Evaluating Immersion in Training Environments

Krista Langkamer Ratwani, Webb Stacy, Alexandra Geyer, Scott Pappada, and Emily Weise
Aptima, Inc.
Woburn, MA

kratwani@aptima.com, wstacy@aptima.com, ageyer@aptima.com, spappada@aptima.com, eweise@aptima.com

ABSTRACT

Within both research and practice, immersion is a topic that has received a lot of attention. The military, in particular, has invested a lot of time and money into creating "immersive" training environments in the hopes of providing personnel with training experiences that prepare them for many different types of encounters. Despite this interest, significant questions remain unanswered regarding the training value of such environments. A review of the literature on training in virtual environments reveals an assumption that higher immersion obtained through increased simulation fidelity results in improved training effectiveness and transfer. However, researchers who have attempted to evaluate this assumption have yet to produce compelling evidence. Further, there is no clear consensus regarding what constitutes immersion. For example, some researchers describe immersion as a state or feeling (e.g., Witmer & Singer, 1998), while others conceptualize it as a physical attribute of the training environment (e.g., Slater, 2003). This lack of agreement over the definition of immersion magnifies questions about its influence in the learning process.

Before the impact of immersion on learning and performance can be properly assessed, a clear operational definition must be provided that distinguishes immersion from other related concepts. Among other things, a meaningful definition will facilitate the development of good measures. Such measures are essential to any large-scale research effort because they provide standardization across efforts, including research evaluating the impact of immersion on training effectiveness. Therefore, the purpose of this paper is to provide a multilevel operational definition of immersion, as well as methods for the creation and real-time measurement of immersion, as it relates to learning in training environments. This analysis is the first step in aiding training designers in determining what level of immersion is required to facilitate effective training.

ABOUT THE AUTHORS

Dr. Krista Langkamer Ratwani is a Senior Scientist and the Team Lead for the Leadership and Team Training team at Aptima. She has experience in leader development and training, training evaluation and design, survey development, and qualitative data analysis. At Aptima, Dr. Ratwani serves as a project manager and principal investigator on efforts focusing on the development of training programs to foster adaptive capabilities within leadership teams, the investigation of cross-cultural competencies and skills, and the development of tools to aid decision-makers in choices made regarding training programs. Prior to joining Aptima, Dr. Ratwani was a Research Fellow at the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Dr. Ratwani holds a Ph.D. and M.A. in Industrial-Organizational Psychology from George Mason University and a B.A. in Psychology from Monmouth University.

Dr. Webb Stacy is a Corporate Fellow at Aptima where he is responsible for managing and developing Aptima's technology portfolio. Dr. Stacy is interested in both the theory and the practice of using Cognitive Science to improve the software development process. His recent work includes fundamental contributions to the emerging field of scenario engineering, including developing ways to leverage pedagogical information to improve the training value of scenarios and ways to create flyable scenarios from flight log data. Dr. Stacy co-founded Softron, Inc., a company whose vision was to revolutionize software development by enabling programmers to create software with diagrams instead of computer languages. He was awarded a United States Patent on the technology. Dr. Stacy holds a Ph.D. in Cognitive Science from SUNY/Buffalo, and a B.A. in Psychology from the University of Michigan.

Dr. Alexandra Geyer is a Senior Cognitive Scientist and the Team Lead for the Applied Cognition and Neuroscience team at Aptima. Her expertise is in the areas of neurophysiology and cognitive psychology, with concentration on neurophysiological and physiological measurement of cognitive and psychological processes. At Aptima, her work focuses on utilizing various types of measurement to determine an individual's cognitive and/or psychological state and then use this information to improve human performance, training systems, decision aids, and human-computer interactions. Dr. Geyer holds a Ph.D. and a M.S. in Cognitive Neuroscience, and a B.S. in Biology and Psychology, from Tufts University.

Dr. Scott Pappada is a Biological Signal Processing Engineer at Aptima. Particular areas of expertise include pattern recognition algorithms, and machine learning (i.e. artificial neural networks). Dr. Pappada's research involves development of medical device algorithms, technologies, and software which facilitate intelligent therapeutic direction and clinical decision support from both clinician and patient perspectives. His previous research initiatives have focused on the development of techniques, technologies, and software to support optimization of glycemic control. Dr. Pappada also has experience in real-time signal processing and modeling of EEG for several applications including but not limited to: seizure detection, critical care patient monitoring, depth of anesthesia monitoring, psychiatry, and sleep medicine. Dr. Pappada received his Ph.D. in Engineering with a Bioengineering concentration from the University of Toledo, and a Bachelors of Science in Biomedical Engineering with a minor in Biomedical Sciences from Marquette University.

