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Gamification, sensory feedback, adaptive function on virtual reality rehabilitation: a brief review

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***Abstract*— Feedback is often linked to rewards element in gamification to motivate users. However, there are more to feedbacks than rewards elements. Feedback can provide user with useful information and at the same time feedback from user are useful for an adaptive system. There has been lack of empirical basis for feedback design to maintain motivation in virtual reality environment especially for the less cognitively abled population such as stroke patients. This paper presents a review study on gamification, sensory feedback, and adaptive function with regards to the use of virtual reality in stroke rehabilitation. A further analysis was conducted on those work that involves gamification and virtual reality design principles. One major finding is the dominant use of visual feedback in the design as compared to auditory and haptics despite their potentials to encourage motivation and engagement. The literature findings will be used to inform future empirical research on virtual reality design for stroke rehabilitation. The idea is to investigate the effect of sensory feedback and the added value on motivation and engagement. Some plans on how to conduct such a study will be illustrated.**

Keywords*— *virtual reality, gamification, sensory feedback, adaptive function, multisensory feedback, stroke, rehabilitation

I. Introduction

According to Barrett et al. [1] the design of gamification is often focused upon several fundamental principles, such as reward, goals, challenge and the concept of meaningful play. The authors stated that these same principles are important in the design of games for rehabilitation. In addition, the authors have revealed that there have been several attempts for the strengthening of the relationship between commercial game design and rehabilitative game design. In which commercial game design provides insight into factors that can increase motivation and engagement with the latter. However, in our observation, most gamification models and implementation only discussed on rewarding user using gamification elements such as points, badges, and other reward systems when describing feedback. For example, the Motivation Needs model in figure 1 shows that the type of feedbacks to enhance motivation are provided through reward systems [2]. Similarly, in the implementation of gamification for rehabilitation via virtual reality (VR), most studies [3-7], focused on systems designs including hardware, graphical user interface, and gameplay to explore the effectiveness of VR in aiding stroke rehabilitation. It seems, although studies found the advantages of using sensory feedback to support rehabilitation, lesser in-depth studies and applications sensory feedbacks are implemented in gamification of stroke rehabilitation via VR. According to Zhu et al. [8], there is a lack of empirical basis for feedback design to sustain motivation during motor skill training due to the non-controlled type or modality of feedbacks condition. The study proved that implementing haptic feedback together with visual display has a stronger motivating effect compared to implementing only visual or auditory feedback on motor learning. However, result might not reflect the needs of stroke patients which have reduced cognitive and physical abilities. Therefore, we are interested to study the design of sensory feedback on motivation and engagement in rehabilitation for stroke patients via VR.

II. Literature Review

An investigation of literature pertaining to the concepts of gamification, sensory feedback, and adaptive function on the motivation and engagement on stroke rehabilitation via VR has been studied. The literature articles are found through searches in the Scopus database, IEEE Xplore, Elsevier database, PubMed, and ResearchGate.

A. *Gamification*

According to Fulton [9], gamification is a relatively new discipline, only emerging significantly in literature since 2011 [10]. The earlier definition of gamification is defined as “the use of video game elements in non-gaming systems to improve user experience and user engagement” [11]. It is also defined as “learning-related game attributes outside the context of a game”, Bedwell taxonomy [12], “with the purpose of affecting learning-related behaviours or attitudes” as added by Landers [13]. Gamification integrates game elements or characteristics into learning materials. It is categorized into two main types, structural gamification, and content gamification. The definition of structural and gamification by [14] is summarized as follows. The content of learning materials remains unaltered, but game elements are added to the structure of the content in structural gamification. The goal of this type of gamification is to push learner through the learning process. Motivation is the key for user to complete the program. Since structural gamification is motivation-oriented through rewards, the

