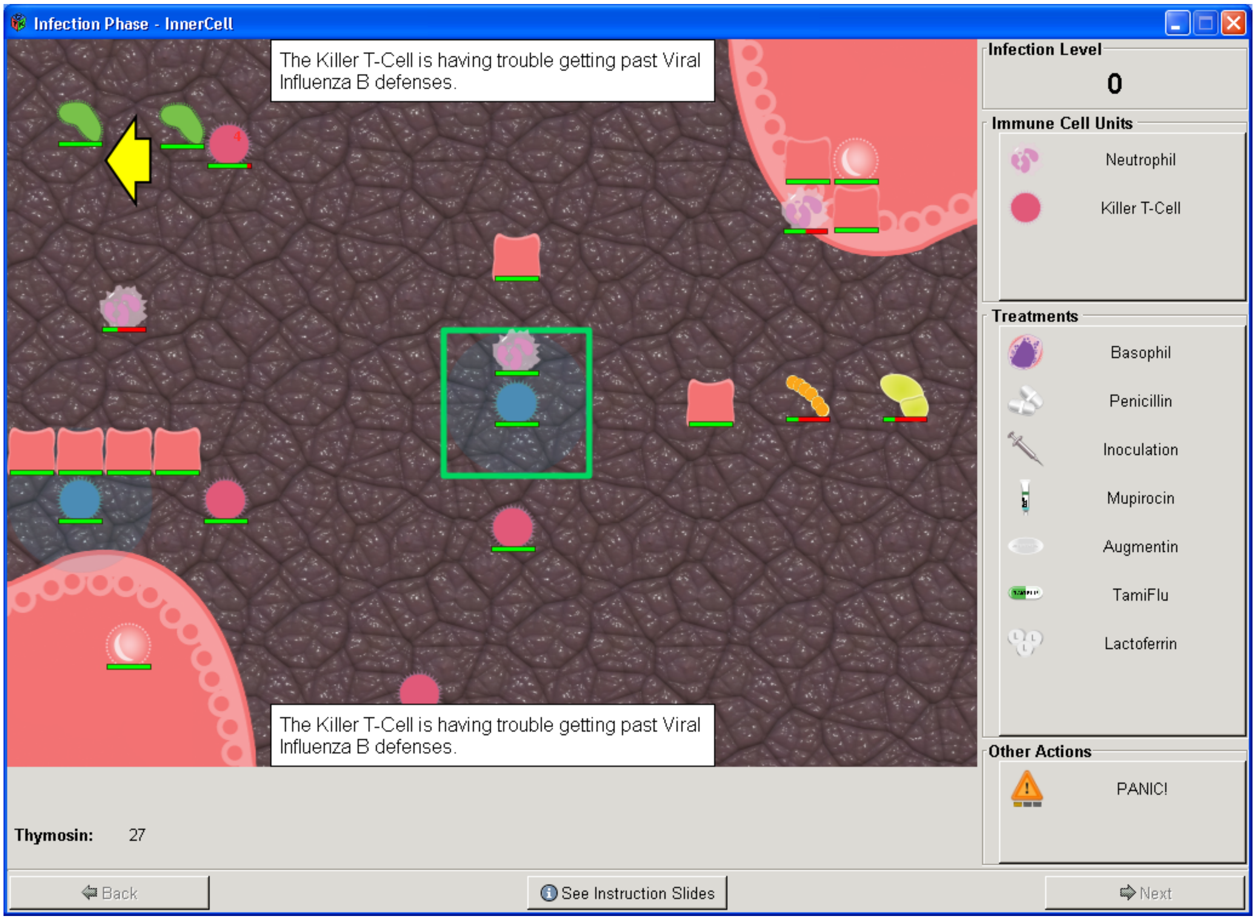

Figure 8: InnerCell infection phase

4.2.1.4 Measures

A number of measures, including the previously created Play Experience Scale, were used in this study. As the purpose of this study was to empirically examine the relationships outlined in the new model of flow in serious games (see Figure 5), each construct of the model was represented by a measure. Additionally, based on the review of factors that influence the constructs of interest (see Table 3), a number of metrics were employed to measure

Table 15: Subscales of the Play Experience Scale: 16-Item

	Item	Dimension and Coding
1	If I wanted to do something in the game, I was able to do it	Freedom
2	I was able to make the game do what I wanted it to	Freedom
3	The game gave me the freedom to act how I wanted to	Freedom
4	The game made it difficult to perform the actions that I wanted to	Freedom (R)
5	I was not worried about someone judging how I performed in the game	No extrinsic
6	Regardless of how I performed in the game, I knew there wouldnt be a real-world consequence	No extrinsic
7	My performance in the game was not going to matter outside of the game	No extrinsic
8	I felt like I had to do well, or the experimenter would judge me	No extrinsic (R)
9	When I was using the game, it felt like I was playing rather than working	Play-direct
10	I would characterize my experience with the game as playing	Play-direct
11	I was playing a game rather than working.	Play-direct
12	Using the game felt like work	Play-direct (R)
13	When I was using the game, I was focused on the task at hand	Autotelic-Focus
14	I wanted to do well in the game, "just because"	Autotelic-Focus
15	When I was using the game, I wanted to do as well as possible	Autotelic-Focus
16	I tried to succeed in the game because I felt like it	Autotelic-Focus

applicable covariates. Full scale descriptions are available in Appendix A. Several measures used in Study 1 were re-used in Study 2, including the Flow State Scale, the Computer Playfulness Scale, and the Intrinsic Motivation scale.

Play Experience Scale

A revised version of the PES-14 was created for use in this study. To remedy the lack of symmetry in the PES-14, two items were added to the freedom subscale, resulting in a symmetric 16-item scale (see Table 15). The validity of these additions were examined as part of this study.

Declarative Knowledge Quiz

The declarative knowledge quiz employed in this study was the same subject matter expert-created test employed in prior studies using the InnerCell game (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009). The quiz provides participants with 43 multiple-choice questions pertaining to the immune system information contained in the game.

Knowledge Organization Test

The knowledge organization test employed in this study was an expert-graded open card sort task using exemplar items encountered during gameplay (Pavlas, Bedwell, Wooten II, Heyne, & Salas, 2009). In this task, the participants sorted 16 immune system items into categories of their own design. The sort data were examined by a single expert rater and graded on a 5-point scale ranging from "very poor" (1) to "very good" (5). Responses were rated as "very poor" (1) when there were only two or fewer groups represented in the sort, with multiple errors in these groups. Sorts were rated as "poor" (2) when respondents provided three groups or more but had more than two "errors" of categorization (e.g., creating a pathogen category and placing an immune cell into it). A rating of "average" (3) was assigned when three groups were created and less than two errors of categorization were present. To move from a rating of "average" (3) to "good" (4), participants had to provide an additional meaningful categorization group (e.g., treatments, bacteria vs. viruses). Finally, a rating of "very good" (5) was assigned for sorts that included semantic linking of treatments, pathogens, and/or immune cells.

Self-Assessment Manikin

The Self-Assessment Manikin (SAM; Bradley & Lang, 1994) is a visual scale designed to measure emotional experience. Responses are indicated along a variable-length scale (similar to a 5, 7, or 9-point Likert) comprised of images that show an abstract human experiencing a range of emotions, including happy/sad, aroused/calm, and in-control/dominated. In this study, the 7-point version of the scale was used. The visual anchors of the scale are included in Appendix A.

Video Game Self-Efficacy

Table 16: Model hypotheses

	Hypotheses
H1	Playfulness will be significantly and positively related to an individual experiencing play behavior.
H2	Videogame Self-Efficacy will be significantly and positively related to an individual experiencing play behavior and flow state.
H3	Play will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.
H4	In-game performance will have a significant impact on learning outcomes. This relationship will be partially mediated by flow state.
H5	Play, emotional experience, and in-game performance during a game play session will be significantly and positively related to flow state in that session.
H6	Prior levels of flow state will be significantly and positively related to later experiences of play, emotional experience, and in-game performance.
H7	Patterns of performance during individual game play rounds that reflect matched challenge/skill will be predictive of flow state.

The scale of video game self-efficacy used in this study was previously modified (Pavlas et al., 2009) from the Schwarzer & Jerusalem scale of general self-efficacy (1995). The scale consists of ten items that reference an individual's confidence in their ability to successfully engage in video game tasks. Participants respond to the measure along a 6-point Likert-type scale ranging from "strongly disagree" (1) to "strongly agree" (6).

4.2.1.5 Procedure

Before training on how to play the game began, participants completed a battery of demographic and trait measures, including the Computer Playfulness Scale and the Video Game Self-Efficacy Scale. These measures were presented via an electronic survey system on the lab computer.

Once participants completed the pre-training measures, they were instructed on how to play the InnerCell game via a training video. This training video presented an overview of the game and explained the basic elements of gameplay. After completing the training, participants played the game for the full three rounds of gameplay. After each round of gameplay, participants responded to the Self-Assessment Manikin, the Play Experience Scale, and the Flow State Scale. Once the three rounds were complete, participants responded to the Intrinsic Motivation Scale. Finally, learning assessment was performed using the test of declarative knowledge and the card sort for knowledge organization. Once all measures and tests were completed, participants were debriefed and thanked for their participation.

4.2.2 Results

Of the 77 participants that participated in the study, 74 provided complete data. Of the three participants with missing data, all were included in the analysis, as each was only missing one or two variables. Data were screened for outliers, with no deletions occurring. Means, standard deviations, and correlations for the primary investigated variables, potential covariates, and demographic information are presented in Table 17. The normality of each of the primary study variables was assessed by performing the Shapiro-Wilks test of normality, the results of which are presented alongside skew and kurtosis values in Table 18. Flow, playfulness, play, intrinsic motivation, and infection level were normally distributed. Knowledge organization, video game self-efficacy, and declarative knowledge scores were not normally distributed.

The lack of normality of the learning outcomes and the video game self-efficacy scores presented a potential issue for further analysis. As these variables were intended for use in a number of analyses, their use carried with it a number of negative contingencies, including the potential for Type I error inflation. However, the analyses used were largely robust against violations of normality. Further, the lack of normality in these data may have been

Table 17: Study 2 correlations, means, and standard deviations

	Mean	*SD*	Age	Gender	Motivation	Play	Flow	VGSE	CPS	Infection	KO
Age	18.84	1.71									
Gender	NA	NA	−0.02								
Motivation	73.34	13.70	0.19	−0.25*							
Play	73.69	11.03	0.24*	−0.22	0.66***						
Flow	40.29	6.57	0.08	−0.19	0.72***	0.78***					
VGSE	44.62	9.05	0.10	−0.35**	0.38***	0.35**	0.48***				
CPS	40.01	4.54	−0.04	−0.08	0.06	0.20	0.27*	0.10			
Infection	2813.00	1478.82	−0.27*	0.37**	−0.46***	−0.48***	−0.38***	−0.29**	0.28*		
KO	3.16	0.78	0.28*	−0.28*	0.20	0.28*	0.17	0.14	−0.03	−0.42***	
DK	27.66	8.02	0.30**	−0.13	0.36**	0.48***	0.31**	0.33**	−0.17	−0.64***	0.41***

* p <.05, ** p <.01, *** p <.001
VGSE = Video game self-efficacy, Infection = Infection level, KO = Knowledge organization, DK = Declarative knowledge, CPS = Playfulness, Gender effects listed are for females.

Table 18: Study 2 normality statistics

Variable	*W*	*p*-value	Skew	Kurtosis
Motivation	0.98	0.18	−0.39	−0.28
Play	0.97	0.09	−0.30	−0.73
Flow	0.98	0.44	−0.33	−0.44
VGSE	0.95	0.01*	−0.77	0.95
Playfulness	0.98	0.14	0.06	−0.59
Infection	0.98	0.44	0.19	−0.65
KO	0.95	0.01*	−0.77	0.94
DK	0.95	0.00*	−0.58	−0.50

VGSE = Video Game Self-Efficacy, KO = Knowledge Organization, DK = Declarative Knowledge
Note: Statistical significance is indicated by *, and indicates a lack of normality.

the result of age and gender effects (see Table 17). Consequently, I decided to use the variables without transformation, to ease interpretation. However, it is important to note that the lack of normality in these variables may nonetheless adversely affect analyses.

