Creation of Games for Physical Rehabilitation of Amputees Using an Adapted Flow Model as a Basis

Bryan Teixeira Paiva
Computer Engineering - UNIPAMPA
Bage - RS, Brasil
bryanpaiva20@gmail.com

Gabriel Ladeia de Souza Costa
Computer Engineering - UNIPAMPA
Bage - RS, Brasil
gabriel.ladeia92@gmail.com

Mauricio de Souza Realan Arrieira
Computer Engineering - UNIPAMPA
Bage - RS, Brasil
mauriciorealan@gmail.com

Julio Saracol Domingues Jr.
Computer Engineering - UNIPAMPA
Bage - RS, Brasil
juliodomingues@unipampa.edu.br

Erico Marcelo Hoff do Amaral
Computer Engineering - UNIPAMPA
Bage - RS, Brasil
ericoamaral@unipampa.edu.br

***Abstract*—This paper proposes the flow model that considering amputees related characteristics. Through studies and analysis on the amputees performance in physical rehabilitation treatment, it was observed the need to particularize the flow theory for amputees. The new flow model considering three axs: challenge, skill and functional coefficient. The functional coefficient is based of concepts Functional Measure For Amputees Questionnaire (FMA). In this way, It are being develop two games that applies in the physical rehabilitation process of amputees. Therefore, the purposes of these games is working the patients motivation during the rehabilitation sessions, given the possibilities offered.**

***Keywords*-amputees; flow; physical rehabilitation;**

I. Introduction

It is notorious that problems of the physical rehabilitation process can be increases by the compromises lack of patients, with different diseases, since the treatment can be tiring and lasting, resulting in several cases of desistance and depression. From this reality, it has been increasingly common the games application in this environment [1].

Granic, Lobel and Rutger (2014) demonstrate a series of benefits resulting from the games application used in cognitive, motivational, emotional and social development, that have been focus of studies in the medical area for motivation and treatment of patients. However, not all game can be used in the treatment of physical rehabilitation of patients [2]. Thus, Cataldi (2017) points the need of studying about the design optics of games applied to the motivation for the physical rehabilitation of individuals [1].

In this sense, an important concept should be consider, the flow state. Described by Csikszentmihalyi in 1990, this state is perceived by the sensation of disconnection with reality and by the loss of temporal notion, focus and total immersion. Thus, the co-relation of the description proposed by Csikszentmihalyi with the action to play, leads researchers to use it as a base for the development of more immersive experiences in games [3]. Chen (2006) reports that the games design must take into account the flow state concepts during development to keep an user experience as immersive as possible. The author defends the dynamic adjustment of difficulty for achieve the flow state in games. This is possible with game system auto adjustment the difficulty according to the actions and decisions of your players, allowing players a sense of control over their actions and their resultings according to their own choices and abilities [4].

The conventional flow model works by analyzing the Challenges and Skills aspects, but amputees have problems that go beyond this context, from congenital diseases until prostheses problems. For example, a patient who is amputated in an exercise session may be able to accomplish of the challenges presented and had the necessary skills to perform it, but he is unable by discomfort in his prosthesis, thus preventing it from reaching the state of flow. Therefore, is perceptible that this patients has specific needs in their personal context that interfere in the measurement of the results in the conventional flow model.

In this way, this works proposes the elaboration of a new flow model adapted to the amputees reality and, based on this model, to guide the construction of games aimed at the physical rehabilitation of amputees. Thus, beyond this introduction section this document still presents: a theoretical reference in section 2; the methodology used, in section 3; in section 4 the elaboration and development of the work; and in section 5 the partial conclusions.

II. Theoretical Reference

A. Flow Theory

The flow theory was proposed by Mihaly Csikszentmihalyi to define the mental state in which the individual is totally immersed and focused on his activity so that nothing is more important than the activity. Csikszentmihalyi's studies report that to reach the flow state, certain elements are required to

be present in the activity, such as: complete involvement in the activity, focus and concentration, clear goals, sense of ecstasy, quiet and worry-free mind, balance between skill level and challenge of activity and intrinsic motivation [3].

Csikszentmihalyi concludes that the flow state tends to occur when there is a fine balance between skill and challenge, when the individual's abilities are fully applied in the activity that is at the limit of their capacities. The flow experience registers the satisfaction of dealing with difficult and challenging situations, having positive feedback on its performance and perceive that it is possible to control the situation [5].