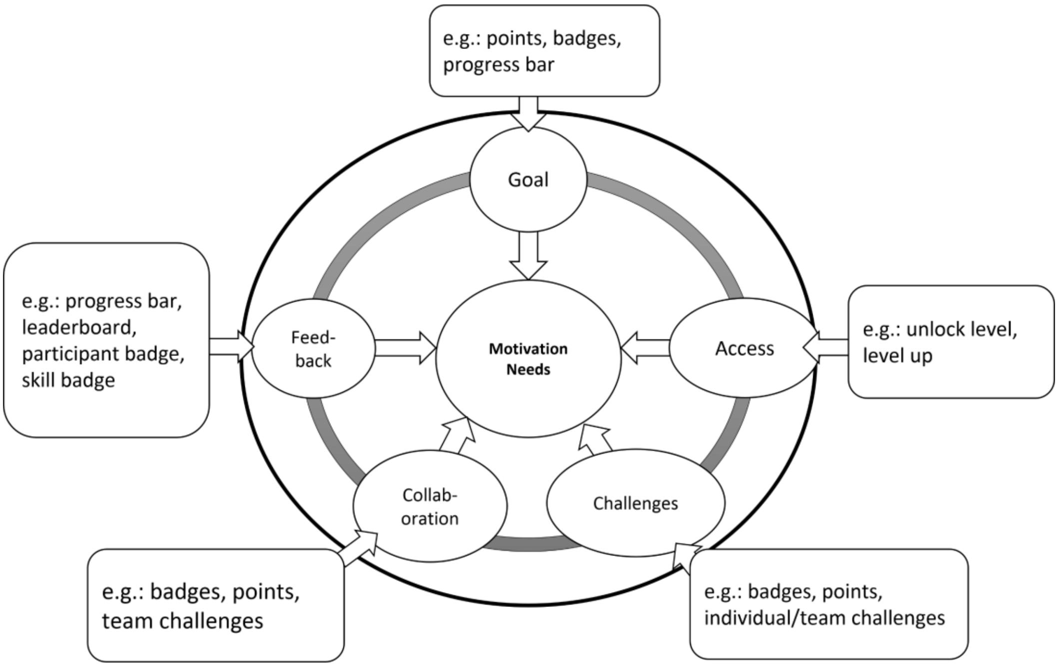

Figure 1. GAFCC Gamification Design Model – Motivation needs, motivating elements, and enablers (game design elements) [2]

forms of games focused on the different ways to present rewards to user.

As the name specifies, content gamification alters the content of the game to be game-like by integrating elements such as challenges, feedback loops, and storytelling. These elements did not actually turn the training into a game. With content gamification, elaborate game does not have to be developed but the content is emphasized in the learning or training process. Therefore, this technique enhances user's engagement with the material.

Gamification has been positively studied for rehabilitation due to its ability to support learning. Joo et al. [15] stated that researchers are pushing interactive gaming for rehabilitation with the purpose of making training fun and contextual. Tuah et al. [16] identified the current implementation of gamification trends in rehabilitation. According to the study, one of the themes of gamification is the outcomes of using the applications. In the study by Tuah, the purpose of gamification implementation and the expected results of the evaluation study are the identifiers of the outcomes. One of the outcome categories is "motivation for, and engagement in, the care". The authors added that adaptation of gamification in rehabilitation could motivate individuals by providing pleasant and engaging environment during rehabilitation. Furthermore, the authors stated that the primary rationale for the gamification of a physiotherapy process is due to the nature of the treatment and care which may be simulated straightforwardly in gamification.

Preliminary studies by [17] also indicated the potential of VR as a tool for physical rehabilitation. Sveistrup et al. [18] then further proved that VR provides a unique medium that achieves the requirements for effective rehabilitation intervention. According to the studies, VR application can provide therapy within a functional, purposeful, and motivating context. Bohil et al. [19] add that VR simulations can be highly engaging, providing crucial motivation for rehabilitative applications requiring consistent, repetitive practice. Combined with the aspect of gamification that allows fun and contextual training, the application of rehabilitation with gamification in VR may encourage motivation and rehabilitation due to its interactivity.

B. Feedback

Involvement from user in receiving and providing feedback to the system is important for the engagement of user with the rehabilitation system. Through engagement, users will have better connection to their emotional commitment [6]. In return, user will have a motive to be motivated in participating in the rehabilitation. Pedersen [20] defined sensory feedback as the generic term for the stimulus human receive in the body and make the brain aware of the body. According to the author, human use and need those stimuli to ensure the brain can register and perceive the body. Fujii, Lulic, and Chen [21] stated that motor learning is process to acquire new skills with practice, and it can be influenced by the feedback provided.

In a study by Winstein [22], feedback is a term to describe sensory information that is available during or after an action. It includes the information of the sensations associated with the movement such as feel and sound. Besides, feedback contains the information related to the result of an action relative to the environmental goal. The author added that there are two sources of feedbacks which are intrinsic and extrinsic.