In the following analyses, each of the seven hypotheses (see Table 16) are examined in sequence. Implications for the findings are presented after all analyses have been presented.

4.2.2.1 Hypothesis 1: Playfulness and Play

The first hypothesis dealt with the relationship between trait playfulness and state play experience. Playfulness and mean play scores were not significantly correlated ($r(72) =$

Table 19: Multiple linear regression: age, playfulness, and VGSE on play

Variable	B	$SE(B)$	β	t	Sig. (p)
(Constant)	14.29	17.05		0.84	0.40
Playfulness	0.42	0.26	0.17	1.63	0.11
Age	1.36	0.68	0.21	1.99	0.05
VGSE	0.38	0.13	0.31	2.94	0.00

VGSE = Video Game Self-Efficacy
Adjusted $R^2 = 0.16 p < .01$

$.20, p = .09$). However, in Study 1, playfulness and play were significantly correlated. Given that playfulness and play were trending towards significant correlation, this lack of a result may be an artifact of the type of game employed or masked by the effects of an additional variable. To test whether variables such as age or video game self-efficacy may have affected this relationship, multiple linear regression was conducted. When mean play scores were regressed onto age and playfulness, age was a significant predictor of play ($\beta = .24, p = .03$) and playfulness was nearly significant ($\beta = .20, p = .07$). A second multiple linear regression was conducted, regressing mean play scores onto age, playfulness, and video game self-efficacy (see Table 19). However, this did not result in playfulness being a significant predictor of play. Thus, while Study 1's results pointed toward a significant relationship between playfulness and play, results from this study did not support Hypothesis 1.

4.2.2.2 Hypothesis 2: VGSE, Play, and Flow

The second hypothesis suggested that video game self-efficacy and flow state would be significantly and positively related. Simple linear regression was used to examine the relationship between video game self-efficacy and flow state as well as play behavior. In two separate regression equations, first mean play scores and then mean flow scores were regressed onto video game self-efficacy. Video game self-efficacy was a significant predictor

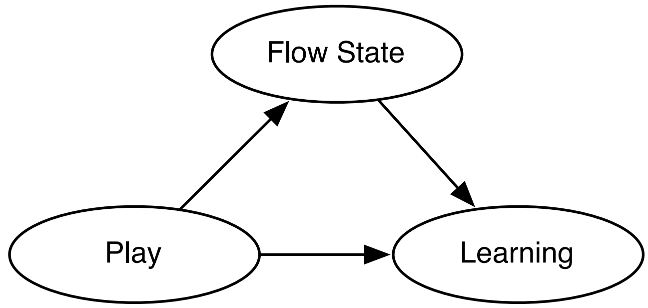

Figure 9: Potential mediation model for Hypothesis 3

of mean play scores ($\beta = .35, R^2 = .11, F(1,74) = 10.37, p < .01$) and mean flow scores ($\beta = .48, R^2 = .22, F(1,75) = 22.33, p < .001$). Based on these results, Hypothesis 2 was supported.

4.2.2.3 Hypothesis 3: Play, Flow, and Learning

Next, the relationship between play, flow, and learning was examined. The potential impact of play on learning was first examined via two simple linear regression equations regressing declarative knowledge and knowledge organization onto mean play scores. Mean play scores were positively and significantly predictive of declarative knowledge ($\beta = .48, R^2 = .22, F(1,73) = 22.39, p < .001$), and knowledge organization ($\beta = .28, R^2 = .06, F(1,73) = 6.14, p = .02$). Thus, play had a significant impact on learning outcomes. Similar tests were performed to examine the impact of flow on learning, indicating that mean flow scores were positively and significantly predictive of declarative knowledge ($\beta = .31, R^2 = .09, F(1,74) = 7.98, p < .01$) but not knowledge organization ($\beta = .17, R^2 = .02, F(1,74) = 2.19, p = .14$). Based on these results, the potential mediating effect of flow on play's relationship to declarative knowledge learning was examined (see Figure 9).

The Preacher & Hayes bootstrap method (Preacher & Hayes, 2008) was used to test for mediation. The Preacher & Hayes method is a bootstrap resampling method that allows for more powerful testing of single and multiple mediation hypotheses. Bootstrapping is especially useful because it does not assume normal distribution of the total and indirect effects. Interpretation of this method is fairly simple, as significance values for the direct mediator-to-DV, direct IV-to-DV, indirect effect, and total effect path coefficients are provided. Based on these paths, it is possible to determine whether the model indicates partial mediation (i.e., significant indirect and direct effects are present), full mediation (i.e., only significant indirect effects are present), or no mediation.

Based on 1,000 bootstrap resamples, no significant indirect effect for play through flow was found ($Z = -1.06, p = .29, \beta = -.10, SE = .09$). Further, when considered alongside play, the direct effect of flow on learning was no longer significant ($p = .30$). Based on these results, flow did not mediate the relationship between play and learning. However, given the inter-correlated nature of some of the study variables (see Table 27), further analysis was necessary. First, age was added as a covariate to the bootstrap mediation test due to its correlation with play. However, there was no meaningful change to the model, with play still not showing an indirect effect through flow ($t(75) = -0.76, p = .45$). When age and video game self-efficacy (which was correlated with flow and play) were added as covariates, the model began to become more meaningful, with flow's direct effect on declarative knowledge increasing in significance ($t(75) = -1.44, p = .16$). However, the effect of flow on declarative knowledge was not statistically significant, even after accounting for these covariates.

Given the results of the mediation analysis, an alternative mediation model was tested, with play mediating the effects of flow on learning. A significant indirect effect of flow through play was found ($Z = 3.64, p < .001, \beta = .48, SE = .13$). As the previous analysis represents the same data, the direct effect of flow on declarative knowledge was once again reduced to non-significance ($p = .30$). However, in this case, this reduction represents full mediation, as the direct effect of flow on declarative knowledge ($\beta = .31, R^2 = .09, F(1, 73) = 7.98, p < .01$) was fully explained by play. Thus, Hypothesis 3 was partially supported. Though flow did not serve as a mediator for the relationship between play and declarative knowledge, this relationship was nonetheless positive and significant.

4.2.2.4 Hypothesis 4: Performance, Flow, and Learning

A similar process was used to examined the relationship between performance, flow, and learning. A number of potential indicators of in-game performance were collected during gameplay sessions. The two primary candidates, infection level (i.e., the amount of infection the player was unable to prevent) and number of successful interactions (i.e., the number of successful treatment-pathogen and immune-pathogen pairings made) were each examined for their potential impact on learning outcomes. Linear regression indicated that infection level (a negative indicator of performance) was significantly and negatively related to declarative knowledge learning outcomes ($\beta = -.64, R^2 = .41, F(1, 74) = 52.21, p < .001$), suggesting performance had a significant and positive impact on learning. Similarly, infection level was significantly related to knowledge organization learning outcomes ($\beta = -.42, R^2 = .16, F(1, 74) = 15.64, p < .001$). Because infection level was a negative indicator of performance (i.e., more infection meant worse performance), these findings supported Hypothesis 4. Similarly, the total number of successful interactions was significantly and positively related to declarative knowledge ($\beta = .50, R^2 = .24, F(1, 74) = 25.17, p < .001$), but not knowledge organization ($\beta = .22, R^2 = .03, F(1, 74) = 3.70, p = .06$).

Table 20: Multiple linear regression: successful interactions and infection level on declarative knowledge

Variable	B	$SE(B)$	β	t	Sig. (p)
(Constant)	35.750	5.069		7.052	0.000
Successful Interactions	0.007	0.020	0.047	0.347	0.730
Infection Level	−0.003	0.001	−0.608	−4.479	0.000

Adjusted $R^2 = 0.40, F(2, 73) = 25.86$ p <.001
Note: 3 decimal places reported due to the high values of infection level

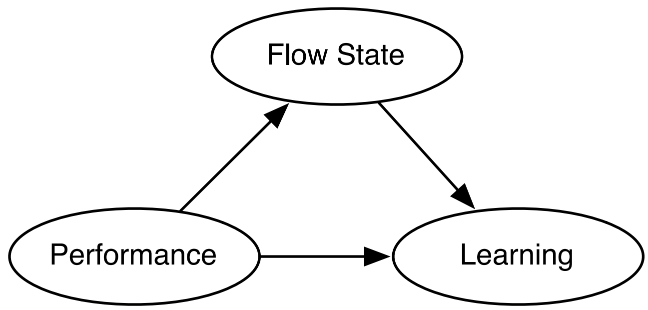

Figure 10: Potential mediation model for Hypothesis 4

To examine whether these two indicators provided unique information about learning, multiple linear regression was used to test the impact of infection level and successful interactions on declarative knowledge. Results for these analyses are presented in Table 20. When included together with infection level in regression the variable, successful interactions no longer served as a significant predictor of performance. Thus, infection level was used in examining the potential mediating effect of flow state on the relationship between performance and learning (see Figure 10).

The Preacher & Hayes bootstrap method was once again used to test for mediation. Based on 1,000 bootstrap resamples, no significant indirect effect for performance through flow was found ($Z = -0.55, p = .58, \beta = -.00, SE = .00$). Additionally, when considered alongside performance, the direct effect of flow on learning was no longer significant ($p = .59$). Based on these results, flow did not mediate the relationship between in-game performance

Table 21: Multiple linear regression: flow, play, and infection level on declarative knowledge

Variable	B	$SE(B)$	β	t	Sig. (p)
(Constant)	26.971	6.577		4.101	0.000
Infection Level	−0.003	0.001	−0.557	−5.492	0.000
Play	0.252	0.107	0.341	2.366	0.021
Flow	−0.238	0.166	−0.194	−1.432	0.157

Adjusted $R^2 = 0.45, F(3, 71) = 21.07$, p <.001
Note: 3 decimal places reported due to the high values of infection level

and learning. However, as was the case with the analysis for Hypothesis 3, a number of variables were potentially meaningful covariates for this analysis. The addition of age (which was correlated with performance) as a covariate in the bootstrap procedure did little to change the effect of flow on declarative knowledge ($t(76) = .60, p = .55$). Once age and mean play (which was correlated with performance and age) included as covariates, in-game performance no longer had a significant relationship with flow ($t(76) = -.53, p = .60$). Given the theoretical relationship between video game self-efficacy and in-game performance, a final bootstrap procedure was conducted using age and video game self-efficacy as covariates. With the addition of these two covariates, the direct effect of flow to learning completely disappeared ($t(76) = -.20, p = .84$). Based on these results, it was unlikely that flow served as a mediator for the relationship between in-game performance and learning. Hypothesis 4 was only partially supported, as in-game performance nonetheless had a significant and positive effect on learning outcomes.

An additional multiple linear regression was conducted to examine the individual contributions of performance, play, and flow state on learning outcomes. Though not tied to any specific hypothesis, this analysis served to further elucidate the model subset examined in this study. Table 21 presents the results of regressing declarative knowledge onto performance, play, and flow in a simultaneous multiple regression equation.

