Application of a rehabilitation game model to assistive technology design

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ABSTRACT

Games are increasingly used by physiotherapists in rehabilitation and the gamification of rehabilitation processes is an increasingly common practice. A key motivation for injecting playful or gameful activities into rehabilitation is to enhance engagement for home rehabilitation exercises by making them more fun. Multi-disciplinary cooperation is important in designing gameful activities. However, system design and development can be challenging between software engineers, health professionals, and academics due to terminology and knowledge differences. Sometimes skill and knowledge levels are also not optimal within the team. In both cases a comprehensive Rehabilitation Game Model (RGM) built on established principles, with an associated tool, can facilitate an effective design process. Factors that can be missed without use of a structured process include the potential impact of symptoms and variation in user demographic, personality or interaction preference. Our RGM helps game designers put a greater focus on variations between people in designing rehabilitation games. In this paper we provide an overview of the RGM and extend it to include rehabilitation aspects. We apply it to upper arm stroke rehabilitation. We present a representation of the output from the RGM that can form the basis for advice and guidance to serious game designers of upper arm stroke rehabilitation games.

1. INTRODUCTION

The creation of serious games for use in assistive technologies is becoming increasingly popular. Physiotherapy is particularly applicable to games and gamification since physical rehabilitation programmes can potentially be mundane, are often challenging, and require adherence to prescribed schedules. Gamification is the application of game-design elements and game principles in non-game contexts (Deterding et al, 2011) so as to improve processes and systems in relation to a broad range of contexts such as user engagement, organizational productivity, learning, motivating behaviour changes, as well as attitudes to diet and physical exercise. Recently, gamification has been used in rehabilitation to help people become more engaged in their rehabilitation (Szaniawski et al, 2015), and to encourage them to complete their exercises more regularly and consistently. Gamification can embed principles of psychology in the form of reinforcement of positive behaviours and rewards mechanisms to improve adherence through motivational techniques. Games and virtual reality (VR) can be used to add fun to the process through structuring the exercises in entertaining contexts and embedded gamification features. To have an effective rehabilitation game, the game design needs to be adapted to the type of exercise and also to the people who will play it. Designing and creating effective assistive technologies can be difficult and time consuming due to the complexity of rehabilitation requirements. Development of games and VR rehabilitation systems is especially challenging as it adds another dimension to the expertise required of the multidisciplinary team; requiring knowledge of game design, game asset creation, technical game development skills, software engineering, physiotherapy and end user experience. This is a challenging process, even for experienced designers, and so we have developed the Rehabilitation Game Model (RGM) (Holmes et al., 2015) to guide the process.

1.1 The Rehabilitation Game Model (RGM)

Having a structured tool that aids the creation and evaluation of personalised games is important for communication between non-professionals and professionals across multiple disciplines during the design and development process. Facilitating the collaboration between disciplines as early as possible helps focus efforts

on games that accounts for personality- rehabilitation guidelines and exercises- as user gaming preferences to encourage enjoyment. Thus allowing all parties to clearly understand and quickly define a personalised game idea ready for development.

The RGM guides the design and implementation of effective rehabilitation games and consists of mappings three core aspects (Fig 1): a gamification typology, a comprehensive set of game design patterns, and core behaviour change techniques from psychology. The RGM is applied to a rehabilitation context such as upper arm stroke rehabilitation. A gamification typology (such as Marczewski, 2015b) takes into account variation between types of people and the ways that they may be motivated. In the RGM, gamification types are based on Marczewski's (2015a) Hexad. The Hexad gamification types are in part based on well-known player types (e.g. Bartle, 2013), and in part on other psychological personality models including Self-Determination Theory. In our application of the RGM these are mapped to a set of game design patterns by Bjork & Holopainen (2004) containing 300 game mechanics that can be used in a number of combinations to design novel gameplay suited to Marczewski's Hexad gamification types. Behaviour change techniques (Michie et al, 2014) are also integrated and mapped against the game mechanics in order to shape behaviour and help tailor games to encourage improved adherence to exercise. The six Hexad gamification user types are:

1. *Disruptor*–motivated by change they want to disrupt the system directly or through others with a positive or negative outcome.
2. *Free Spirit*–motivated by autonomy they want to explore, be creative and have choices.
3. *Achiever*–motivated by mastery they are all about self-improvement and like to be challenged in order to better themselves.
4. *Player*–motivated by rewards they are selfish and do what is necessary to win or be better than others.
5. *Socializer*–motivated by relatedness they want to create a social connection with others.
6. *Philanthropist*–motivated by purpose they need a purpose for interacting and are also altruistic towards others.