B. Eight Channel Model

In 1975 Csikszentmihalyi has proposed a three-channel model of Flow experience. The model is based on the relationship between the ability of the individual and the challenge found in the activity carried out. In 1988, based on the concepts of the three-channel model proposed by Csikszentmihalyi, Massimini and Carli developed a model more sensitive, with eight channels. From their studies and a research that involved students at a school in Italy, Massimini and Carli found that the Flow experiences happen when the skills and challenges were in self-balance [6].

In this way, from the model of eight channels, it can be observe that the flow channel and the channel Apathy are the positive and negative extremes, respectively, to rank the quality of experience of the individual. In addition, the closer to the central point, the more the individual will be in a neutral state of mind, however, by raising the level of the challenges, the concentration widens [6].

C. Flow in Games

Starting from the observation of the criteria defined by Csikszentmihalyi to achieve the state of flow it is evident that games offer a favorable environment. Thus, if a game can incorporate these criteria in a controlled environment, it can also be used to overcome real-world situations to provide the state of flow [7].

Holt (2000) contextualizes the criteria presented by Csikszentmihalyi, necessary to achieve the state of flow, to the prospect of games as follows: 1) the task is achievable by the player; 2) the player is able to focus on the task; 3) clear objectives; 4) every action has immediate feedback; 5) deep Involvement; 6) feeling of control of actions; 7) personal concerns disappear.

In games, when applying the concepts of flow, it has be the goal of finding the balance between skills and challenges. In order to provide this balance some games adopt the technique known as Dynamic Difficulty Adjustments (DDA). This technique bases the difficulty of the game on the player's performance during the game [4].

III. Methodology

Considering the observation of the inefficiency of eight-channel model in evaluating individuals amputees this work proposes a new flow model that regarding of amputee reality in rehabilitation process. Subsequently, it was elaborated the proposal of a model, based on the eight-channel model, which enables the assessment of the state of flow in amputees. Then, the concepts of the proposed model will be applied in the development of games used in the physical rehabilitation of patients amputees.

From a questionnaire specifically designed to analyze the patients state, it was performed the relation in the spectrum of the new model proposed, that generated a score called Functional Coefficient. In order to better meet the requirements established by Flow Theory, the games bring a DDA proposal where the level of challenge proposed in the goal is adapted to the player's performance. The Functional Coefficient generated, in this case, has a direct influence on the calculation of the DDA system objective. This is a way to take into account the psychological and physical aspects of an individual amputated in the design process of digital games.

IV. Elaboration and Implementation

A. Model Construction

From the observation that the eight-channel model proposed by Massimini and Carli is not satisfactory, in the analysis of flow status in amputees, was elaborated a new model. Thus, this model is based on the inclusion of a third axis, this in relation to the eight-channel model that presents the axes challenges and abilities. In this way, as the objective of this axis is to frame several features involving the daily life of patients amputees, to your definition were used the concepts of quality of life (QoL) and functional average method.

In this sense, according to Milioli et al. (2012) the QoL is more than the absence of disease or infirmity. Three main domains are identified: physical, social and psychological well-being. In the evaluation of physical functioning are included: fatigue, pain, sleep, independence from everyday activities and freedom from signs and symptoms of the disease. In assessing the social functioning are considered the perception of individuals about your role and social relations with others, leisure and sexual life. Psychosocial issues are increasingly highlighted as important factors for the QoL of the amputees. This results in changes in daily life, at work, in interaction with society and in the performance of activities [8].

In addition, another fundamental approach in defining the third axis for the proposed flow model, is the concept implicit in the Functional Measure For Amputees Questionnaire (FMA). The FMA questionnaire provides valuable information by correlating the use of the prosthesis with the

execution of daily activities. This method is also able to assess differently the use of prosthesis from one individual to another [9]. Thus, it is possible to observe that considers the concepts that correspond to the use of prostheses in the definition of the proposed model is of very important.