Table 22: Multiple linear regression: SAM, play, successful interactions, and VGSE on flow

Variable	B	$SE(B)$	β	t	Sig. (p)
Round 1					
(Constant)	−2.40	3.20		−0.75	0.456
Play	0.31	0.05	0.51	6.40	.000
VGSE	0.13	0.05	0.15	2.40	.019
SAM Composite	0.86	0.20	0.32	4.28	.000
Successful Interactions	0.08	0.05	0.11	1.52	.133
Round 2					
(Constant)	4.43	3.98		1.11	0.270
Play	0.20	0.06	0.35	3.43	.001
VGSE	0.25	0.06	0.33	3.84	.000
SAM Composite	0.67	0.22	0.29	3.04	.003
Successful Interactions	0.02	0.03	0.07	0.71	.478
Round 3					
(Constant)	1.20	3.39		0.35	.724
Play	0.26	0.05	0.41	5.12	.000
VGSE	0.09	0.05	0.12	1.66	.101
SAM Composite	1.03	0.17	0.44	5.97	.000
Successful Interactions	0.02	0.01	0.14	1.87	.066
Mean Scores					
(Constant)	−0.49	2.91		−0.17	.867
Play	0.27	0.05	0.45	5.56	.000
VGSE	0.15	0.05	0.21	3.35	.001
SAM Composite	0.88	0.18	0.36	4.97	.000
Successful Interactions	0.01	0.01	0.11	1.53	.130

SAM = Self-Assessment Manikin, VGSE = Video Game Self-Efficacy
Round 1 Adjusted $R^2 = 0.74, F(4, 71) = 53.87$, p <.001
Round 2 Adjusted $R^2 = 0.50, F(4, 71) = 19.85$, p <.001
Round 3 Adjusted $R^2 = 0.69, F(4, 71) = 42.10$, p <.001
Mean Adjusted $R^2 = 0.74, F(4, 71) = 53.35$, p <.001

4.2.2.5 Hypothesis 5: Play, Emotion, Performance, and Flow

Hypothesis 5 suggested that play, emotion, and performance would be significantly related to flow state. This hypothesis was examined for each of the three rounds of gameplay, as well as for the overall mean scores based on the three rounds. Because of the prior evidence for the impact of video game self-efficacy on flow, it was included as a predictor

Table 23: Multiple linear regression: SAM, play, and VGSE on flow

Variable	B	$SE(B)$	β	t	Sig. (p)
(Constant)	-0.84	2.90		-0.29	0.78
Play	0.30	0.04	0.50	6.74	.000
VGSE	0.15	0.05	0.21	3.28	.002
SAM Composite	0.90	0.18	0.36	5.02	.000

Adjusted $R^2 = 0.73, F(3,72) = 69.07,\ p < .001$

in these analyses. A composite emotional experience score was calculated based on simple aggregation of the Self-Assessment Manikin subscales. Because each of the three subscales (happiness, activation, and control) are conceptually related to flow state, theory suggests that high composite scores should also be related to flow state. Table 22 shows the results of multiple linear regression for the scores from each of the three rounds and for the overall mean scores. Because performance was not a significant predictor, another multiple regression was conducted for the mean scores without including in-game performance. Table 23 presents the results of this analysis.

With the effect of these variables established, the additional predictors of age and gender were included into this mean-level multiple regression analysis. Table 24 presents the results of simultaneously regressing flow onto emotional experience, play, video game self-efficacy, age, and gender. Though gender provided no significant addition to the model, age was a significant and negative predictor of flow state (see Table 24).

Finally, simple linear regression was conducted to examine whether in-game performance had any individual relationship to flow state. The number of total successful interactions was significantly and positively related to mean flow score ($\beta = .49, R^2 = .23, F(1,75) = 23.62, p < .001$). Thus, while in-game performance was indeed related to flow state, it did not provide any additional predictive power when included alongside play, emo-

Table 24: Multiple linear regression: SAM, play, VGSE, age, and gender on flow

Variable	B	$SE(B)$	β	t	Sig. (p)
(Constant)	5.14	5.09		1.01	.317
Play	0.32	0.04	0.53	7.19	.000
VGSE	0.17	0.05	0.23	3.50	.001
SAM Composite	0.93	0.17	0.37	5.29	.000
Age	−0.50	0.23	−0.13	−2.17	.033
Gender	0.74	0.83	0.06	0.89	.375

SAM = Self-Assessment Manikin, VGSE = Video Game Self-Efficacy
Adjusted $R^2 = 0.74, F(5, 70) = 44.43,\ p < .001$

tional experience, age, and video game self-efficacy. These results supported Hypothesis 5, though it must be noted that the individual impact of in-game performance was accounted for by the other predictor variables.

4.2.2.6 Hypothesis 6: Temporal Patterns of Flow

Hypothesis 6 related to the short-term relationship between flow state and future performance. This relationship was examined by conducting a set of linear regression equations using Round 1 flow scores to predict Round 2 play scores, composite SAM scores, infection level, and successful interactions. The same set of variables were also examined using Round 2 flow scores as predictors of Round 3 play, SAM, and performance scores. Table 25 present the results of these analyses. To further explain these results, correlations between flow scores were calculated for Round 1 flow and Round 2 flow ($r(73) = .70, p = .00$), Round 1 flow and Round 3 flow ($r(73) = .80, p = .00$), and Round 2 flow and Round 3 flow ($r(73) = .80, p = .00$). While the flow scores were highly correlated, they were not equivalent, suggesting that the use of prior flow scores to predict later outcomes has merit. As prior flow scores were predictive of later performance, emotional experience, and play experience, Hypothesis 6 was supported.

Table 25: Regression equations for next-round variables regressed onto prior-round flow

Equation	B	$SE(B)$	β	t	Sig. (p)	Adj. R^2
Flow 1 to Play 2	0.92	0.15	0.59	6.25	.000	0.34
Flow 1 to SAM 2	0.18	0.04	0.46	4.52	.000	0.20
Flow 1 to Infection 2	−32.92	28.40	−0.13	−1.16	.250	0.00
Flow 1 to Successful Interactions 2	0.75	0.30	0.27	2.47	.016	0.06
Flow 2 to Play 3	1.06	0.14	0.66	7.62	.000	0.43
Flow 2 to SAM 3	0.24	0.04	0.55	5.75	.000	0.30
Flow 2 to Infection 3	−110.90	48.30	−0.26	−2.30	.024	0.05
Flow 2 to Successful Interactions 3	1.78	0.61	0.32	2.91	.004	0.09

Note: Each line represents a single linear regression equation.

4.2.2.7 Hypothesis 7: Challenge-Skill Fit and Flow

The final hypothesis dealt with the archetypal relationship of challenge-skill fit and flow state. Because of this, the examination of Hypothesis 7 necessitated the use of challenge-skill fit metrics. The FSS-2 challenge subscale assessed the relationship between player skill and game challenge with regards to fit (i.e., the degree to which their skills were appropriate for the challenge). However, as the primary indicator of flow state was the FSS-2, the challenge-skill balance score from the scale could not be used to test the impact of challenge-skill fit on flow. Thus, indicators of challenge-skill fit were generated from the available gameplay data. These data provided infection level, number of successful interactions, and number of unsuccessful interactions for every 15-second interval of gameplay. The slopes of these performance variables over time were used as indicators of challenge-skill fit. For participants experiencing appropriate challenge-skill fit, the slopes should be not be too steep, as this would indicate that performance was sharply increasing or decreasing due to gameplay being too difficult or easy. For each participant, the slopes of their three equations of time and outcome variables (i.e., infection level, successful interactions, and ratio of successful to unsuccessful actions) were calculated. These slopes were calculated using linear regression, with β used for ease of interpretation.

As the first step of analysis, flow scores for each round were regressed onto successful interaction slopes for each round. Round 1 success slope was not related to Round 1 flow score ($\beta = -.17, R^2 = .02, F(1, 72) = 2.26, p = .14$), Round 2 success slope was not related to Round 2 flow score ($\beta = -.07, R^2 = .00, F(1, 74) = 0.42, p = .52$), and Round 3 success slope was not related to Round 3 flow score ($\beta = .22, R^2 = .04, F(1, 75) = 3.79, p = .06$). Similar analyses were performed for the relationship between infection level slope and flow score for Round 1 ($\beta = -.34, R^2 = .10, F(1, 44) = 5.75, p = .02$), Round 2 ($\beta = -.04, R^2 = -.01, F(1, 71) = 0.11, p = .74$), and Round 3 ($\beta = .10, R^2 = .00, F(1, 72) = 0.80, p = .37$). These results indicated that unmodified performance variable slopes were generally not predictive of flow state.

A categorical variable was created to serve as an indicator of overall player success. The slopes of the ratio of successful to unsuccessful actions were used to seed a three-level categorical variable of challenge-skill fit. Slopes of 0 and below were categorized as "difficult", slopes between 0 and .35 were categorized as "matched", and slopes above .35 were categorized as "easy." For each of the three rounds, ANOVA was conducted using challenge-skill fit category as a predictor of flow state score. Challenge-skill fit category was not a significant predictor of flow state scores for Round 1 ($F(2, 61) = 1.30, p = .28$) or Round 2 ($F(2, 73) = .37, p = .69$). Challenge-skill fit category was a significant predictor of flow state scores for Round 3 ($F(2, 74) = 4.49, p = .01$), with post-hoc Tukey LSD tests showing that the "easy" category had significantly higher flow scores than both the "matched" category (M diff = 3.95, $p = .031$) and the "difficult" category (M diff = 7.03,

p <.01). This reflected a roughly linear relationship rather than the curvilinear relationship suggested by Hypothesis 7.

Finally, a test of Hypothesis 7 was conducted using the PES-16 as a potential flow state analog. Play scores for each of the three rounds of gameplay were regressed onto respective FSS-2 challenge-skill balance scores for each round. FSS-2 challenge-skill balance scores were significantly and positively related to play scores for Round 1 ($\beta = .69, R^2 = .47, F(1, 74) = 66.74, p <.001$), Round 2 ($\beta = .33, R^2 = .10, F(1, 74) = 9.04, p <.01$), and Round 3 ($\beta = .56, R^2 = .30, F(1, 74) = 33.49, p <.001$). While challenge-skill balance was a significant predictor of play in each of the three rounds, these results do not strongly support Hypothesis 7, as play and flow are treated as separate constructs in this study. Further implications for these findings are presented in the discussion. Based on these results, Hypothesis 7 was not supported.

4.2.2.8 Further Play Scale Validation

These final analyses were performed to further validate the Play Experience Scale. As previously noted, two items were added to the PES-14 to remedy the lack of symmetry in Study 1's resulting scale. The revised 16-item version of the PES (see Table 15) was very highly correlated with the 14-item version of the PES ($r = .99, t(74) = 72.09, p <.001$). Based on item-total correlation (see Table 26), the two new items (items 1 and 4) were meaningful contributors to the overall scale. Unfortunately, the data were insufficient to perform reliable component analysis. However, given the correlation between the 14-item version of the scale and the 16-item version of the scale and the item-total correlations, it was reasonable to suggest that the 16-item version of the scale did not reduce the validity of the PES. For purposes of symmetry, the two new items were thusly retained in the final version of the scale.

Alphas for each of the three administrations of the 16-item version of the scale were calculated. Alpha ranged from 0.86 to 0.90 (Round 1 $\alpha = .90$; Round 2 $\alpha = .89$; Round 3 $\alpha = .86$), indicating good reliability. For comparison, alphas for the 14-item version of the scale were also calculated. These scores were very slightly lower, but still indicated good reliability (Round 1 $\alpha = .89$; Round 2 $\alpha = .88$; Round 3 $\alpha = .86$).

The utility of the extrinsic motivation items of the PES were also examined. In Study 1, the extrinsic motivation items were not strongly related to the overall play scale. Item-total correlations for the scale are presented in Table 26. Items 5 through 8 showed more reasonable item-total correlations in this more outcome-oriented context, suggesting they be retained in the final version of the scale.

4.2.3 Discussion

The prior study served as an initial empirical examination of the new model for flow in games as well as a second validation for the newly established Play Experience Scale. Results for the model hypotheses were mixed: while two of the seven hypotheses were not supported by the study, the remaining five hypotheses were fully or partially supported. The results of Study 2 are discussed below, with an emphasis placed on interpreting the findings in terms of the hypotheses themselves. These results are integrated with the broader dissertation effort in the overall discussion following this section.