Ms. Emily Weise is a Principal Scientist and the Associate Division Director of the Human Performance Division at Aptima. She provides expertise in performance measurement and has experience in applying Cognitive Work Analysis to the design of information systems. She specializes in identifying competencies, developing performance measures, and analyzing system usability in command and control domains. Ms. Wiese applies this knowledge to developing performance measurement systems that assess operational readiness in simulated and live training exercises. She also develops multimedia training programs. Ms. Wiese received a M.S. and B.S. in Industrial Engineering from the University of Iowa.

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INTRODUCTION

The popularity of training in computer-based gaming environments has exploded, as these types of virtual environments are typically deemed very engaging. Computer-based games and virtual environments enable a wide variety of interactions among users and can provide experiences that push beyond the constraints of the laws of physics and provide access to technologies that exist only within the virtual environment. Interest in gaming environments has extended to the military. General James Mattis said, in a recent conference keynote address, that training through virtual, immersive environments is our best strategy for enhancing the skills troops need for irregular warfare. The Department of Defense has been investing heavily in these virtual environments, largely based on the beliefs expressed by military leadership and the need to economize training.

While the interest in virtual, immersive training environments in the military is evident, there are significant questions that remain unanswered regarding how much training value is provided by the immersion itself. A review of the literature on training in virtual environments reveals an assumption that higher immersion obtained through higher levels of simulation fidelity will result in increased training effectiveness and improved performance in the real-world. However, researchers who have attempted to evaluate this assumption have yet to produce compelling support for this idea. In addition, depending upon the targeted training objectives, highly immersive environments may not always be necessary nor the best fit. Therefore, additional research is needed to investigate the impact that different levels of immersion have on various training outcomes.

Likely, one of the reasons for the dearth of solid evidence regarding the impact of immersion on training effectiveness comes from the lack of consistent, reliable measurement approaches. At the root of the measurement concern is that there is not a clear consensus regarding what immersion actually is. For example, some researchers describe immersion as a state or feeling (e.g., Witmer & Singer, 1998); some equate it with concepts such as presence and flow; yet others conceptualize it as a physical attribute of the training environment (e.g., Dede, 2009; Slater, 2003). Given the lack of agreement over how to define immersion, it is no wonder questions remain over its influence on the learning process.

Thus, before the impact of immersion on learning and performance can be properly assessed, a clear, operational definition of immersion that distinguishes it from other related concepts must be provided. This definition can then facilitate the development of good measurement, which is the hallmark of doing competent research and presenting conclusive results.
A common definition of immersion is essential to any large-scale research effort, within and across studies, in order to accurately compare results. Otherwise, conflicting, or semantically incomparable results may emerge simply as an artifact of inconsistent definition and measurement. Once constructs are defined, we can begin to consider how immersion is best measured in various training environments, leading to the ability to reliably evaluate the impact of immersion on training effectiveness.

Given the recognized importance of immersion and the lack of clarity associated with the construct, this paper seeks to provide an operational definition of immersion as it relates to learning in experiential training environments. We will first discuss how research has been defined and measured in the past and how these approaches relate to other similar constructs that may not be the same as immersion. This theoretical discussion about what immersion is and is not will lay the foundation for a discussion regarding innovatively measuring immersion in unobtrusive ways to capture the underlying nuances of the construct. Finally, the implications of the proposed definition and measurement approach will be discussed. This paper should ultimately facilitate the development of effective training that is closely tied to desired learning outcomes.

DEFINING IMMERSION

Much research has been conducted on immersion. In order to understand what this research is measuring and testing, it is necessary to examine how past research has defined immersion. Table 1 below highlights definitions of immersion offered in the literature. One of the clearest conclusions that can be drawn from this table is that there is no obvious consensus on a definition of immersion. However, when examined in total, past research can provide insight into what immersion is and also what it is not.