Therefore, the 16-channel model becomes more sensitive than the 8-channel model, since the new axis adds the psychological factor in flow measurement, approaching the original Csikszentmihalyi theory and the aspects defined by him to achieve the flow, such as total involvement in activity, focus and concentration and worry-free mind. This axis is important for measuring the state of flow for amputees, because even though the challenges imposed by the game are proportional to the abilities of the amputee, he has physical and emotional aspects that can make the game experience uncomfortable and unpleasant, making it impossible to reach the flow.

In this way, from the theoretical basis and through the presented concepts, defined the third axis of the proposed model, called functional coefficient. It is necessary to point out that in the analysis of functional coefficient going to be only weighted with low and high measures, without owning the average rating, as on the challenges and abilities axes. This is due to the understanding that a median weighting does not significantly interfere with the standard analysis of the eight-channel model. Thus, Table 1 presents the definition of the channels of the model from each possibility of evaluation. Just as the eight-channel model abstracts the channel in which the skill and challenge are average, the proposed model also abstracts some channels that were disregarded by understanding were not needed.

Table I
COMBINATIONS OF CHANNELS.

Channel	Skill	Challenge	Functional Coefficient
Flow	High	High	High
Frustration	High	High	Low
Control	High	Moderate	High
Instability	High	Moderate	Low
Relaxation	High	Low	High
Discontentment	High	Low	Low
Arousal	Moderate	High	High
Affliction	Moderate	High	Low
Boredom	Moderate	Low	High
Annoyance	Moderate	Low	Low
Anxiety	Low	High	High
Stress	Low	High	Low
Worry	Low	Moderate	High
Anguish	Low	Moderate	Low
Apathy	Low	Low	High
Repulse	Low	Low	Low

The differential of this model in relation to the model proposed by Massimini and Carli is the flow approach not only from the perspective of skill and challenge. The proposed model goes beyond, with the functional coefficient axis it takes into consideration the psychological factors that are present in any game, such as motivation, enthusiasm, pleasure and happiness of the player. Thus, the functional coefficient indicates the player psychological state, if it is high means that the player is happy and motivated, on the other hand if its is low means that the player is dissatisfied and unhappy with the activity. These psychological factors are not necessarily related to the difficulty of the game or to the player's ability, for example in amputees the discontent may be related exclusively to factors related to their amputation, such as discomfort, pain and other adversities that may occur during the activity.

Thus, the sixteen-channel model is divided into two levels, the functional coefficient being the axis that determines this level. If the functional coefficient is high the channel will be at the top of the model and if it is low then the channel will be at the bottom of the model. For example, while a patient with high ability, high challenge and high functional coefficient experiences the flow sensation, another patient with the same levels of skill and challenge but with the low functional coefficient experiences a feeling of frustration. In this way, Figure 1 shows the graph generated to demonstrate the relationship of the channels, through their conditions in skills, challenges and in the functional coefficient.

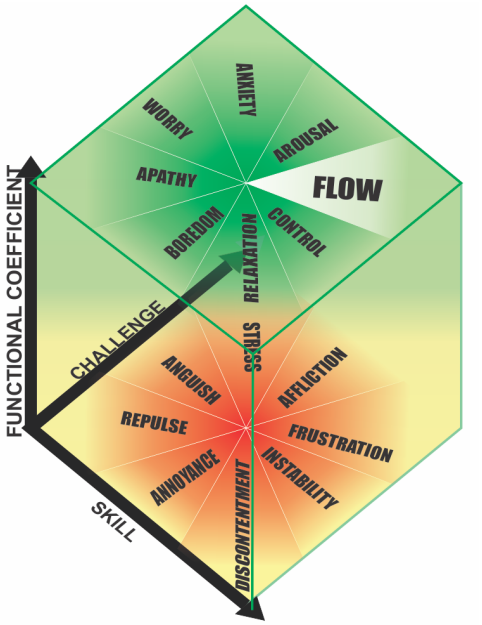

Figure 1. Sixteen-Channel Flow Model Graphic.

B. Games Development for Rehabilitation

In these context, it is necessary to pay attention to the motivation of the individual in the process of rehabilitation, the success of the recovery of the patient is directly linked to the commitment and dedication of the patient himself [10]. In this way, it was proposes the development of two games, the first game applies to lower limb amputees and the other

to upper limb amputees. Both games are in the early stages of development, from the implementation using the game engine Unity 3D.