Intrinsic feedback is fundamental to the action and includes sensory feedbacks. The sensory feedback includes kinesthetics, visual, cutaneous, vestibular, and auditory signals which are collectively termed as "response-produced feedback". According to the author, these normal sources of feedback may be absent or damaged in patient with certain disabilities.

On the contrary, extrinsic feedback is the information supplied from an external source and is supplemental to intrinsic feedback sources. The ability to provide extrinsic feedback to its user is another key aspect of therapy in VR[20]. Extrinsic feedback can be verbal or nonverbal as stated by Winstein and can be channeled through any means

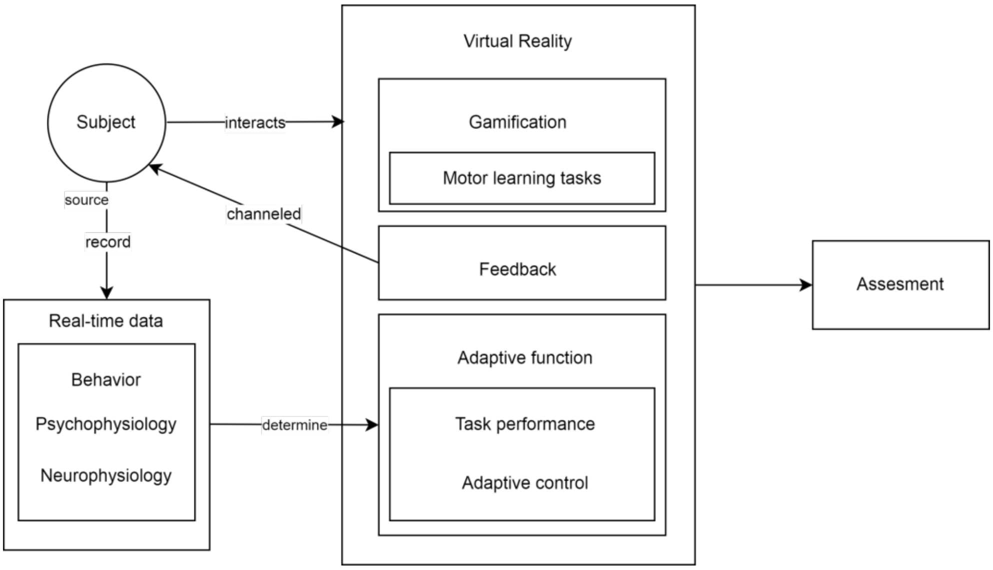

Figure 2. Summary of relationship among gamification, sensory feedback, and adaptive function in VR rehabilitation

such as auditory, visual, or haptic. Based on the theoretical framework by Teo et al., there is no definite guidelines as to how and what types of information should be provided by extrinsic feedback. However, Winstein stated that extrinsic feedback can be provided concurrently, immediately following, or delayed in time with respect to the applicable action.

The role of feedback on engagement in stroke patient rehabilitation can also be observed in the study by Nithianantharajah and Hannan [23] where enriched VR enhanced with increased sensory stimulation and specific motor training improve engagement. Another study that shows the added value of feedback on motivation and engagement is from [24] whereby informational sensory cues has been found to enhance the overall user experience and sense of presence which also indicates engagement.

C. Adaptive function

A feature of VR is its ability to alter aspects of a virtual environment (VE) in real-time to create personalized experiences to suit individual users through adaptive functions [25]. Real-time model of the user is created through the monitoring of behavior, psychophysiology, and neurophysiology data of the user. The study by [26] adopted adaptive function in a rehabilitative training that is adapted to the capabilities of stroke patients. In the study, the difficulty of tasks depends on the performance of the user and is always adaptable to the individual performance of the user. The findings of the study suggest an induced sustained improvement during treatment paired with benefits in the performance of daily activities. Besides the varying the difficulty of tasks through the outcome of performance, VR is also capable to execute adaptive control to assist in rehabilitation. The effectiveness of adaptive control can also be observed in the study by [24] whereby there is an improvement to the participant's rehabilitation result after undergoing robot assisted training in VR environment.

D. Relationship of the Concepts

Based on the literature review of the three concepts i.e. gamification, sensory feedback, and adaptive function, a summary of relationship among them could be drawn. Figure 2 depicts such a relationship. The figure indicates that the three concepts are the influencing factors (input) to motivate and engage a subject (stroke patient) in the rehabilitation process. The subject's performance is captured in the assessment (output).