What Immersion Is

Upon examining the definitions offered in Table 1, one main theme that stands out is that the majority of the definitions relate immersion to a sense of involvement within the context (e.g., Brown & Cairns, 2004; Jennett et al., 2008, Cox, Cairns, Dhoparee, Epps, Tijs, & Walton, 2008). Whether the word "absorption," "engrossment," or "involvement" is used, an individual immersed within a context experiences being part of that context, and perhaps even experiences a lost sense of time due to that involvement. Another major theme that emerges from these definitions is that immersion appears to be a state, which indicates that it is temporary in nature (e.g., Witmer & Singer, 1998). The temporal nature of the construct necessitates that immersion is brought on by some trigger. These triggering events or circumstances (e.g., narratives, challenging events) are important for understanding how to create immersion. Finally, as the definitions in Table 1 illustrate, there is disagreement as to whether immersion is a subjective experience that differs from person to person (e.g., Dede, 2009), or whether it is a more objective property of the environment (e.g., Slater, 2003). For those definitions that support the latter, immersion is considered a physical property of the simulated environment and not an experience by the individual within the environment. We disagree with this perspective, given that there are various environments in which individuals can be immersed. For example, individuals can get "immersed" in books and movies, not just virtual environments that appear to be real. Therefore, given the large differences that exist in the "environments", such as reading a book versus being in a simulated, virtual environment, it does not appear that immersion can be a property of the environment itself. By subscribing to the idea that immersion can occur in a variety of environments, it appears that different levels of immersion may exist; depending upon the experiences offered within an environment, there may be potential for different levels of immersion to be reached. The idea of levels of immersion has been articulated by Brown and Cairns (2004), who describe immersion in a gaming context. They delineate three levels of immersion through which an individual progresses by overcoming specific barriers: Engagement, to Engrossment, to Total Immersion. By the time level 3 (total immersion) is reached, an individual should be engaging in the game with a directed attention and focus (level 1), have his or her emotions impacted (level 2), and also feel empathy toward (i.e., be attached to) the characters in the game (level 3). How levels of immersion relate to training and learning will be more fully explored later in this paper when we offer our own definition of immersion. First, however, to more comprehensively understand what immersion is, it is useful to examine the constructs we believe immersion not to be.

What Immersion Is Not

There are a number of constructs that are related to, or in some cases, equated with immersion. Technologies such as head-mounted displays (HMDs), for example, are often called "immersive technologies" (e.g. Mania, Coson, & Watten, 2010). While we agree that these technologies can increase one's ability to be immersed, the properties of these technologies themselves are more related to something like fidelity. Table 2 provides a list of constructs that are commonly discussed in relation to immersion but that we view as having distinct differences from immersion. Table 2 provides a definition of each construct to demonstrate how the construct differs from immersion. In addition, these definitions will be directly contrasted to our definition of immersion in the next section. Some of the constructs may help facilitate immersion (i.e. fidelity, cognitive absorption), while for others, immersion may facilitate their occurrence (i.e. addiction, flow state, presence)

Table 1. Definitions of Immersion

Source	Immersion Definition or Description
Brown & Cairns (2004)	The degree of involvement within a game, characterized by three levels, ranging from Engagement, to Engrossment, to Total Immersion
Cheng & Cairns (2005)	Describe immersion as having different levels but do not offer an explicit definition of the construct
Cox, Cairns, Shah, & Carroll (2012)	"The sense of being cognitively involved in the game to the exclusion of the world around you" (p. 79).
Dede (2009)	The subjective impression that one is participating in a comprehensive, realistic experience
Harvey, Loomis, Bell & Marino (2008) [from Bitgood, 1990]	Describe immersion in the context of museum exhibits; refers to the degree to which an exhibit effectively involves, absorbs, engrosses, or creates for visitors the experience of a particular time and place
Jennett, Cox, Cairns, Dhoparee, Epps, Tijs, & Walton (2008)	Immersion is characterized by the following: • Lost sense of time • Involvement and a sense of being part of the environment • Loss of awareness of the real world Five components of the immersive experience are (1) cognitive involvement, (2) real world dissociation, (3) emotional involvement, (4) challenge and (5) control
McMahan (2003)	Sense of immersion in virtual reality consists of three conditions: (1) User's expectations of the game or environment must match the environment's conventions fairly closely (2) User's actions must have a non-trivial impact on the environment (3) Conventions of the world must be consistent, even if they do not match those of "meatspace"
Murray (1997)	Described as "… being transported to an elaborately simulated place... a metaphorical term derived from the physical experience of being submerged in water… the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus… the enjoyment of immersion as a participatory activity…" (p.98-99).
Nacke & Lindley (2008)	Describes the audiovisual or sensory experience of the game environment; operationally defined immersion by the following game design features: • Complex and exploratory environment • Various opponents • Fitting sensory effects • Variety of models, textures and dynamic lights to establish a mood and scenery • Narrative framing
Qin, Rau, & Salvendy (2009)	A description of players being totally submerged in their fictional surroundings
Ortqvist & Liljedahl (2010)	Defined as presence; "the success in a game to create an experience of escapism for the gamer…a psychological experience of nonmediation" (p. 3)
Seah & Cairns (2007)	Being lost in the game
Slater (2003) [also used by Schuchardt & Bowman, 2007; McMahan, et al. 2006]	The objective level of fidelity of the sensory stimuli produced by a technological system; that is, immersion is an aspect of the technology, not the user's experience
Witmer & Singer (1998)	A psychological state characterized by the perception of being enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences

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Table 2. Constructs Related to Immersion