Figure 1 provides an operational illustration of the RGM, integrating the well-known MDA (mechanics, dynamics, aesthetics) model of a game. The core component is the **game** and respective game mechanics are constructed from fundamental game design patterns. A model of **player** motivation is embedded using gamification types (in this instance Hexad types). Player behaviour is modelled using **COM-B** (Michie et al, 2014) (Capability, Opportunity, Motivation for Behaviour change) and in particular key behaviour change techniques which are mapped to a particular group of game mechanics and thus player type (see colour coding). Player interactions on the game mechanics (Dynamics) result in a change of game state and the provision of feedback to the player. Feedback to the player can be visual, auditory, or haptic and is central to the user experience (Aesthetics). Game mechanics can promote certain behaviour changes according to the challenges brought about by the particular player type's interactions on the games mechanics. For example, Achievers may want to fight (interact) against a boss monster (game mechanic) to test their learnt skills and knowledge, giving a sense of progression when achieving this high level goal (feedback, behaviour technique (Goal setting) & aesthetics).

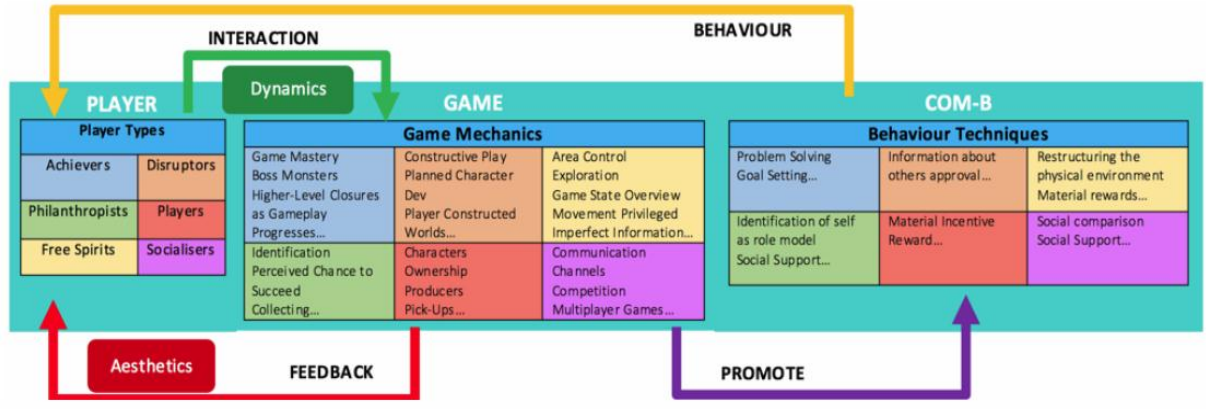

Figure 1. *The Rehabilitation Game Model (RGM) has three core aspects player motivational type, game design patterns, and user behaviour types.*

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2. APPLICATION OF THE RGM TO UPPER ARM STROKE REHABILITATION

Our RGM and initial online prototype tool was constructed over a six-month period and links core game mechanics from around three hundred game design patterns to core gamification types. An appropriately designed tool can embed much of the multi-disciplinary expert knowledge, logical processing and decision making required to support a less experienced team to make good design decisions. In this way rehabilitation games may be created that are more usable, user friendly, functional and fun, thus ensuring patients who will use it will be more motivated and more inclined to engage in regular, high quality rehabilitation. Our system extends the RGM to enable clinicians to input data and tailor system parameters based on patient requirements. This input is essential to establishing patient motivations and specific game mechanics, narrowing game ideas towards rehabilitation. For example, side effects or comorbidities that the game designer needs to take into account to create effective games for a given population and health condition. As well as the specific rehabilitation requirements, demographics factors such as age, gender and culture are also taken into account. In this way we can use available statistical population information to guide design guidance outcome from the tool.