Playfulness was not a significant predictor of play (Hypothesis 1), though Study 1 showed this to be the case. Because the play-playfulness correlations across the disserta-

Table 26: PES-16 item-total correlations

Item	Item-Total Correlation
Item 1	0.74***
Item 2	0.76***
Item 3	0.72***
Item 4	0.53***
Item 5	0.63***
Item 6	0.38***
Item 7	0.41***
Item 8	0.40***
Item 9	0.82***
Item 10	0.81***
Item 11	0.82***
Item 12	0.66***
Item 13	0.74***
Item 14	0.77***
Item 15	0.75***
Item 16	0.73***

*** $p < .001$,
N = 77, two-tailed significance values reported.

tion's two studies were similar, this was likely the result of the lower power of Study 2. The relatively low correlation between these two constructs is more troublesome, however. Given the theoretical fit between playfulness and play, this may point to some issue with the Computer Playfulness Scale's validity, as prior literature has suggested (Kruger, 1995). Hypothesis 2 was supported, as video game self-efficacy predicted both flow state and play experiences. This finding is in line with prior evidence (Pavlas et al., 2010), indicating that video game self-efficacy remains a useful construct to investigate (or simply covary) in game-based learning studies.

The investigation of Hypothesis 3 and Hypothesis 4 revealed what is perhaps the most interesting pattern of results. While flow was linked to learning outcomes, it did not mediate the relationship between play and learning or performance and learning. When play was considered alongside flow to predict learning outcomes, flow no longer provided a significant contribution to the prediction. This suggests that, contrary to expectations, the current definition of play experience may largely describe flow experience. Nonetheless, play, flow, and in-game performance explained a substantial amount of variance in learning outcomes (specifically, 45% of the variance in declarative knowledge outcomes). The potential definitional overlap between flow and play provide an interesting avenue for future research, which is discussed in greater detail in the overall discussion section.

Hypothesis 5, which was central to the new model for flow in games, was also supported. As predicted, play, video game self-efficacy, and emotional experience were significantly linked. Together with age, these three variables predicted an overwhelming amount (74%) of the variance in flow state scores. Hypothesis 6, which dealt with the reciprocal relationship between these variables was also supported. Flow state scores were predictive of play experience, emotional experience, and performance for later rounds, indicating that the relationship between these constructs is not simple enough to study with a single set of post-task measures. If flow arising during a task influences later performance and experience during a task, then a model purporting that performance and experience influence flow must address this two-way relationship. This reciprocal relationship also muddles the degree to which causation can be inferred. If flow influences and is influenced by these constructs via a temporal feedback loop, then it is questionable whether they can be said to "cause" flow or vice-versa.

Surprisingly, the degree of challenge-skill fit was not predictive of flow state (Hypothesis 7). However, this may be the result of poor challenge-skill fit metrics. The game performance variables used may not have adequately represented the subjective state of participants. Similar objective patterns of game performance may have resulted in different subjective states for the participants. While secondary analysis showed that challenge-skill fit as defined by the flow state scale was related to play experience, this may be an artifact of the strong overall relationship between the two scales. Additionally, the challenge-skill fit item of the FSS-2 was significantly related to play experience. While these results do not discount the existing evidence for the importance of challenge-skill balance in reaching flow state, they do highlight the difficulty in examining this relationship via pure performance data.

Study 2 also served to provide additional validation of the Play Experience Scale. The two items added to the PES-14 to create the PES-16 correlated well with the overall scale. While factor analysis was not possible due to sample size restrictions, evidence based on correlations suggests that the two items added to the scale did not alter its meaning. Additionally, the external motivation items of the scale were more meaningful in Study 2, resolving concerns that arose during Study 1. The key difference between these two contexts may have been the framing of gameplay as an actual learning activity in Study 2, which provided participants with a degree of external motivation. As a result of these analyses, the PES-16 was chosen as the final version of the scale.

CHAPTER 5
DISCUSSION

This dissertation examined play and flow in the context of game-based learning. A review of the theory revealed that there are numerous purported benefits of flow and play when seeking to create learning outcomes. However, empirical research into these constructs was found to be insufficient. To this end, this dissertation sought to examine previously unmapped relationships based on a new model of flow in games. The empirical studies conducted as part of this dissertation provided two primary outcomes. First, a measure of play – the Play Experience Scale – was created and validated. Second, a subset of the new model of flow in games was empirically examined. Success was found in both of these endeavors. The Play Experience Scale served as an effective and valid measure of play experience, though some definitional questions regarding play must now be addressed by the field. Similarly, the new model of flow in games was partially examined. The subset of the model investigated in this dissertation was largely accurate, emphasizing the inter-connected relationships that work to create flow and play during gameplay. Alongside these material contributions to the field, an extensive discussion of the theory underlying flow, play, and serious games was conducted. In this section, the overall findings and implications for the studies are discussed. Additionally, the limitations of the overall effort are addressed. During this discussion, critical future research needs are posed, including suggestions for expanding the new model of flow in games and potential avenues for using the Play Experience Scale.

5.1 Study Summaries

As previously noted, Study 1 was conducted to develop and validate a scale of play experience. To this end, Study 1 was primarily a validation effort. After an extensive review of the literature, an initial 20-item version of the Play Experience Scale was drafted. This scale was used to assess the subjective play experience of participants engaging in one of three different online tasks. These tasks included the classic game *Tetris*, the flow-supporting game *flOw*, and a letter search task created specifically for this study. Comparing the game and non-game conditions made it possible to view whether the newly developed scale was consistent with the theoretical definition of play. Similarly, comparisons to scales of intrinsic motivation, amotivation, playfulness, and external regulation were conducted to establish the convergent, discriminant, and construct validity of the scale. More in-depth analyses such as principal component analysis and structural equation modeling were used to determine which items of the scale were meaningful contributors to an overall score of play. The various analyses performed resulted in a 14-item version of the Play Experience Scale that showed good reliability and evidence of convergent, discriminant, and construct validity. This 14-item version was updated to a 16-item version for further validation in Study 2.

Whereas Study 1 was conducted as a validation effort for a newly develop scale, Study 2 empirically examined the newly developed model of flow in games. Because the entire model was too large for testing in a single empirical effort, a subset of the model was chosen for in-depth examination. The constructs of playfulness, video game self-efficacy, challenge-skill balance, emotional experience, performance, play, flow state, and learning were chosen as the elements to be tested. To test this subset, InnerCell, a previously-developed immune system serious game, was used. The game was well-suited to this empirical effort due to its ability to capture a variety of in-game performance metrics, which supplemented the measures employed outside of the game.

Study 2 provided a number of meaningful results. Playfulness was not significantly related to play experience in this study, though the relationship was positive and trended towards significance. Video game self-efficacy was a significant predictor of both flow state and play experience, corroborating and expanding prior evidence of the importance of video game self-efficacy as a construct. Flow was significantly and positively related to learning outcomes, though this relationship was not mediated by play as suggested by the model. Indeed, play consumed the variance that flow accounted for, suggesting that flow may be subordinate to play within the context of games. The relationship between performance learning was also significant, indicating that performance and learning in endogenous serious games go hand-in-hand. Contrary to the hypothesis, this relationship was not mediated by flow. Nonetheless, play, emotion, and in-game performance accounted for a very large proportion of the variance in flow state, as suggested by the model. More complex analysis of the temporal patterns of flow indicated that, as expected, flow experiences in prior rounds influenced emotional experiences and performance in later rounds. Finally, the previously established challenge-skill relationship was not supported in Study 2, though this may have been the result of issues with the challenge-skill metric employed.

The majority of Study 2's hypotheses were supported or partially supported, suggesting the model was a reasonable descriptor of flow, play, and learning in games. However, as noted above, a number of unexpected results were also revealed, including a more complex relationship between flow and play than was previously theorized. Alongside the findings and scale development generated in Study 1, these results provide significant illumination for the field. Implications for these various findings are provided in the following sections.

5.2 The Play Experience Scale

The most material outcome of this dissertation is the Play Experience Scale. This scale was created to fill a particular gap: until now, no scale measuring the subjective experience of play existed. Given that the subset of the field that studies serious games investigates the relationship between games and learning, being able to examine the player's response in terms of one of the most core characteristics of games is intuitively appealing. The scale was created based on a number of definitions of play, with an emphasis placed on using concepts that were tied to established psychological theory.

Across two studies, the created scale was validated. In this dissertation, a number of versions of the Play Experience Scale were discussed. Initially, a 20-item version of the scale was created based on five aspects of the play definition. Study 1 demonstrated that the reduced 14-item candidate scale was a valid measure of play experience. The 14-item version of the scale reflected four aspects of the play definition, with the previous elements of autotelic experience and focus merged into one aspect. The scale's relationships to existing measures of intrinsic motivation, external regulation, amotivation, and playfulness emerged as expected. Playfulness predicted play scores, which were positively correlated with intrinsic motivation, negatively correlated with external regulation, and negative correlated with amotivation. Further, the scale was sensitive to variations in game characteristics, with identified "boring" games reflecting lower play scores. In Study 2, the scale was expanded to a more symmetrical 16-item version. Though full validation efforts were not performed with this revision, the

PES-14 and PES-16 showed the same relationships to other variables and measures. Thus, the 16-item version of the scale is recommended as the final product of these efforts, as the calculation of a summary play score is simplified when the number of items in each category of questions is the same.

As previously noted, the Play Experience Scale fills a rather conspicuous gap in the game literature. Play is one of the defining characteristics of serious games and games in general (Baranauskas, Neto, & Borges, 1999; Ang, 2006). The toolset available to researchers investigating game-based learning is incomplete without a method by which to investigate play. With the creation and validation of this new scale, it is now possible for researchers to directly examine play experiences in games using a simple post-task measure. The general lack of play studies is indicative of a large theoretical gap in the literature. The introduction of a scale that assesses play experience will hopefully spark a surge of interest into investigating how play influences a wide range of behaviors, states, and experiences.

5.3 The New Model of Flow in Games

The second product of this dissertation effort is the new model of flow in games (see Figure 5). While one version of the model was already presented earlier in this dissertation, it is necessary to update the model based on the results of the studies. Study 2 was conducted primarily to test the relationships in a subset of this model that was focused on the experiences that arise during and surrounding flow (see Figure 6). To this end, a number of hypotheses were proposed and tested during Study 2 (see Table 4).

Of the seven hypotheses, five were fully or partially supported: Video game self-efficacy was linked to both flow and play (*H2*); flow and performance were linked to learning

(*H3*, *H4*); play, emotional experience, video game self-efficacy, and age were linked to flow (*H5*); and flow state in prior rounds predicted performance and experience outcomes in later rounds (*H6*). However, some of the results were not as expected. Hypothesis 1, which predicted that playfulness would be a significant predictor of play, was not supported. This finding was especially interesting, as Study 1 results supported this link in three other game contexts. Most likely, this was an artifact of the lower power of Study 2, as the correlations were similar. While the hypothesis was not supported for Study 2, in the larger view of the dissertation the playfulness-play link is maintained in the model.