Related Construct	Definition
Addiction	An excessive, compulsory need to obtain a substance or perform a behavior (Roper, n.d.); is typically evaluated by the extent to which an individual experiences damage to multiple levels of functioning (e.g., family, social, and psychological functioning) (Gentile, 2009).
Cognitive Absorption	A state of deep involvement with software (Agarwal & Karahanna, 2000).
Fidelity	"The degree to which a model or simulation reproduces the state and behavior of a real world object or the perception of a real world object, feature, condition, or chosen standard in a measurable or perceivable manner" (Gross, 1999, p.3).
Flow State	The "holistic sensation that people feel when they act with total involvement" (Csikszentmihalyi, 1975); characteristics include a balance of challenge and skills; clear goals; explicit feedback; loss of self-consciousness; feeling of enjoyment and control.
Presence[1]	Psychological sense of being in a virtual environment (Slater, et al, 1994); the subjective experience of being in one place or environment, even when one is physically situated in another (Witmer & Singer, 1998).

[1]Another construct mentioned in relation to immersion is transportation. However, given that transportation has also been referred to as *telepresence* (Steuer, 1995), we equate presence and transportation as the same construct, and therefore, do not include the latter separately.

Defining Immersion in the Learning Context

This current research effort is focused on defining immersion as it relates to *learning*. Based on the research discussed above, we offer the following definition for immersion within training or learning contexts: Immersion is a *subjective state* that involves *mindful engagement*, *goal-directed behavior*, and *perspective taking* in the context of a training environment.
Our definition of immersion was influenced by the definition put forth by Brown and Cairns (2004), as well as examining what learning means. First, Brown and Cairns defined immersion as a multi-level construct. This multi-level approach seems particularly important for defining immersion in the context of learning because it provides a method by which to examine this construct in relation to learning in a variety of training contexts, not just games or simulations. For example, it may be possible to be immersed within a scenario-based training system, while playing a video game in one's own living room, or in a simulator while surrounded on every side by sound and graphics. However, immersion in each of these contexts may look slightly different (i.e., be present in varying degrees), resulting in different learning outcomes. In addition, defining immersion according to levels provides a testable definition of the construct by implicitly offering various measurement strategies. Therefore, thinking of immersion from a multi-level perspective allows for a more specific and systematic investigation into differing manifestations of immersion.

In addition to being influenced by the definition of immersion provided by Brown and Cairns (2004), a critical component of our understanding about immersion as it relates to learning comes from Vygotsky's (1978) definition of learning as a socially-mediated activity. This description implies that learning happens through interaction. In a video-game, it is easy to see that interaction occurs through the characters in the game. However, what about other learning environments where "characters" may not be present? Moore (1989) proposes that there are three types of interactions that can occur: learner-to-instructor, learner-to-learner, and learner-to-content. Even if individuals are engaging with training on their own, interaction can be present with the content itself. Thus, while Browns and Cairns discussed interactions with characters in their definition of immersion within videogames, in a more general training context, we adopt the broader conceptualization of interaction offered by Moore, and propose that interaction with training content, instructors, or other learners are all useful in creating immersion. At each level of immersion, one or more of these types of interaction may be occurring. No matter the form of the interaction, the extent to which an individual is interfacing with the training environment creates the varying levels of immersion. The next few paragraphs provide greater detail about our definition of immersion *as it relates to learning* (influenced by the work by Brown and Cairns and Vygotsky).

Brown and Cairns (2004) define the first level of immersion, *Engagement,* as involving time, effort, and attention on the part of the individual playing the game. Therefore, in order to attain the first level of immersion, individuals must like the type of game being played to pay any attention to it; they must devote time to it so that they can become focused; and they must invest some amount of energy into learning how to play the game. This description of engagement can be compared to *learner* engagement, which is defined as the learner being "mindfully engaged in the process of building, practicing, evaluating, and applying the capability to be mastered during instruction" (Orvis, 2007, p. 5). According to Orvis, learner engagement consists of two sub-dimensions: practice and progress evaluation information. The former represents the degree to which the learner must produce either a cognitive or physical response during the training. The latter is akin to feedback and is the degree to which the training provides information about progress with respect to learning. There is a wealth of research demonstrating the importance of learner engagement for knowledge/skill acquisition and retention (e.g., Gagne & Foster, 1949; Shute, Gawlick, & Gluck, 1998). The key take away from this definition is that immersion, as it relates to learning, requires individuals to not simply be passive observers in the experience. Instead, they must be *mindfully engaged* in the training or activity. As levels of learner engagement increase (as measured by an increase in practice and progress evaluation information), immersion will occur such that learners will direct their time, effort, and attention toward the training content in a way that promotes learning.