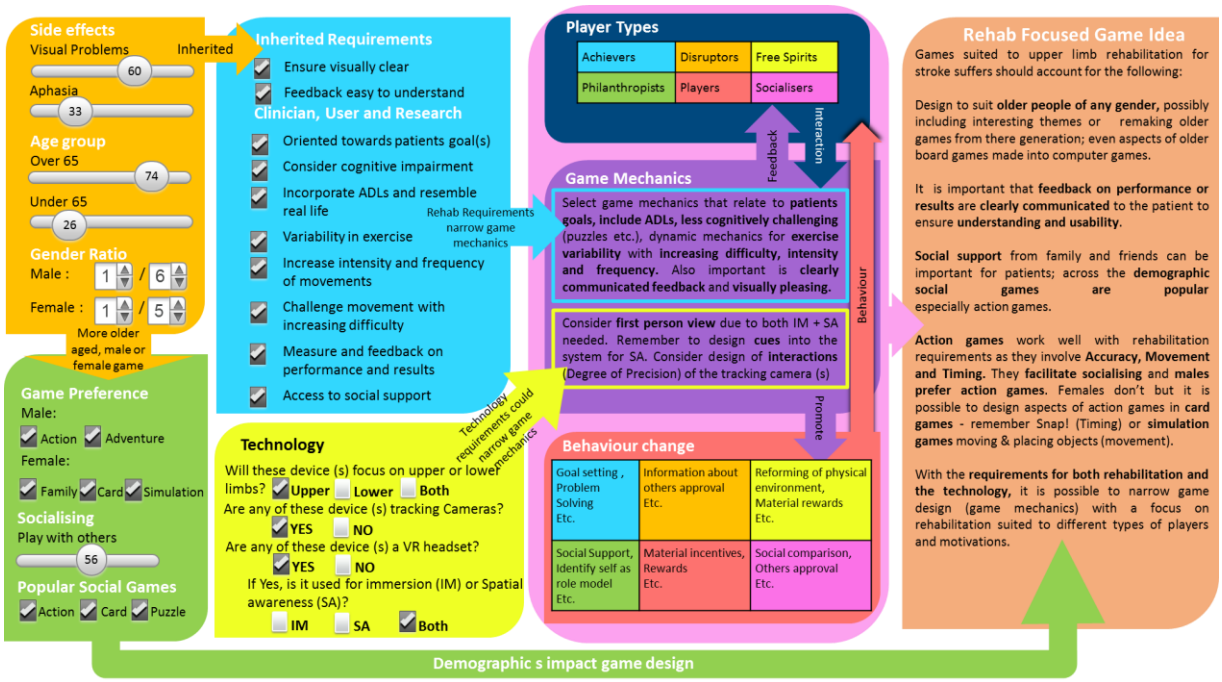

Figure 3: *Application of the Rehabilitation Game Model (RGM) to create an adapted serious game for upper limb stroke physical therapy.*

2.1 RGM Applied to Upper Limb Stroke Rehabilitation

The process proceeds as follows and may be implemented with an online tool or offline with guidance documentation:

1. *Key side effects following a stroke are identified*: For stroke we may consider ataxia, visual problems, spasticity, focus, thinking problems and aphasia. For example, aphasia is a communication disorder that results from damage or injury to language parts of the brain. Aphasia gets in the way of a person's ability to use or understand words (Lava 2014). These side effects create new requirements from upper limb rehabilitation.
2. *Stroke demographics are specified*: Statistics of people who have suffered a stroke, as well as age and gender. For example, typically people afflicted by a stroke tend to be from the older population and that there are almost identical numbers of men and women (Stroke Association 2016).
3. *Gamer demographics are identified*: Statistics of game players and how they might relate to the *stroke demographic* can influence the design of the game. For example the gender ratio from figure 3 shows little difference between the amount male and female stroke suffers, meaning that consideration needs to be taken to create game for both genders.

4. *Rehabilitation requirements*: Inherited requirements from the key side effects and requirement of clinicians, users and literature help refine the game mechanics from our RGM that are suitable for rehabilitation games.
5. *Technology requirements:* Different types of technology can produce different requirements to meet particular objectives in rehabilitation. It is important to remember these requirements just like rehabilitation requirements can influence game mechanics.
6. *Rehabilitation Focused Game Idea*: With all the requirements considered, the refinement of game mechanics narrow the amount of game design ideas possible allowing designers to create suitable games for upper limb rehabilitation. This gives clearer identification of player types and the typical behaviours that motivate the patients to keep playing. Game demographics should also be considered at this stage as it could impact the game design. The game genre "action" along with the socialising statistics, impact design because it relates greatly towards the rehabilitation requirements.

3. CONCLUSION

In this paper we have outlined our Rehabilitation Game Model and provided an illustration of its application to stroke rehabilitation. From this illustration, we can see a paper based or online tool embedding the RGM can aid the design process and safeguard against designer play preference or experience bias. It encourages the designer not to just consider the core physiotherapy requirements based on an average patient but take in consideration a wide range of factors and demographics. The approach supports experts (and non-experts) with different background to work effectively on the same rehabilitation game project, reducing project risks related to difficulty in communication. We are currently using this RGM online tool to design upper arm rehabilitation games for stroke survivors. This will enable us to evaluate the approach more fully. It is also our intention to develop the tool further to produce more detailed and rehabilitation focused game ideas, so that it can be made available online for other designers.

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