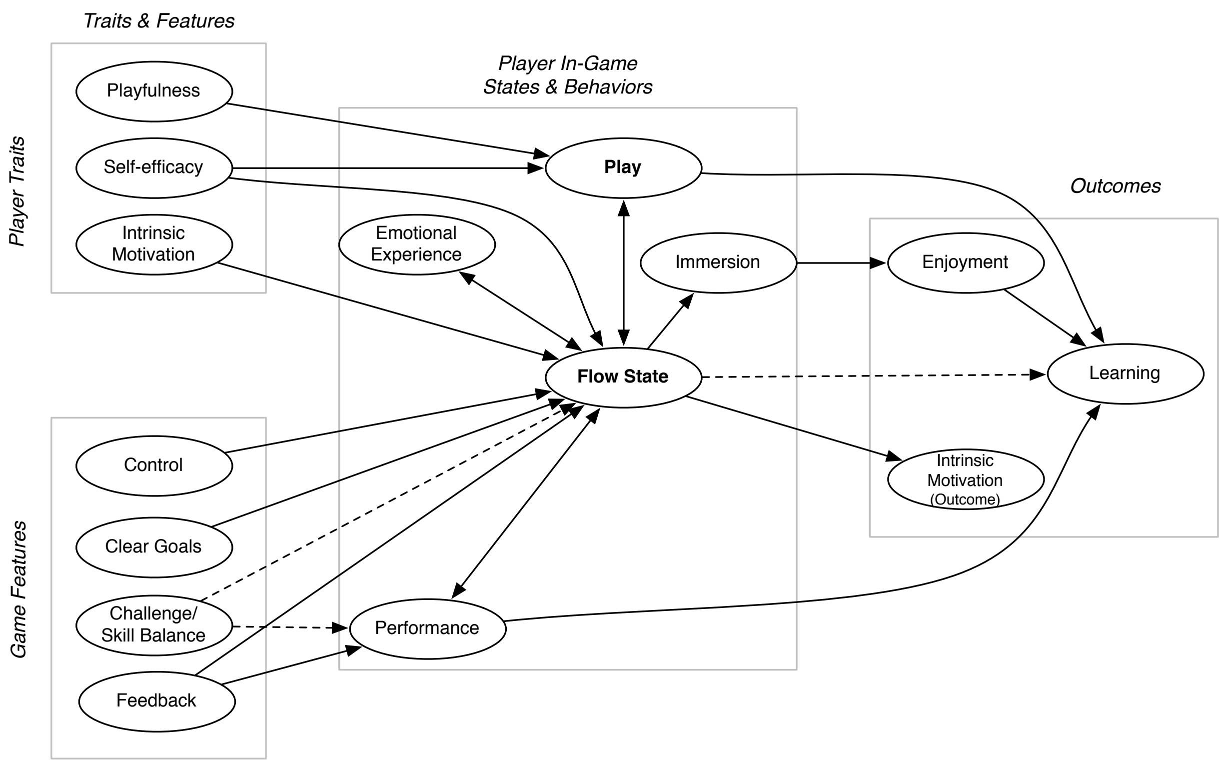

Figure 11: Updated model of flow in games

While Hypothesis 3 and Hypothesis 4 were partially supported, the results did not support the mediating relationship suggested in the initial version of the new model. Though flow was linked to learning outcomes, this effect disappeared when play was considered alongside flow. This suggests that flow does not account for substantial unique learning outcome variance above and beyond the variance the Play Experience Scale already accounts for. This suggests several potential implications. First, it is possible that play (as defined in this effort) describes experiences very similar to flow state. However, by definition it should be possible to experience play without experiencing flow. Second, it may be the case that the learning benefits of flow are due to the learning benefits of play. Third, the definition of play used in this dissertation effort may be overly inclusive, encroaching upon definition space that is not uniquely play. Finally, the use of a flow measure that examines flow along a continuum rather than a binary flow or no flow state may have made the overlap between play and flow more visible, as "moderate" flow scale responses by individuals who did not subjectively attain flow state may be indicative of play behavior. Regardless of the theoretical issue that explains these results, the findings suggest that a large portion of variance in game-based learning can be accounted for by play and in-game performance. This, in turn, suggests that play is indeed a valuable element of game-based learning applications.

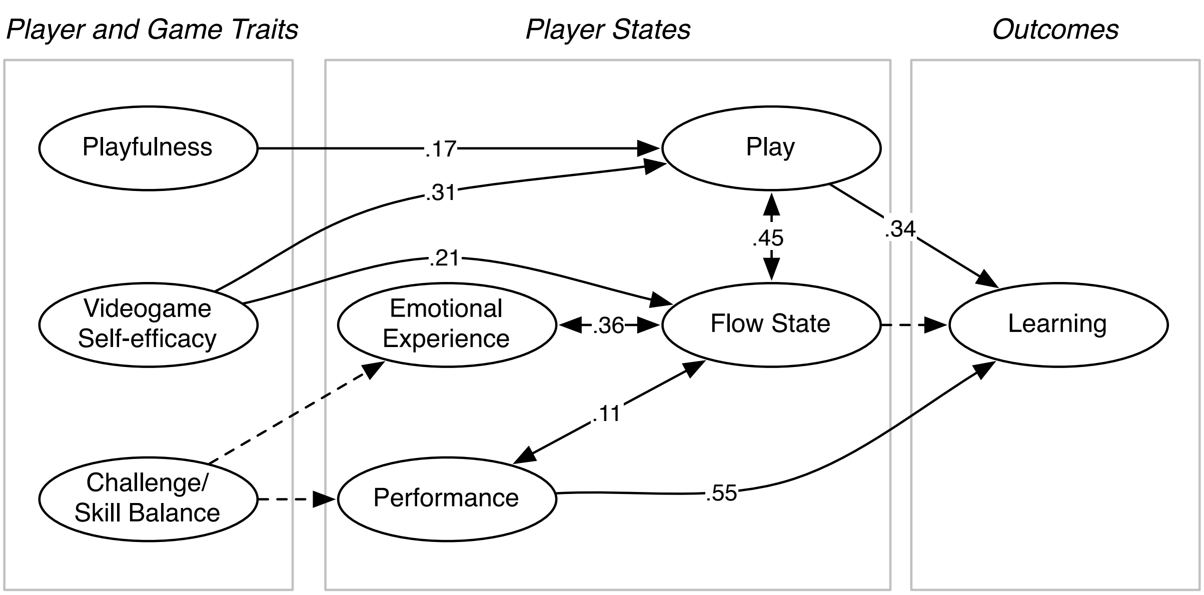

Figure 12: Updated subset of the model of flow in games with beta weights

As flow did not serve as a mediator for the play-learning and performance-learning relationships, the link between flow and learning in the model becomes more tentative. Figures 11 and 12 present updated versions of the new model of flow in games (and the subset thereof investigated in Study 2). While the link between flow and learning is maintained in these models, this link is tentative. Future research may build upon the results of this dissertation and show that the impact of flow in learning is wholly explained by play behavior. Conversely, this result may have been due to a unique characteristic of the study or game context, in which case the link may be restored. In this revised version of the new model of flow in games, play is of increased importance. This importance is evident in the weights for the relationships examined in Study 2, which are provided in Figure 12.

Compared to the other flow models presented in this dissertation, this model is more explicitly open to investigation. Many conceptual models of flow are useful from a theoretical standpoint, explaining the nature of the construct and proposing relationships between various player states. However, such models often do not allow for distinct quantification of the relationships between constructs (e.g., Kiili, 2005). As the field attempts to build a larger nomological network of game-related traits, states, and outcomes, a model that is open to empirical investigation is critical. The new model of flow in games described in this dissertation fills exactly this role. While this model focuses on flow and play in games (specifically, serious games), there are many more game constructs that must be studied within the context of other game processes. This new model provides a starting point for integrating similar or related research efforts.

5.4 Limitations

Though the two studies conducted as part of the dissertation were able to reveal a number of interesting relationships and produce meaningful results, they were not without limitations. The most overarching limitation of this dissertation is that it examined the proposed model of flow in games in only one context. While the InnerCell serious game has shown that it is effective in producing learning outcomes (Pavlas et. al, 2009), it is entirely possible that the model relationships manifest themselves differently in other contexts. As this effort represents a first step in establishing a more empirically sound model of flow in games, this limitation is acceptable. Future studies should re-examine these relationships and continue to refine the model proposed herein.

Additionally, though the dissertation examined a subset of the new model for flow in games, it did so via piecemeal examination of hypotheses and multiple regression. While such an approach can reveal useful information about the relationships between constructs, a simultaneous examination of entire model subsets using techniques such as structural equation modeling may provide more accurate information about the model's appropriateness. Given the required sample size for such analysis, however, such an effort would be best performed after the model of flow in games has already been revised through multiple smaller studies.

Another limitation of the study was its reliance on subjective, post-experience measures of play, flow, learning, and related constructs. These constructs were measured as though they were outcomes that could be easily quantified post-experience. However, these constructs did not occupy a simple linear causal space, but were instead related to each other reciprocally. While this limitation was appropriately addressed through the examination of the round-to-round relationships of these constructs (i.e., Hypothesis 6), the limitation does restrict the degree to which casual inferences can be described in the new model of flow in games.

Though Study 2 assessed learning via a serious game, no effective pre-measure of learning was used as a covariate for prior experience with the learning content. This limitation was partially addressed by the reasonable sample size used in the study. While there were no outliers for learning outcomes, it is possible that the effects observed may have been more accurate if a measure of initial immune system content had been employed.

Though not a traditional limitation per se, the issue of reification is meaningful to address here. In this dissertation, the Play Experience Scale was created based on the various play definitions evident in the literature. However, it is possible that the scale does not measure play, but rather a construct that occupies a number of conceptual regions. In other words, the scale is not a measure of play simply by virtue of naming. Rather, validation efforts must determine whether a scale actually measures the constructs it purports to measure. The results of the validation studies suggest that the Play Experience Scale did indeed measure play experience, especially due to its relationships to constructs such as playfulness, intrinsic motivation, and external regulation. Nonetheless, the potential for an error of reification remains a limitation of the conducted studies.

The method used to infer challenge-skill balance during Study 2 was not particularly effective in showing a previously established precursor for flow state. Methods that rely on subjective responses (e.g., the two-item sum approach used in Waterman, Schwartz, Goldbacher, Green, Miller, & Philip, 2003) may be more appropriate than methods that rely solely on performance data. Though the performance data provided by the game was able to diagnose performance, it was questionable whether the metrics used were able to determine the degree to which this performance matched the player's skill. However, as this element of the investigation was not a critical part of the tested model or the empirical studies in general, this limitation did little to hamper the impact of Study 2.

Finally, the studies conducted as part of this dissertation were, like many psychology studies, conducted based on a sample of volunteer undergraduates. As the subject matter of the dissertation (e.g., serious games, game-based learning) deals with technology and processes largely employed by populations similar to the sampled populations, this limitation may not be particularly troublesome.

5.5 Implications for Theory

The development and empirical testing of the new model of flow in games has resulted in a number of implications for the theory of flow, play, and game-based learning. Most critically, the definitional overlap between flow and play that was found during Study 2 presents the field with an issue in need of theoretical and empirical investigation. While flow and play are ostensibly defined as distinct concepts, with flow being optimal experience (Csikszentmihalyi, 1990) and play being intrinsically motivated, free, and focused activity (O'Connor & LaPoint, 1980), there is overlap between the two constructs. Definitions for both constructs make reference to focus, motivation, and freedom from external consequences. The question, then, is whether the two constructs are actually distinct experiences. If they are truly distinct, it should be possible to create measures that are less closely tied. If they are not distinct, then the theory underlying these two constructs must be revised to make note of the strong conceptual link between them. Given the conceptual and definitional overlap between these two constructs, resolving this ambiguity presents a major task for the field.

The observed overlap between flow and play also suggests that the purported learning benefits of flow (Choi, Kim, & Kim, 2007) may actually be attributed to play. However, it is important to note that the studies in this dissertation were conducted within the context of game tasks, which are inherently open to play experiences. Thus, it is not unexpected that play coincided with learning and flow. Outside of a games context, it is possible that this overlap may disappear. Flow was originally discussed within the context of work behaviors and has only recently been applied to electronic games. Thus, while flow and play were strongly related in the prior studies, these findings may not be externalizable to non-game contexts. Nonetheless, previously established findings for flow in games are called into question by these results. Are the previously identified effects of flow in games truly attributable to flow, or did they emerge from play? This question cannot be answered without further research efforts. The resolution of this ambiguity will result in considerable theoretical advancements for the field of game study, and presents a key next step for researchers seeking to build upon the theoretical findings of this dissertation.