Level 2 immersion, *Engrossment*, occurs when the emotions of the individual are directly impacted by the game or the training (Brown & Cairns, 2004). Getting to this level of immersion requires that the game is constructed in such a manner that the individual is able to become emotionally invested into the game. In terms of relating this level 2 immersion to learning, we suggest that becoming engrossed in training facilitates *learner motivation* and promotes *goal-directed behavior*. In the learning context, individuals who are immersed at this level are interacting with the training while in pursuit of some sort of goal. This goal may come from an instructor, the content itself, or perhaps even be a self-set goal. Therefore, by the time learners reach level 2 immersion, they should be mindfully engaged in the training (meaning they are putting forth effort) and should also be motivated to continue within that training context due to the need to accomplish a goal.

Finally, according to Brown and Cairns (2004), level 3 immersion, *Total Immersion*, occurs when individuals are cut off from reality and develop an emotional attachment to the characters in the game. In order to step away from the specific context of games, we must expand upon this definition and think of characters as one way that individuals can interact with the training content. During level 3 immersion, from a learning perspective, there should be increased motivation and enjoyment for the training, causing "the learner to cognitively process the learning material more deeply" (Huang, Rauch, & Liaw, 2010, p. 1173). Such an involved cognitive processing is facilitated by interaction, no matter the type. Deep cognitive processing enables learners to create expanded frames of references. Frames of reference are the knowledge structures through which individuals view the world; expanded frames of reference are created when learners adopt new perspectives and integrate new information to create changed behavioral patterns (Smith, Ford, & Kozlowski, 1997). One way that an individual can expand his or her frame of reference is by being exposed to new and diverse information (Langkamer, 2008). As learners interact within the training environment, they may be exposed to new problems that characters face, gain additional information from an instructor or other trainees, or think about known concepts freshly in the context of new information. At this point, learners are not only becoming emotionally immersed, *but cognitively immersed,* as well. In other words, we propose that total immersion (from a learning perspective) goes beyond emotional attachment to a more cognitive attachment. Learners engaged within a certain context should gain the ability to see problems presented from a new perspective – hence expanding their current frame of reference and problem solving capacity. In other words, when total immersion occurs, learners are engaging in active information exploration and problem solving *from another point of view developed as a result of a deep level of interaction with the training*. Therefore, once an individual has reached the third level of immersion, he or she is not only actively thinking about the information offered to him or her, but also adopting new perspectives as a result of that information. At this point, cognitive processing is occurring at a deep level, promoting the construction of more complex knowledge structures.

MEASURING AND MODELING IMMERSION

Given the proposed definition, any measurement of immersion must consider that it is a subjective state that has different levels or manifestations. Much of past research on immersion has utilized self-report approaches (e.g., Cox et al., 2012; Qin et al., 2009;

Scoresby & Shelton, 2011; Witmer & Singer, 1998). While such an approach is useful for understanding the subjective nature of immersion, differing levels of immersion are difficult to measure with one self-report measure (often obtained post-training). A few studies have made use of other measurement approaches. For example, Jennett et al. (2008) used measures such as task time completion and eye tracking in addition to self-report measures of immersion. By using an approach like eye-tracking, immersion can be measured continuously, and changes in an individual's state can be examined. Such continuous measurement of immersion is important in order to assess immersion according to the proposed definition. It may be the case that different levels of immersion are present at different times throughout training and facilitate different performance outcomes. For example, reaching level 1 of immersion may be needed for some learning outcomes (e.g., the achievement of declarative knowledge), whereas level 3 immersion is needed to achieve other outcomes (e.g., training transfer to real world performance). In addition, in certain task settings, level 3 immersion may not be desirable. For example, if training a power plant operator, individuals should not be so completely immersed in the task at hand that they become oblivious to the environment around them; such high levels of cognitive effort may lead to disastrous consequences (e.g., not noticing when there is an emergency at the plant). Therefore, a measurement approach that can continuously and unobtrusively measure immersion while still taking into account the construct's subjective nature is needed to sufficiently assess the impact of immersion on various training outcomes, and ultimately performance.

We have defined immersion as a subjective state involving three levels: (1) mindful engagement, (2) goal-directed behavior, and (3) perspective taking. The measurement approach proposed here involves using machine learning algorithms to build a classifier that can determine which (if any) of these levels of immersion a trainee is in. The classifier will be especially useful if it uses measures that will not themselves break immersion, as such a break in immersion decreases the possibility of real-time measurement of immersion. Therefore, the data that feed the classifier will not involve self-report or any other disruptive procedure.