The concept of gamification, sensory feedback, and adaptive function are applicable in the realm of virtual reality. Subject interacts with VR that has the element of gamification of the motor learning tasks for rehabilitation. Feedbacks are channeled to the subject through VR devices to the subject during the interaction. Adaptive function is applicable in virtual reality through the influence of the gamification element. Personalized experience such as difficulty can be adapted to subject by performance such as points, level, scores, and other rewards system as illustrated in figure 1.

Concurrently, real-time data of subject while interacting with the VR rehabilitation application can be recorded for assessment as well as to determine the adaptive function for each subject. Information such as behavior and physiological data can be recorded in real-time in determining the tasks, difficulties, or level of assistance that is suitable to subject's capability.

Finally, the assessment of subject's performance after undergoing rehabilitation in VR can be assessed by appropriate outcome measures.

III. APPLICATION OF CONCEPTS FOR MOTIVATION & ENGAGEMENT

The application of the concepts on gamification, sensory feedback, and adaptive function were observed in three studies [5, 6, 27] as a preliminary study. These four studies are selected as each study discussed on the design principles of VR rehabilitation in stroke that utilizes gamification techniques to optimize motivation and engagement.

From the studies, we observed that visual feedback is mostly used in VR rehabilitation applications. These studies explored on different representation of multimedia in the virtual environment (VE) such as dynamic background in the study by [6] to encourage fun therefore motivate users to play more. In Ahmad et al. [5], instructions and images in the VE are labelled with guided text to ensure direct and clear instructions for elderly user.

An important element of gamification is reward. In these studies, rewards are presented to users as multisensory feedback as opposed to only visual feedback. Besides displaying points graphically, Burke et al. has integrated audio feedback as an alert when user scores a point or has successfully completed a level in the VR rehabilitation game. Audio feedback is also used by Elor et al. to indicate achievement when user reached the goals for accumulated points. Furthermore, as Elor et al. has utilize haptic feedback to the handheld controller in addition to visual and audio feedback to indicate when user has successfully scored a point.

The VR application of the three studies have the aspect of adaptive function as a part of their gamification of rehabilitation. The studies apply the concept of "levels" to increase difficulty based on the improvement and achievements of the user. Other elements of gamification, Burke et al. [27] used a webcam to track the position of users thus dynamically position the game elements to be reachable to the user. As the game progresses, depending on the performance of the user, challenges in the game are adapted dynamically by changing the pace, positions, and size of the game element.

The observation on the small sample of existing studies, shows that multisensory feedback is much underutilized in VR rehabilitation. Visual feedback is mandatory since the majority of interface and interaction is displayed graphically to users. However, visual feedback alone can cause the rehabilitation session to be too quiet and boring. The addition of background noises, for example, background sounds or music might increase engagement.

Unfortunately, the analysis showed that while auditory feedback complements visual feedbacks, it is mostly optional in VR rehabilitation. Auditory feedback is often used to indicate success or failure in completing tasks in these games. It is rarely used to relay information to user. In the virtual environment, instructions are visually displayed through text. While guided text and labels implemented by [5] are useful, elderly users or cognitively impaired users with limited eyesight or limited ability to read can benefit more from audio narration.

The use of haptic feedback is the least popular as observed from the studies. Mostly because not all VR games needs controller to navigate around the system in which feedbacks can be given to user through vibration. The use of other haptic devices in in VR also might not be as popular in stroke rehabilitation since it might be expensive to be purchased by individuals or organizations. Furthermore, bulky and heavy haptic devices may be uncomfortable or hindering to users thus decreasing the motivation to continue with rehabilitation.

The current practice of VR rehabilitation still relies majorly on visual feedback as the main interaction channel between system and human. Feedbacks such as audio and haptic are less popular and utilized although beneficial to the enhancement of engagement and motivation for stoke patients to undergo rehabilitation.

IV. Moving Forward

Based on the findings of literature and existing studies, this work proposes an integration of gamification, multisensory feedback, and adaptive function to encourage motivation and engagement of stroke rehabilitation via VR.