Beyond the observed overlap between flow and play in games, this dissertation illuminated the temporally reciprocal relationship between play, flow, emotional experience, and in-game performance. Research investigating flow state often examines flow as a simple outcome rather than a true process (e.g., Huang, 2007). However, the results of this dissertation suggest that flow emerges over time as a result of the relationship between a variety of experiential factors. This suggests that sampling methods that examine flow over time, such as experience sampling methods or the multiple-round measurement technique employed in Study 2 are more theoretically aligned with the construct than one-time post-task administrations of subjective scales.

Though this dissertation primarily investigated the construct of flow, the theoretical contributions of the present effort extend beyond flow. As illustrated by the new model of flow in games (see Figure 11), flow does not emerge out of a vacuum. The field's understanding of the complex relationships between flow, play, and learning has been improved as a result of this dissertation, but much work remains to be done.

5.6 Implications for Practice

Beyond the theoretical contributions that the investigation of the new model of flow in games has provided, the results of this dissertation suggest a number of implications for serious game developers, game researchers, and industry practitioners. First, it is clear that play is one of the core benefits of a game-based learning platform. Learning outcomes were tied to play experience, suggesting that the creation of effective serious games is not only contingent upon sound instructional design, but also closely tied to the creation of successful entertainment games. In other words, play and entertainment should not be secondary in serious games. This conclusion is in line with existing theoretical discussion of serious games, including those writings which have touted the utility of endogeny (i.e., tying game interactions to learning content; Squire, 2006), the benefits of curiosity and exploration of game content (Malone, 1980), and the overall motivational benefits of game play (Sweetser & Wyeth, 2005). It is the great paradox of serious games that these games are simultaneously praised for their learning benefits but reduced in "game-ness" in order to appear more valid. As evidenced by this dissertation, serious games are enhanced by the very thing that makes them games: play. Indeed, one of the defining features separating serious games from simulations is their reliance upon play interactions (Baranauskas, Neto, & Borges, 1999).

The effects of video game self-efficacy show that serious games are more effective when employed for an appropriate audience. As is the case with all training tools, the individual differences in the learner must be considered when deciding whether a tool or method is appropriate. In the case of serious games, it is only natural that the learner's game self-efficacy is one such individual difference. Variables dealing with the player's prior experiences with serious games are other likely candidates for such analysis. As prior research has suggested, video game self-efficacy is a useful predictor of learning outcomes (Pavlas et al., 2010). However, the extent of the construct's relationship with other processes and states has not been significantly investigated until this dissertation. Though this work focused on flow and play, the impact of video game self-efficacy is clear from the results. Researchers seeking to study game-based learning are thus advised to strongly consider including video game self-efficacy measures.

Finally, the most direct implication this dissertation has on practice is rather straightforward. Where it was once impossible to directly study play experience via a self-report scale, it is now simple to include the PES-16 and assess subjective play experience. For game scholars, developers, and researchers, this has profound implications. Industry studies investigating game playability now have a direct metric of play experience available by which to quantify the results of changes introduced during the development cycle. In industry, iterative development and testing processes such as the Rapid Iterative Testing and Evaluation (RITE) method assess both the playability and usability of games (Medlock, Wixon, Terrano, Romero, & Fulton, 2002). A common critique of industry testing is that it focuses on usability rather than playability. Unfortunately, usability assessment alone is insufficient to characterize user experience in games (Snchez, Zea, & Gutirrez, 2009). With the emergence of the Play Experience Scale, assessing game play experience has become more accessible for industry practitioners. Similarly, the Play Experience Scale allows serious game developers and researchers to capitalize on the dissertation's play-focused findings. If play is an important quality to capture and enhance for game-based learning, then it follows that a method by which to view play experience is key. The Play Experience Scale fills exactly this role, allowing researchers to easily investigate play in games. With additional validation from the broader scientific community, the scale will fill an second role, allowing researchers to investigate play in non-game contexts such as exploratory learning.

5.7 Future Research

As this dissertation presented the first applications of a new measure of play experience and provided a new theoretical model for flow in games, there are a number of avenues for researchers to pursue based on these studies.

Though the validation efforts performed in this dissertation were fruitful, additional validation of the Play Experience Scale is required. While the scale was validated based on four different game contexts, it is still in need of validation in other contexts. In particular, this dissertation only examined the utility of the Play Experience Scale within the context of video games. However, play is observed across the full range of human experience. Future research efforts should examine the Play Experience Scale in contexts other than video games (e.g., music, performance, sport, work). Additionally, the scale was only examined with a relatively limited population (i.e., young college students). The scale may have different psychometric properties when employed with different populations. Future research should investigate how the Play Experience Scale functions for different kinds of respondents.

Additionally, validation against non-subjective measures of emotional experience may provide further evidence to determine the overall appropriateness of the Play Experience Scale. For example, modeling emotional experience through physiological indicators such as galvanic skin response, electromyography, and heart rate can provide additional insight into how individuals respond to play experiences (Mandryk & Atkins, 2007). Tying these objective measures of experience to the newly developed subjective measure of play would provide an excellent addition to the present validation efforts.

The overlap between flow and play observed in Study 2 presents the most tantalizing lead for researchers investigating flow, play, games, and learning. In the games literature, flow is characterized as being useful for reasons of immersion, focus, play enhancement, and improved learning (Sweetser & Wyeth, 2005; Cowley, Charles, Black, & Hickey, 2008; Pavlas et al., 2010). The results presented in this dissertation suggest that there is more to the story than "flow improves X." Instead, it is evident that flow in games has a complex relationship with performance and play experience. Future research efforts should carefully scrutinize the overlap between these constructs and continue to examine how flow relates to the constructs presented in the new model of flow in games (see Figure 11).

Additionally, the relationship between flow and play should be investigated in non-game contexts. It is possible that the overlap between flow and play observed in these studies was a result of the task context (i.e., video games) requiring play behavior in order to reach flow. Outside of a games context, flow and play may represent more distinct concepts.

Finally, the model of flow and play presented in this dissertation was only partially examined. As previously noted, empirical examination of the various relationship posed by the theoretical literature is critical to the continued growth of the field. Numerous areas of the model remain open for empirical testing, and the field would be greatly aided by their careful empirical investigation.

5.8 Conclusion

This dissertation represents a number of firsts. Across the two empirical studies conducted, the first scale of play experience was created, providing researchers with a new tool by which to examine games. Additionally, first steps were taken to empirically examine a new model of flow in games. While this model is now more appropriately termed a model of flow and play in games, the work investigating this model has just begun. Numerous relationships in the model remain unexamined. This dissertation is just the beginning of the field's further empirical examination of the various constructs of the model. As this dissertation has demonstrated, constructs such as play, flow, video game self-efficacy, emotion, and in-game performance are key in understanding player experience and learning in serious games.

APPENDIX A
APPENDIX: MEASURES

A.1 Computer Playfulness Scale

(Webster & Martocchio, 1992)

The following questions ask how you would characterize yourself in general. For each adjective listed below, please choose the number that best matches the description of yourself.

Scale

1 - Strongly Disagree

2 - Disagree

3 - Somewhat Disagree

4 - Neither Agree nor Disagree

5 - Somewhat Agree

6 - Agree

7 - Strongly Agree

Items

I am...

1) Spontaneous

2) Unimaginative [R]

3) Flexible

4) Creative

5) Playful

6) Unoriginal [R]

7) Uninventive [R]

A.2 Declarative Knowledge

(Bedwell et al., 2009)

(Correct answer(s) noted with ->)

1 - Which immune cell is effective against Rhinovirus?

Neutrophil

-> Killer T-Cell

Basophil

Other Cell

2 - Which immune cell is effective against Staphylococcus?

-> Neutrophil

Killer T-Cell

Basophil

Other Cell

3 - Which immune cell is effective against Streptococcus pyogenes?

-> Neutrophil

Killer T-Cell

Basophil

Other Cell

4 - Which immune cell is effective against Haemophilus?

-> Neutrophil

Killer T-Cell

Basophil

Other Cell

5 - Which immune cell is effective against Viral Influenza B?

Neutrophil

-> Killer T-Cell

Basophil

Other Cell

6 - Which immune cell is effective against Enterovirus?

Neutrophil

-> Killer T-Cell

Basophil

Other Cell

7 - Which treatment increases Thymosin production?

-> Fever

Penicillin

Inoculation

Augmentin

8 - What cell boosts Killer T-Cell strength?

-> Helper T-Cell

Neutrophil

Fever

Chemical Wall

9 - What happens when you attack a virus with a Neutrophil?

-> It is not able to destroy the virus

It destroys the virus

Both the Neutrophil and the virus are destroyed

Nothing happens

10 - What happens when you attack bacteria with a Neutrophil?

It is not able to destroy the bacteria

-> It destroys the bacteria

Both the Neutrophil and the bacteria are destroyed

Nothing happens

11 - What happens when you attack bacteria with a Killer T-Cell?

-> It is not able to destroy the bacteria

It destroys the bacteria

Both the Neutrophil and the bacteria are destroyed

Nothing happens

12 - What happens when you attack a virus with a Killer T-Cell?

It is not able to destroy the virus

-> It destroys the virus

Both the Neutrophil and the virus are destroyed

Nothing happens

13 - Which of the following treatments are antiviral?

-> Lactoferrin

Augmentin

Chemical Wall

Neutrophil

14 - Which of the following pathogens does not require a treatment?

Enterovirus

Haemophilus

-> Rhinovirus

Augmentin

15 - What treatment is effective against Rhinovirus?

-> No treatment necessary

Helper T-Cell

Mupirocin

Lactoferrin

16 - What treatment is effective against Staphylococcus ?

-> No treatment necessary

Helper T-Cell

Mupirocin

Lactoferrin

17 - What treatment is effective against Streptococcus pyogenes?

No treatment necessary

Helper T-Cell

-> Mupirocin

Lactoferrin

18 - What treatment is effective against Haemophilus?

No treatment necessary

Helper T-Cell

-> Augmentin

Mupirocin

19 - What treatment is effective against Viral Influenza B?

No treatment necessary

Helper T-Cell

Lactoferrin

-> TamiFlu

20 - What treatment is effective against Enterovirus?

No treatment necessary

Helper T-Cell

Mupirocin

-> Lactoferrin

21 - What combination of treatment and immune cell is effective against Rhinovirus?

Chemical wall + Neutrophil

-> There is no combination – Killer T-Cells are effective

Mupirocin + Helper T-Cell

Viral Influenza B + Flu

22 - What combination of treatment and immune cell is effective against Staphylococcus?

Chemical wall + Killer T-Cell

-> There is no combination – Neutrophil is effective

TamiFlu + Helper T-Cell

Streptococcus pyogenes + Impetigo

23 - What combination of treatment and immune cell is effective against Streptococcus pyogenes?

Chemical wall + Killer T-Cell

-> Mupirocin + Neutrophil

Lactoferrin + Helper T-Cell

Viral Influenza B + Flu

24 - What combination of treatment and immune cell is effective against Haemophilus?

Chemical wall + Killer T-Cell

-> Augmentin + Neutrophil

Lactoferrin + Helper T-Cell

Viral Influenza B + Flu

25 - What combination of treatment and immune cell is effective against Viral Influenza B?

Chemical wall + Neutrophil

-> TamiFlu + Killer T-Cell

Lactoferrin + Helper T-Cell

Viral Influenza B + Flu

26 - What combination of treatment and immune cell is effective against Viral Influenza B?