In order to create the classifier, test subjects are run through conditions likely to create different levels of immersion, and unobtrusive measures linked to the three levels of immersion are taken during the session (see the next section for a description of potential measurement approaches). Then, the subjects provide a self-report of their level of immersion using an approach like that put forth by Witmer and Singer (1998) or Jennett et al. (2008). The self-report responses become labels for the rest of the measurements to be used to create the classifier, as shown on the left-hand side of Figure 1. Essentially, the self-report data provide baseline information about whether the test subject was immersed at all, and if so, some preliminary information about the degree of immersion. This information is called a *label*. The label will be then compared and matched to the unobtrusive measurement data of the test subject during the same time period. The result of repeating this process multiple times is a large set of *cases*, which together, provide unifying information to specifically determine levels of immersion. The cases will be used by machine learning algorithms to create a classifier. Examples of machine learning approaches that might be used are artificial neural nets (Bertsekas & Tsitsilklas, 1996) and support vector machines (Boser, Guyon, & Vapnik, 1992.)

Once the classifier is created, we will be in a position to use it to measure immersion during training events. To do so, we simply feed it the unobtrusive measures used when creating the classifier, and the classifier provides the best estimate of the level of immersion that applies at that particular moment. This process can be seen on the right-hand side in Figure 1.

Unobtrusive Measures

Three kinds of unobtrusive measurement approaches will be useful for the measurement of immersion: system measures, observer-based measures, and neural and physiological measures. Of these, system measures (measures derived from the training environment itself, such as timeline of training events or trainee actions taken within the environment) and observer-based measures are likely to be of limited usefulness in classifying immersion since it is, in general, difficult to judge a trainee's level of immersion from behavioral or observational measures. However, these measures may prove useful in further investigations of the causes of immersion and in the relationship of immersion to trainee performance.

On the other hand, neural and physiological measures can provide an objective assessment of immersion that may significantly contribute to understanding the reasons for trainee actions at any given time**.** Based on the definition proposed in this paper and research on each measurement approach, an assessment can be made about what level of immersion each measurement approach is tapping. For example, it is likely that neural and physiological correlates of attention (Klimesch, Doppelmayr, Russegger Pachinger, & Schwaiger, 1997), alertness (Jung, Makeig, Stensmo, & Sejnowski, 1997), fatigue/drowsiness (Milosevic, 1997; Raggatt & Morrissey, 1997) and engagement (Freeman, Mikulka, Prinzel, & Scerbo, 1999) will be useful to the classifier for identifying level 1 immersion. Two EEG-based measures show promise in identifying that the subject has formed an intent to act, and therefore that they have a goal, which would help determine that they are exhibiting the goal-directed behavior required for Level 2 immersion: the Lateralized Readiness Potential (LRP; Roggeveen & Ward, 2004) and the Error Related Negativity signal (ERN; Gehring, Goss, Coles, & Meyer, 1993). Both involve looking for certain characteristic waveforms at some number of milliseconds after an event or response has taken place in the game or simulator. The LRP simply reflects the subject's intent to perform motor activity. The ERN occurs when a subject provides a response different from the one they intended (and thus indicates that the subject actually had an intent.) For level 3 immersion, which requires perspective-taking, perhaps some indicator of activity in the Temporal Parietal Junction, a region known to be involved in understanding the viewpoints of others (Saxe, 2010), will be useful.

In summary, a classifier-based measurement approach to measuring immersion that uses various kinds of unobtrusive measures as input is likely to be an effective way to ensure that the results that emerge from this line of research are robust and reliable across a broad population of trainees. Such a measurement approach provides a method by which to measure immersion continuously throughout a training event while delineating between the different levels of immersion through which a trainee may progress. Such a nuanced approach to measurement will not only validate the differences between the three levels of immersion, but will also allow for conclusions to be drawn about how the three levels differentially impact performance.

