The Pursuit of Flow in the Design of Rehabilitation Systems for Ambient Assisted Living: A Review of Current Knowledge

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ABSTRACT

This review paper gathers together the key sources on the science of engagement and immersion, in particular the concept of flow. Flow is a psychological description for full immersion in an activity. It provides a useful framework within which to understand the coupling between pervasive computing and end users. The article discusses the concept of flow in a general psychological sense and extracts those features relevant to gaming, and in particular the human-computer interaction (HCI) aspect of such systems. The requirements for achieving flow such as reward, situational control, feedback and clarity of purpose as applicable to a pervasive computing environment are discussed in detail. The primary application focus of flow in this paper lies in the area of ambient-assisted living solutions for rehabilitation purposes. In the context of using virtual environments to aid in skill training or medical rehabilitation, dynamic difficulty adjustment (DDA) and enjoyment are two key elements used to create a fully immersive experience. This paper both reviews the techniques for creating these elements and describes possibilities for harnessing related methods as evaluation techniques for immersion in HCI-based rehabilitation environments, which may offer an alternative to current survey-based mechanisms.

Keywords: Ambient-Assisted Living Solutions, Gaming, Human-Computer Interaction, Pervasive Computing, Rehabilitation

INTRODUCTION

Rehabilitation therapy for restoration of functional movement is based on mass practice of clinician-prescribed physical exercises. Traditionally these exercises require that the patient focus their efforts on the affected limb(s) and build strength and coordination through simple movement tasks (Laino, 2010; Alankus, Lazar, May, & Kelleher, 2010). These activities tend to be of a monotonous nature and patient compliance can be poor due to lack of motivation (Flores, Tobon, Cavallaro, Cavallaro, Perry, & Keller, 2008). This is especially common when the patient is required to practice at home, without the rehabilitation therapist. Recently in...
order to improve engagement, rehabilitation scientists and practitioners have been making increasing use of advances in computer gaming technology which is allowing the creation of virtual environments tailored to rehabilitation therapy (Alankus, Lazar, May, & Kelleher, 2010). The primary interest of this review is the integration of such rehabilitation technologies in an ambient-assisted living environment and it is within such a context that this paper discusses the science of flow and engagement.

Computer gaming is increasingly harnessing ambient computing concepts. Ambient or pervasive computing describes the application and deployment of computer-based systems in day-to-day activities through non-obtrusive ubiquitous means. Some pervasive systems are designed in such a way that the computing is mostly hidden from the user. To the user it will seem less and less like they are interacting with an autonomous system. This trend of ambient computing in gaming is marked by an emphasis on the development of more natural and intuitive control interfaces. Motion sensing game controllers such as the Nintendo Wii and more recently Microsoft’s Xbox Kinect exemplify particularly well this new focus in the industry. The user feels more involved in the environment as their movements are directly reflected on-screen by an avatar. The Wii controller comprises an infrared sensor that allows the controller’s position in space and time to be tracked. When the user generates a motion, such as when wielding a sword or throwing a bowling ball an in-game character will do the same. Such single point tracking has revolutionised gaming interaction and has led to the emergence of even more sophisticated technology such as the Xbox Kinect. Through two cameras and a depth sensor this sensor tracks up to 46 joints on the body completely hands-free. The resultant sense of immersion for the user is such that they feel they are actually jumping over obstacles or using a sword to combat an opponent. This moves the game another significant step closer to an immersive ambient environment. The whole game world becomes more realistic making the user less aware they are interacting with an artificial reality creates a greater connection with the virtual environment. We describe later how maximising this immersion aspect of ambient computing is key to creating the optimal gaming experience in the context of rehabilitation.

There has been a lot of research carried out on movement-based rehabilitation therapy which concludes that ambient virtual environments are the way forward in improving patient compliance and engagement (Alankus, Lazar, May, & Kelleher, 2010; Burke, McNeill, Charles, Morrow, Crosbie, & McDonough, 2009). Riva, Castelnuovo, and Mantovani (2006) have researched the benefits of these virtual environments, specifically stating that they allow for the use of more immersive and motivating rehabilitation games. Experiments they discuss claim that two sets of patients significantly benefitted from using virtual environments over more traditional methods.

This transition of rehabilitation exercises from more traditional repetitive movement activities into advanced computer gaming allows more room for exciting activities with relatively simple and intuitive controls such as the aforementioned Wii and Kinect. For example, a patient with very limited right-arm movement may enjoy gardening but creating useful rehabilitation exercises based on real work in the patient’s garden is just not practical or feasible. Through the use of virtual environments a gardening game can be created that requires the user make gestures with their arm to control aspects of the game. Riva et al. (2006) give the example of a virtual world they tested which allowed a patient with limited mobility to “walk” through mountain scenery, to which the users gave positive feedback.

These advances in technology (especially visual realism and physics-enabled environments) are excellent for creating an immersive world, but recently there has been an upsurge in research focused on what is required to make a game engaging, immersive and motivating. It would seem that technology is only one part (although often a very significant one) of an intricate set of qualities required to create a game.
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