Chemical wall + Neutrophil

-> Lactoferrin + Killer T-Cell

Mupirocin + Helper T-Cell

Viral Influenza B + Flu

27 - Which of the following is not a symptom of Rhinovirus?

Coughing

Fever

Sore Throat

-> Tooth Pain

28 - Which of the following is not a symptom of Staphylococcus?

Headache

Bad Breath

-> Dizziness

Fever

29 - Which of the following is not a symptom of Steptococcus pyogenes?

Blisters on the face

Sores

Blisters on the hands

-> Sore Throat

30 - Which of the following is not a symptom of Haemophilus?

Yellow/Greenish nasal discharge

Stuffy Nose

Reduced sense of taste/smell

-> Muscle Pains

31 - Which of the following is not a symptom of Viral Influenza B?

Chills

Muscle Pains

-> Tooth Pain

Fever

32 - Which of the following is not a symptom of Enterovirus?

Stiff Neck

Vomiting

Rash

-> Sores on hands and face

33 - What is the function of the Chemical Wall?

To increase Thymosin production

-> To redirect pathogen movement

To strengthen Killer T-Cells

To raise the temperature of the body

34 - Which units are placed during the planning stage?

-> Chemical Walls

Killer T-Cells

-> Helper T-Cells

Neutrophil

35 - What chemical is required to create immune cells?

-> Thymosin

Plasma

Oxalic Acid

Antimony Trisulfide

36 - What happens when a pathogen reaches an infection area?

-> The player's health decreases

Thymosin production increases

The game is over

The pathogen quickly dies

37 - What happens when a Killer T-Cell enters a Helper T-Cell's radius?

-> Its strength is increased

Its strength is decreased

Its speed is doubled

The Helper T-Cell moves

38 - What happens when a Neutrophil enters a Helper T-Cell's radius?

It's strength is increased

It's strength is decreased

-> Nothing

The Helper T-Cell moves

39 - What happens when a pathogen enters a Helper T-Cell's radius?

The Helper T-Cell attacks it

The Pathogen attacks the Helper T-Cell

-> Nothing

The Helper T-Cell signals for a Killer T-Cell

40 - Which of the following is not a White Blood Cell?

Killer T-Cell

Helper T-Cell

Neutrophil

-> Chemical Wall

41 - Which of the following is not effective against a pathogen?

Helper T-Cell

Neutrophil

Killer T-Cell

-> Chemical Wall

42 - Which of the following is the best option when Viral Influenza B comes into a Helper T-Cell's radius?

Attack with Neutrophil

Attack with Killer T-Cell

-> Treat with Tami-Flu then attack with Killer T-Cell

Treat with Mup - irocin then attack with Neutrophil

43 - Which of the following is a pathogen?

-> Haemophilus

Mupirocin

Chemical Wall

Augmentin

A.3 Demographics (Study 1)

Age: [Free response]

Gender: [Male/Female/Prefer not to answer]

Do you consider yourself a "gamer"? [Yes/No]

A.4 Demographics (Study 2)

Sex: [Male, Female]

Race/Ethnicity: [White/Caucasian, Black/African American, Hispanic, Asian, Pacific Islander, American Indian, Alaskan Native, Other (please specify)]

Age: [Free response]

Class: [Freshman, Sophomore, Junior, Senior (please indicate year)]

What is your UCF GPA? [Free response]

SAT Verbal: [Free response]

SAT Math: [Free response]

SAT Written: [Free response]

SAT Total: [Free response]

ACT Total: [Free response]

What is your primary language? [English, Spanish, Other (please specify)]

How long have you been using the Internet (in years)? [Free response]

How many hours per day do you spend online? [Free response]

How many hours per day do you spend playing video games? [Free response]

Have you ever played the InnerCell game before? [Yes, No, I don't know]

A.5 Enjoyment Scale

(Modified from Lin, Gregor, & Ewing, 2008)

Scale

1 - Strongly Disagree

2 - Disagree

3 - Somewhat Disagree

4 - Neither Agree nor Disagree

5 - Somewhat Agree

6 - Agree

7 - Strongly Agree

Items

(Engagement) While playing the game,

1) I was deeply engrossed 2) I was absorbed intently 3) My attention was focused 4) I concentrated fully

(Positive Affect) While playing the game, I felt

5) Happy 6) Pleased 7) Satisfied 8) Contented

(Fulfillment) Playing the game was

9) Fulfilling 10) Rewarding 11) Useful 12) Worthwhile

A.6 Flow State Scale 2 - Short Form

(modified from Jackson, Martin, & Eklund, 2008)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Please answer the following questions in relation to your experience with the activity. These questions relate to the thoughts and feelings you may have experienced. There are no right or wrong answers. Think about how you felt during the training game and answer the questions using the rating scale below.

1 - I felt I was competent enough to meet the high demands of the situation. [Challenge-Skill Balance]

2 - I did things spontaneously and automatically without having to think. [Action-Awareness Merging]

3 - I had a strong sense of what I want to do. Clear Goals (subsection 3.1.3)

4 - I had a good idea while I was performing about how well I was doing. [Unambiguous Feedback]

5 - I was completely focused on the task at hand. [Concentration]

6 - I had a feeling of total control over what I was doing. [Sense of Control]

7 - The way time passed seemed to be different from normal. [Transformation of Time]

8 - The experience was extremely rewarding. [Autotelic Experience]

9 - I was not worried about what others may have been thinking of me or my performance. [Loss of Self-Consciousness]

A.7 Intrinsic Motivation Scale

(McAuley, Duncan & Tammen, 1989)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Please answer the following questions in relation to your experience with the game. These questions relate to the thoughts and feelings you may have experienced. There are no right or wrong answers. Think about how you felt during the training game and answer the questions using the rating scale below.

Items

1 - I enjoyed the game very much. (INT-ENJ)

2 - I think I am pretty good at this game. (COMP)

3 - I put a lot of effort into this game. (EFF-IMP)

4 - It was important to me to do well in this game. (EFF-IMP)

5 - I felt tense while playing the game. (r) (TEN-PRES)

6 - I tried very hard while playing the game. (EFF-IMP)

7 - Playing the game was fun. (INT-ENJ)

8 - I would describe this game as very interesting. (INT-ENJ)

9 - I am satisfied with my performance in this game. (COMP)

10 - I felt pressured while playing this game. (r) (TEN-PRES)

11 - I was anxious while playing this game. (r) (TEN-PRES)

12 - I did not try very hard at playing this game. (r) (EFF-IMP)

13 - While playing the game, I was thinking about how much I enjoyed it. (INT-ENJ)

14 - After playing the game for a little while, I felt pretty competent. (COMP)

15 - I was very relaxed while playing the game. (TEN-PRES)

16 - I am pretty skilled at this game. (COMP)

17 - The game did not hold my attention. (r) (INT-ENJ)

18 - I could not play this game very well. (r) (COMP)

A.8 Knowledge Organization

(Bedwell et al., 2009)

Please sort the following items into categories of your choosing.

Killer T-Cell

TamiFlu

Helper T-Cell

Staphyloccocus

Influenza

Augmentin

Lactoferrin

Neutrophil

Enterovirus

Tymosin

Haemophilus

Chemical Wall

Lymphocyte

Streptococcus

Mupirocin

Rhinovirus

A.9 Play Experience Scale (Initial Version)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Please answer the following questions in relation to your experience with the game. These questions relate to the thoughts and feelings you may have experienced. There are no right or wrong answers. Think about how you felt during the task and answer the questions using the rating scale below.

1 - I felt that I was free to use whatever strategy I wanted to while I was using the game. [Freedom]

2 - I was able to make the game do what I wanted it to. [Freedom]

3 - The game gave me the freedom to act how I wanted to. [Freedom]

4 - The game made it difficult to do what I wanted to do. [Freedom, Reverse]

5 - I was not worried about someone judging how I performed in the game. [No extrinsic]

6 - Regardless of how I performed in the game, I knew there wouldn't be a real-world consequence. [No extrinsic]

7 - My performance in the game was not going to matter outside of the game. [No extrinsic]

8 - I felt like I had to do well, or the experimenter would judge me. [No extrinsic, Reverse]

9 - When I was using the game, it felt like I was playing rather than working. [Play-direct]

10 - I would characterize my experience with the game as "playing." [Play-direct]

11 - I was playing a game rather than working. [Play-direct]

12 - Using the game felt like work. [Play-direct, Reverse]

13 - When I was using the game, I didn't worry about anything in the real world. [Focus]

14 - I was able to concentrate on the game without thinking about other things. [Focus]

15 - When I was using the game, I was focused on the task at hand. [Focus]

16 - I had a hard time concentrating on the game. [Focus, Reverse]

17 - I wanted to do well in the game, "just because." [Autotelic]

18 - When I was using the game, I wanted to do as well as possible. [Autotelic]

19 - I tried to succeed in the game because I felt like it. [Autotelic]

20 - During the game, my performance didn't matter to me. [Autotelic]

A.10 Play Experience Scale (14-Item Version)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Please answer the following questions in relation to your experience with the game. These questions relate to the thoughts and feelings you may have experienced. There are no right or wrong answers. Think about how you felt during the task and answer the questions using the rating scale below.

1 - I was able to make the game do what I wanted it to. [Freedom]

2 - The game gave me the freedom to act how I wanted to. [Freedom]

3 - I was not worried about someone judging how I performed in the game. [No extrinsic]

4 - Regardless of how I performed in the game, I knew there wouldn't be a real-world consequence. [No extrinsic]

5 - My performance in the game was not going to matter outside of the game. [No extrinsic]

6 - I felt like I had to do well, or the experimenter would judge me. [No extrinsic, Reverse]

7 - When I was using the game, it felt like I was playing rather than working. [Play-direct]

8 - I would characterize my experience with the game as "playing." [Play-direct]

9 - I was playing a game rather than working. [Play-direct]

10 - Using the game felt like work. [Play-direct, Reverse]

11 - When I was using the game, I was focused on the task at hand. [Autotelic Focus]

12 - I wanted to do well in the game, "just because." [Autotelic Focus]

13 - When I was using the game, I wanted to do as well as possible. [Autotelic Focus]

14 - I tried to succeed in the game because I felt like it. [Autotelic Focus]

A.11 Play Experience Scale (16-Item Revision)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Please answer the following questions in relation to your experience with the game. These questions relate to the thoughts and feelings you may have experienced. There are no right or wrong answers. Think about how you felt during the task and answer the questions using the rating scale below.

1 - If I wanted to do something in the game, I was able to do it. [Freedom]

2 - I was able to make the game do what I wanted it to. [Freedom]

3 - The game gave me the freedom to act how I wanted to. [Freedom]

4 - The game made it difficult to perform the actions that I wanted to. [Freedom, Reverse]

5 - I was not worried about someone judging how I performed in the game. [No extrinsic]

6 - Regardless of how I performed in the game, I knew there wouldn't be a real-world consequence. [No extrinsic]

7 - My performance in the game was not going to matter outside of the game. [No extrinsic]

8 - I felt like I had to do well, or the experimenter would judge me. [No extrinsic, Reverse]

9 - When I was using the game, it felt like I was playing rather than working. [Play-direct]

10 - I would characterize my experience with the game as "playing." [Play-direct]

11 - I was playing a game rather than working. [Play-direct]

12 - Using the game felt like work. [Play-direct, Reverse]

13 - When I was using the game, I was focused on the task at hand. [Autotelic Focus]

14 - I wanted to do well in the game, “just because.” [Autotelic Focus]

15 - When I was using the game, I wanted to do as well as possible. [Autotelic Focus]

16 - I tried to succeed in the game because I felt like it. [Autotelic Focus]

A.12 Self-Assessment Manikin

(Bradley & Lang, 1994)

For each of the questions below, consider how you felt while you were playing the game. Respond to the either-or question along the provided scale.