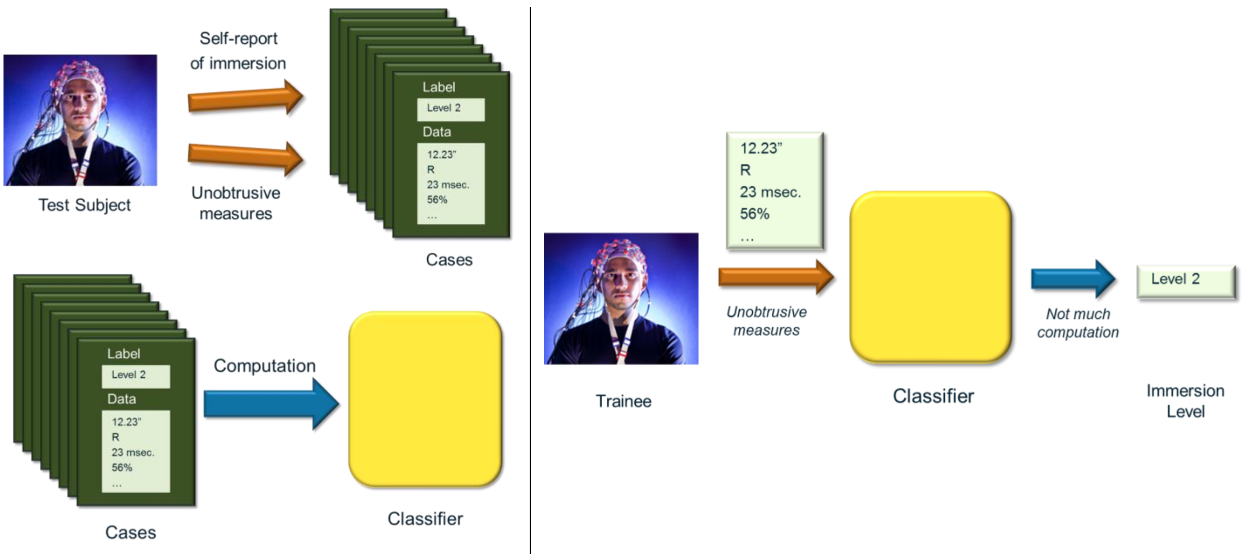

Figure 1. Left: Creating the Classifier; Right: Using the Classifier

CONCLUSION

In this paper we have proposed a three-level definition of immersion at it relates to training and have further proposed an approach to measuring those three levels. While the measurement ideas proposed here are a start, the paper illustrates how an unobtrusive, continuous measurement approach is needed to measure nuances associated with a dynamic construct like immersion. It is the intent of this paper to suggest that by developing a clear definition and providing measurement ideas, a program of empirical studies can begin. Such studies should explore both effective methods to increase immersion and a deeper understanding of the effects of immersion on training efficiency and effectiveness. In addition, studies should examine what level of immersion is most useful for the desired outcomes. This knowledge, in turn, will lead both to more cost-effective means to create immersion and to more effective experiential training, leading to the ultimate goal of a higher level of readiness for all.

REFERENCES

Agarwal, R., & Karahanna, E. (2000). Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS Quarterly*, *24*(4), 665-694.

Bertsekas, D.P., Tsitsiklis, J.N. (1996). *Neuro-dynamic programming*. Athena Scientific

Boser, Bernhard E.; Guyon, Isabelle M.; and Vapnik, Vladimir N.;(1992) *A training algorithm for optimal margin classifiers*. In Haussler, David (editor); 5th Annual ACM Workshop on COLT, pages 144–152, Pittsburgh, PA, 1992. ACM Press.

Brown, E., & Cairns, P. (2004) A grounded investigation of immersion in games. *ACM Conf. on Human Factors in Computing Systems, CHI 2004,* ACM Press, 1297-1300

Cheng, K., & Cairns, P. A. (2005). Behavior, realism and immersion in games. *ACM Conf. on Human Factors in Computing Systems, CHI 2005,* ACM Press, 1272-1275.

Cox, A. L., Cairns, P., Shah, P., & Carroll, M. (2012). Not doing but thinking: The role of challenge in the gaming experience. *CHI 2012,* Austin, TX.

Csikszentmihalyi, M. (1975), *Beyond Boredom and Anxiety*. Jossey-Bass, San Francisco, CA.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323,* 66-69.

Freeman, F. G., Mikulka, P. J., Prinzel, L. J., & Scerbo, M. W. (1999). Evaluation of an adaptive automation system using three EEG indices with a visual tracking task. *Biological Psychology,* 50(1), 61-76.

Gagne, R. M., & Foster, H. (1949). Transfer to motor skill from practice on a pictured representation. *Journal of Experimental Psychology, 39,* 342-354.

Gehring, W. J., Goss, B., Coles, M. G., & Meyer, D. E. (1993). A neural system for error detection and compensation. *Psychological Science, 4*(6), 385-390.

Gentile, D. (2009). Pathological video-game use among youth ages 8 to 18: A national study. *Psychological Science, 20(5),* 594-602.

Gross, D. C. (1999). Report from the Fidelity Implementation Study Group. *Simulation Interoperability Standards Organization (SISO) SISO-REF-002-1999.* http://www. sisostds.org/Products Publications/ ReferenceDocuments.aspx

Harvey, M. L., Loomis, R. J., Bell, P. A., & Marino, M. (1998). The influence of museum exhibit design on immersion and psychological flow. *Environment and Behavior, 30,* 601-627.

Huang, H., Rauch, U., & Liaw, S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers and Education, 55,* 1171-1182.

Jennett, C., Cox, A., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of Immersion in games. *International Journal of Human-Computer Studies, 66*(9), 641-661.

Jung, T.P., Makeig, S., Stensmo, M., & Sejnowski, T.J. (1997). Estimating Alertness from the EEG Power Spectrum. *IEEE Trans on Biomed Eng, 44*(1), 60-69.

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters,* 244(2), 73-76.