Figure 2 presents an amputated patient using a first version of the game designed for upper limb amputees. The goal is to build a solution that uses an Arduino hardware prototyping platform and techniques to monitor and process electromyographic (EMG) signals through sensors. The solution should allows the simulation of a set of activities necessary to the process of physical rehabilitation of these individuals. Thus, the interaction of the game allows the patient, through the sensors positioned in their residual muscles, to move a horizontal bar on the screen, in order to counter the fall of a ball.

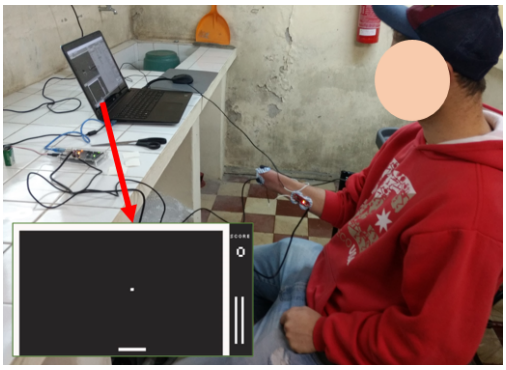

Figure 2. Game for Upper Limb Amputees.

On the other hand, Figure 3 presents an amputated patient playing the initial game proposal prepared for lower limb amputees. In short, it is a serious game, with the proposal to motivate lower limb amputees to perform, more productively, physical therapy sessions on a stationary bicycle. For this, the sensors used in conjunction with the Arduino platform are distributed on the bicycle in order to collect clinical data, monitor them and also use the information of speed and distance traveled, to control the game.

Figure 3. Game for Amputees of Lower Members.

Therefore, the development of the games are in the phase of elaboration of system of type DDA, where it is intended to implement the systems for calculations of challenges adapted to each individual. The intention is to insert the Flow model of sixteen channels, appropriately, in the calculation of the goal suggested in the games and thus to achieve a high motivation state and, preferably, the Flow state.

V. Final Considerations

It is important to point out that the purpose of this study was proposes a more pleasant and motivating physical rehabilitation process for patients, and also the new conditions for monitoring the treatments progress. In this way, the new concepts proposes in this paper was show promisses, and that it is possible applies the computation techniques in a social context. Thus, the project is in the development phase by of games aimed at the physical rehabilitation of amputees. In the next phase, the sixteen-channel flow model concepts applied in the games, going to be test. Moreover, it going to be tests on the applications developed with physiotherapists and, later, going to be tests with patients, in order to evaluate the reception of the individuals the use of the games and their motivation during the sessions.

References

[1] Cataldi, Pedro Cesar Pedreira, and Tiago Barros Pontes. "Parmetros para a concepo e avaliao de jogos para reabilitao de pacientes vtimas de AVE." Design - Tecnologia 7.14 (2017): 69-90.

[2] Granic, Isabela, Adam Lobel, and Rutger CME Engels. "The benefits of playing video games." American psychologist 69.1 (2014): 66.

[3] Csikszentmihalyi, Mihaly, and Isabella Csikszentmihalyi. Beyond boredom and anxiety. Vol. 721. San Francisco: Jossey-Bass, 1975.

[4] Chen, Jenova. "Flow in GamesMFA Thesis." University of Southern California (2006).

[5] KAMEI, Helder. "Flow e psicologia positiva: estado de fluxo, motivao e alto desempenho." Goinia: IBC (2014).

[6] Massimini, Fausto, and Massimo Carli. "The systematic assessment of flow in daily experience." (1988).

[7] Holt, Robertson, and J. Mitterer. "Examining video game immersion as a flow state." 108th Annual Psychological Association, Washington, DC (2000).

[8] Milioli, Renata, et al. "Qualidade de vida em pacientes submetidos amputao." Revista de Enfermagem da UFSM 2.2 (2012): 311-319.

[9] Almeida, Camila Cadena de. "Estudo da variabilidade da frequłncia cardaca e do nvel funcional de amputados transfemorais." DISSERTAO DE MESTRADO EM ENGENHARIA BIOMDICA (2015).

[10] Silva, Ana Patrcia Matos da Costa. Amputao e reabilitao: Estudo dos aspectos psico-legais do sujeito com amputao. Diss. Instituto Superior de Psicologia Aplicada, 2006.