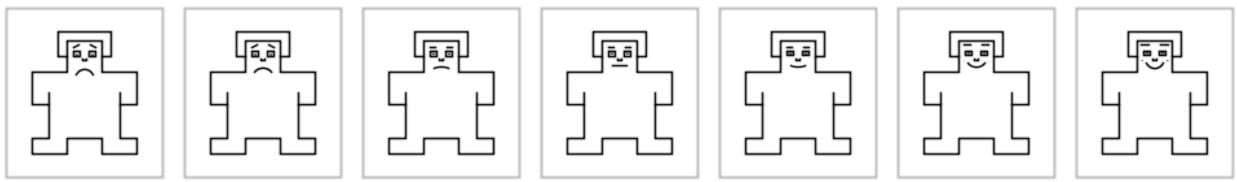

Figure 13: SAM Valence Scale: Did you feel sad or happy?

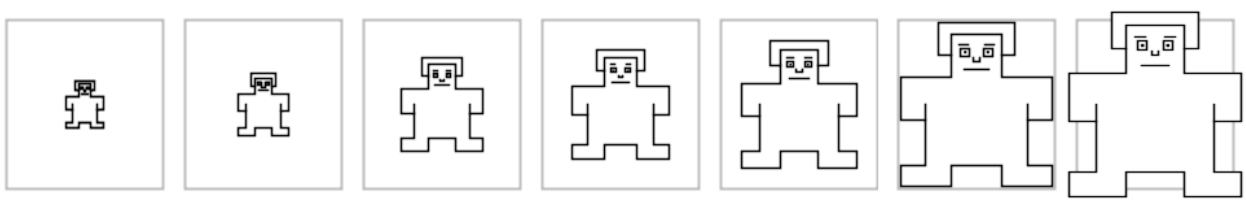

Figure 14: SAM Dominance Scale: Did you feel dominated or in control?

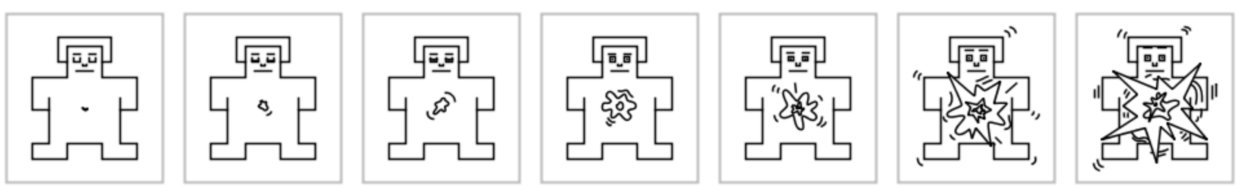

Figure 15: SAM Arousal Scale: Did you feel calm or activated?

A.13 Situational Motivation Scale

(Guay, Vallerand, & Blanchard, 2000)

Scale (adapted)

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Why are you currently engaged in this activity?

1 - Because I think that this activity is interesting

2 - Because I am doing it for my own good

3 - Because I am supposed to do it

4 - There may be good reasons to do this activity, but personally I don't see any

5 - Because I think that this activity is pleasant

6 - Because I think that this activity is good for me

7 - Because it is something that I have to do

8 - I do this activity but I am not sure if it is worth it

9 - Because this activity is fun

10 - By personal decision

11 - Because I don't have any choice

12 - I don't know; I don't see what this activity brings me

13 - Because I feel good when doing this activity

14 - Because I believe that this activity is important for me

15 - Because I feel that I have to do it

16 - I do this activity, but I am not sure it is a good thing to pursue it

Intrinsic Motivation: Items 1, 5, 9, 13

Identified Regulation: Items 2, 6, 10, 14

External Regulation: Items 3, 7, 11, 15

Amotivation: Items 4, 8, 12, 16

A.14 Videogame Self-Efficacy

(Modified from Schwarzer & Jerusalem, 1995)

Scale

1 - (Strongly Disagree)

through

6 - (Strongly Agree)

Items

Please answer the following questions about how you play video games using the provided response scale.

1 - I can always manage to solve difficult problems within a video game if I try hard enough.

2 - In a video game, if someone opposes me, I can find the means and ways to get what I want.

3 - It is easy for me to stick to my plans and accomplish my goals in a video game.

4 - I am confident that I could deal efficiently with unexpected events in a video game.

5 - Thanks to my resourcefulness, I know how to handle unforeseen situations in a video game.

6 - I can solve most problems in a video game if I invest the necessary effort.

7 - I can remain calm when facing difficulties in a video game because I can rely on my coping abilities.

8 - When I am confronted with a problem in a video game, I can usually find several solutions.

9 - If I am in trouble in a video game, I can usually think of a solution.

10 - I can usually handle whatever comes my way in a video game.

APPENDIX B

APPENDIX: SUPPLEMENTAL TABLES

B.1 Study 1 Correlations, Means, and Standard Deviations

(presented rotated on the next page)

Table 27: Study 1 correlations, means, and standard deviations

	Mean	*SD*	Age	Gender	Gamer	Playfulness	PES R1	PES R2	Motivation R1	Motivation R2	SIMS Ext R1	SIMS Ext R2	SIMS Amot R1
Age	21.01	4.95											
Gender	NA	NA	−0.24***										
Gamer	NA	NA	0.17*	−0.48***									
Playfulness	5.59	0.78	0.05	0.05	0.07								
PES R1	4.36	0.78	−0.09	−0.07	0.12	0.09							
PES R2	4.22	0.83	−0.04	0.01	0.11	0.20**	0.73***						
Motivation R1	3.82	0.76	0.00	0.00	0.12	0.05	0.67***	0.61***					
Motivation R2	3.76	0.84	0.06	−0.03	0.17*	0.10	0.64***	0.79***	0.80***				
SIMS Ext R1	3.55	1.18	−0.23**	0.09	−0.16*	−0.07	−0.23***	−0.33***	−0.27***	−0.37***			
SIMS Ext R2	3.51	1.15	−0.26***	0.12	−0.10	−0.09	−0.11	−0.20**	−0.19**	−0.27***	0.76***		
SIMS Amot R1	3.29	1.03	−0.03	0.00	−0.06	−0.06	−0.31***	−0.41***	−0.43***	−0.46***	0.60***	0.48***	
SIMS Amot R2	3.36	1.08	−0.07	−0.03	−0.10	−0.04	−0.25***	−0.35***	−0.30***	−0.40***	0.52***	0.58***	0.72***

* $p < .05$, ** $p < .01$, *** $p < .001$
$N = 203$, two-tailed significance values reported.
PES = Play Experience Scale 14, Gamer = Self-Identified Gamer, SIMS Ext = SIMS External Regulation, SIMS Amot = SIMS Amotivation, R1 = Round 1, R2 = Round 2, Gender effects listed are for females.

B.2 PES Item Correlations

(presented rotated on the next page)

Table 28: PES item correlations

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1																			
2	0.34***																		
3	0.43***	0.63***																	
4	0.21**	0.38***	0.36***																
5	0.33***	0.25***	0.27***	0.21**															
6	0.10	0.07	0.06	0.13	0.38***														
7	0.27***	0.18*	0.18*	−0.03	0.37***	0.25***													
8	0.15*	0.02	0.07	0.34***	0.49***	0.25***	0.27***												
9	0.17*	0.40***	0.30***	0.28***	0.16*	0.02	0.05	0.02											
10	0.18**	0.49***	0.35***	0.37***	0.19**	0.11	0.04	0.00	0.78***										
11	0.31***	0.47***	0.39***	0.36***	0.16*	0.03	0.06	0.00	0.82***	0.81***									
12	0.07	0.36***	0.25***	0.46***	0.05	0.11	0.03	0.24***	0.63***	0.64***	0.62***								
13	0.36***	0.26***	0.24***	0.19**	0.18*	0.02	0.15*	−0.07	0.36***	0.34***	0.40***	0.18**							
14	0.32***	0.40***	0.30***	0.23**	0.13	0.05	0.07	−0.09	0.54***	0.50***	0.52***	0.42***	0.50***						
15	0.31***	0.49***	0.37***	0.13	0.13	0.07	0.21**	−0.08	0.48***	0.52***	0.48***	0.39***	0.37***	0.62***					
16	0.19**	0.35***	0.26***	0.43***	0.07	0.05	0.04	0.14	0.52***	0.53***	0.51***	0.59***	0.35***	0.61***	0.56***				
17	0.43***	0.29***	0.27***	0.17*	0.27***	0.06	0.19**	−0.02	0.51***	0.51***	0.57***	0.33***	0.43***	0.54***	0.60***	0.43***			
18	0.34***	0.32***	0.28***	0.09	0.16*	0.00	0.17*	−0.09	0.53***	0.52***	0.52***	0.31***	0.46***	0.54***	0.71***	0.48***	0.71***		
19	0.31***	0.29***	0.23***	0.12	0.13	0.05	0.20**	−0.04	0.49***	0.49***	0.50***	0.32***	0.38***	0.46***	0.64***	0.45***	0.67***	0.73***	
20	0.06	0.09	0.09	0.19**	−0.15*	−0.15*	−0.17*	−0.01	0.16*	0.19**	0.16*	0.30***	0.18**	0.33***	0.34***	0.33***	0.26***	0.43***	0.33***

Note: Second administration correlations presented. $N = 203$. Two-tailed significance values reported.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

B.3 Potential Covariate Table

(presented rotated on the next page)

Table 29: Identified confounds and covariates

Construct Name	**Affects**	**Direction**	**Effect Size**	**Approach**	**How**	**Source(s)**
GPA	Performance	Positive	r = .30	Covariate	Self-report	Hunter & Hunter, 1984
Game Fiction	Immersion	Variable	Medium	Control	Moderate Fantasy	Pavlas et al., 2009
Mood	Motivation	Variable	Small	Random	n/a	n/a
Extroversion	Learning	Positive	rho = .26	Ignore	n/a	Barrick & Mount, 1991
Conscientiousness	Learning	Positive	rho = .23	Ignore	n/a	Barrick & Mount, 1991
Openness	Learning	Positive	rho = .25	Ignore	n/a	Barrick & Mount, 1991
Emotional Stability	Learning	Positive	rho = .07	Ignore	n/a	Barrick & Mount, 1991
Agreeableness	Learning	Positive	rho = .10	Ignore	n/a	Barrick & Mount, 1991
Goal Orientation (Learning)	Learning	Positive	rho = .16	Covariate	VandeWalle Measure	VandeWalle, 1997
Goal Orientation (Prove)	Learning	None / Negative	Small (ns)	Covariate	VandeWalle Measure	Gully & Chen, 2009 Payne, Youngcourt, Beaubien, 2007
	Performance	None / Negative	Small (ns)			Payne, Youngcourt, Beaubien, 2007
Goal Orientation (Avoid)	Learning	Negative	Medium (ns)	Covariate	VandeWalle Measure	Payne, Youngcourt, Beaubien, 2007
	Performance	Negative	rho = -.13	Covariate		Payne, Youngcourt, Beaubien, 2007
Gender (Female)	Performance	None / Negative	None / Small	Covariate	Self-report	Boyle & Connolly, 2008
Motivation (Extrinsic)	Learning	Variable	Small	Control	Same population, for-credit	Winne & Nesbit, 2010 Ryan & Deci, 2000
Field Dependence	Learning	Negative	Small	Ignore	n/a	Morgan, 1997
Field Independence	Learning	Positive	Small	Ignore	n/a	Morgan, 1997
Initial Knowledge	Learning	Positive	Medium	Covariate	Secondary Quiz	Cohen & Levinthal, 1990
Usability	Challenge	Positive	Small / Medium	Ignore	n/a	Kiili, 2005
Age	VGSE	Negative	None / Small	Covariate	Self-report	Nacke, Nacke, & Lindley, 2009
Affect	Enjoyment	Variable	Medium	Covariate	I-PANAS-SF	Thompson, 2007

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