Langkamer, K. L. (2008). *Development of a nomological net surrounding leader self-development*. Unpublished doctoral dissertation, George Mason University.

Mania, K., Badariah, Coxon, M., Watten, P. (2010). Cognitive transfer of spatial awareness states from immersive virtual environments to reality. *ACM Transactions on Applied Perception,7(2),* 1-14.

McMahan, A. (2003). Immersion, engagement and presence: A method for analyzing 3-D video games. In M. Wolf & B. Perron (Eds.), *The Video Game Theory Reader* (pp.67-86). New York, NY: Routledge.

McMahan, R. P., Gorton, D., Gresock, J., McConnell, W., & Bowman, D. A. (2006). Separating the effects of level of immersion and 3D interaction techniques. Proceedings of the ACM symposium on *Virtual Reality Software and Technology*, Limassol, Cyprus.

Milosevic, S. (1997). Drivers' fatigue studies. *Ergonomics, 40*(3), 381-389.

Moore, M. G. (1989). Editorial: three type of interaction. *The American Journal of Distance Education, 3*(2), 1–6.

Murray, J. H. (1997). *Hamlet on the holodeck: The future of narrative in cyberspace.* Cambridge, MA: The MIT Press.

Nacke, L., & Lindley, C. A. (2008). Flow and immersion in first-person shooters: Measuring the player's gameplay experience. *FuturePlay,* ACM Press, 81-88.

Ortqvist, D., & Liljedahl, M. (2010). Immersion and gameplay experience: A contingency framework.

International Journal of Computer Games Technology, 1-11.

Orvis, K. A. (2007). *Supervisory performance feedback as a catalyst for high quality employee self-development*. Unpublished doctoral dissertation, George Mason University.

Qin, H., Rau, P. P., & Salvendy, G. (2009). Measuring player immersion in computer game narrative. *Journal of Human-Computer Interaction*, *25*, 107-133.

Raggatt, P. T. F., & Morrissey, S. A. (1997). A Field Study of Stress and Fatigue in Long-Distance Bus Drivers. *Behavioral Medicine, 23*(3), 122-129.

Roggeveen, A., Ward, L. (2004). Parsing action and cognition: Using the lateralized readiness potential to quantify perceptual/cognitive slowing in older adults. Journal of Vision, 4, http://www.journalofvision.org/4/8/750/.

Roper, C.N. (n.d.). Definitions and characteristics of addiction. Retrieved March 11, 2011 from http://www.alcoholanddrugabuse.com/article1.html

Saxe, Rebecca. (2010). The right temporo-parietal junction: a specific brain region for thinking about thoughts. *Handbook of Theory of Mind*. 'Ed'. Alan Leslie & Tamsin German.

Seah, M., & Cairns, P. (2007). From immersion to addiction in videogames. In D. England & R. Beale. *Proceedings of HCI 2008, vol 1* BCS, 55-63.

Schuchardt, P., & Bowman, D. A. (2007). The benefits of immersion for spatial understanding of complex underground cave systems. Proceedings of the ACM symposium on *Virtual Reality Software and Technology*, Newport Beach, California.

Scoresby, J., & Shelton, B. E. (2011). Visual perspectives within educational computer games: Effects on presence and flow within virtual immersive learning environments. *Instructional Science*, *39*, 227-254.

Shute, V. J., Gawlick, L. A., & Gluck, K. A. (1998). Effects of practice and learner control on short- and long-term gain and efficiency. *Human Factors*, *40*(2), 296-310.

Slater, M. (2003). A note on presence terminology. *Presence-Connect*, *3*, http://s3.amazonaws.com/publicationslist.org/data/melslater/ref-201/a%20note%20on%20presence%20terminology.pdf.

Slater, M., Usoh, M., & Steed, A. (1994) Depth of Presence in Immersive Virtual Environments, Presence: Teleoperators and Virtual Environments, MIT Press 3(2), 130-144.

Smith, E. M., Ford, J. K., & Kozlowski, S. W. J. (1997). Building adaptive expertise: Implications for training design strategies. In M. A. Quinones & A. Ehrenstein (Eds.), *Training for a rapidly changing workplace: Applications of psychological research* (pp. 89-118). Washington, DC: American Psychological Association.

Steuer, J. (1995). Defining virtual reality: Dimensions determining telepresence. In F. Biocca & M. Levy (Eds.), *Communication in the age of virtual reality* (pp. 33-56). Hillsdale, NJ: Lawrence Erlbaum and Associates.

Vygotsky, L.S. (1978). Mind and society: The development of higher mental processes. Cambridge, MA: Harvard University Press.

Witmer, B.G and Singer, M.J. (1998) Measuring Presence in Virtual Environments: A Presence Questionnaire, Presence*: Teleoperators and Virtual Environments*, **7**(3), 225-240.