Our future study will be addressing the issue which relates to the representation of feedback through different sensory feedbacks. The aim is to discover the added value of multisensory feedback (audio, haptic, visual) on the motivation and engagement of stroke patients while undergoing rehabilitation with VR. For this objective we would like to know whether applying different sensory feedbacks will produce superior at enhancing motivation and engagement than the usual visual only representation. As the research aim is to gain information on the multisensory feedbacks in virtual reality and the added value it imposes on the motivation and engagement of rehabilitation, we have come up a hypothesis to support future work.

- Hypothesis: multisensory feedback brings better engagement and task performance

The interaction in VR involving gamification, multisensory feedback, and adaptive function based on the summary of concepts as shown in figure 2 will be applied in this study. It will be based on the mirror neuron theory in using the potential of VR technologies in rehabilitation. The mirror neuron theory supports similar cerebral activations of neurons in motor cortex in the execution of voluntary movement as well as during the sensorial perception of the same movement through observation, hearing, and haptic sense [28, 29]. In this approach, the mirror is replaced by the representation of virtual avatar in an immersive VR experience, in which participant will have to perform motor learning tasks.

The concept of structural gamification can be applied to add gaming elements to the rehabilitation program. Possible application of structural gamification in this study includes element of rewards which will be awarded to user for successfully performing motor learning tasks, for example allowing user to level up where tasks can become more challenging. Other possible application of the gamification technique is by implementing the content gamification in which the motor learning tasks are altered into game-like activities.

Due to stroke, user might have some difficulties in moving while undergoing the rehabilitation. An adaptive function is proposed here to compensate the potential limitations of subjects in movement. The aim of the adaptive function is to act as an amplifier of the user's movement in VR environment to maintain motivation and engagement of the patient and improve the benefit of mirror neurons activation. A potential application of adaptive function to motivate and engage user is through non-linear mapping in of movement of user and movement of avatar in VR.This method has the potential of motivating rehabilitation for patients with little to no range of movement into thinking they are capable to do more extension of their limb by through interactively growing extension of user's arm and non-linear mapping for reaching and manipulating objects in a distance.

V. Conclusion and Future Work

Rewards element is known as the main element in the feedback component of the GAFCC Gamification Design Model. Studies rarely discuss on the importance of different types of sensory feedback and its effect on motivation and engagement while using VR. One study discussed the superiority of implementing multiple sensory feedbacks to motivate users in VR; however, it is tested against the normal sample. Therefore, we are interested to conduct a similar study to investigate the design of different and multiple sensory feedbacks on motivation and engagement in rehabilitation for stroke patients.

A literature review was conducted on topics pertaining gamification, sensory feedback, and adaptive function on the motivation and engagement on stroke rehabilitation via VR. From the study, it is shown that gamification either alter the content of learning into games or applies gaming elements to motivate tasks completion. Gamification has also been found to be effective in the rehabilitation field due to its ability to support learning by providing pleasant and engaging environment during rehabilitation. Due to its interactivity, gamification in VR may also encourage motivation and engagement for rehabilitation. Interactivity is only made possible with feedback. The key aspect to VR is its ability to provide and receive feedback to and from user through different channels. In short, there are two types of feedbacks: intrinsic feedback and extrinsic feedback. Studies on role of feedback on engagement in stroke patients have shown that enriched VR with increased sensory simulation improve engagement. Besides, informational cues have been shown to enhance stroke patient's overall user experience and sense of presence. Rehabilitation in VR with gamification techniques with supplementary feedback allows adaptivity of function in the application. There are two ways adaptive function can be adopted into a rehabilitation application. Firstly, using the data of user's task performance to increase or decrease difficulty. Secondly, executing adaptive control to assist in rehabilitation by aiding movement virtually or physically with robot assistance.

A small investigation was made on three studies that discussed the design of rehabilitation in VR. The implementation of multisensory feedback is present in the virtual environment and gameplay of the VR rehabilitation games. However, most interactions and multimedia presentation were presented graphically through visual feedback. Although audio and haptic feedback are proven to encourage motivation and engagement, these feedbacks remain understudied.

With all the potential the three elements have in encouraging motivation and engagement of stroke rehabilitation via VR, research is proposed to address the issue pertaining the implementation of sensory feedbacks on stroke patients. The objective is to discover the added value of multisensory feedback (audio, haptic, visual) on the motivation and engagement of stroke patients while undergoing rehabilitation in VR. In the future, studies will be conducted to answer the objective and test the formulated hypothesis.

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