# Design Considerations in Therapeutic Exergaming

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*Abstract*— **In this paper we discuss the importance of feedback in therapeutic exergaming. It is widely believed that exergaming benefits the patient in terms of encouraging adherence and boosting the patient's confidence of correct execution and feedback is essential in achieving these. However, feedback and in particular visual feedback, may also have potential negative effects on the quality of the exercise. We describe in this paper a prototype single-sensor therapeutic exergame that we have developed and provide some preliminary user feedback regarding enjoyment and perceived competence when using the exergame compared to exercising without the exergame. Our results indicate that all participants found exercising with the game more enjoyable. However, additional work is needed to increase participants' confidence in their correct execution of the exercise.**

***Keywords- therapeutic exergaming; visual feedback; design requirements; sensors***

## I. INTRODUCTION

Much research into rehabilitation through technology stresses the importance of feedback to motivate the rehabilitation process [1], [2], through increasing a patient's enjoyment of the task and their sense of confidence in their ability to carry out their exercises correctly. There is much less discussion on the potential negative effects such engaging feedback might have on the quality of the exercise being performed. While increasing adherence is crucial, an equally important topic is whether such technology can ensure maintenance of correct technique when exercising. If a patient is not executing their exercise accurately they may not gain the full benefit of the exercise. With certain complex exercises, inaccuracy can potentially cause further injury. However, therapeutic exergames have the potential to provide feedback on accuracy, allowing the patient to adjust their movements to the correct position during rehabilitation, without the need for a physiotherapist to be present.

Given this importance of feedback, a significant challenge in designing therapeutic exergames is how to integrate feedback that both fosters intrinsic motivation and provides objective feedback regarding accuracy, without cognitively overloading the patient. External stimuli can have a significant effect on motor function. Visual overload may focus the patient's attention on the screen, rather than on the exercise itself, potentially decreasing accuracy and thus limiting physical benefit. However, to date there is comparatively little empirical research in this field and thus the relationship between the sensory and motor systems is not well understood. With our research, we are beginning to address this issue by evaluating the effects of different levels of visual feedback on the performance of rehabilitation tasks within therapeutic exergaming applications, in addition to assessing patients' intrinsic motivation to exercise under different levels of feedback. Thus we began with the simplest, most basic level of on-screen feedback as a first stage of a series of planned experiments to evaluate the above questions, with the premise of adding additional feedback as required, whilst evaluating that the newly added feedback did not negatively affect exercise accuracy.

In this paper, we evaluate whether this simple, on-screen visual feedback within an exergaming environment can increase a person's motivation to exercise by enhancing their enjoyment and perceived competence. We present preliminary results which indicate that while an exergaming environment is more enjoyable than exercising without feedback, or with a simple video demonstration, more research into different types of feedback is necessary to further increase a person's perceived competence.

## II. RELATED WORK

While there exists a body of research on the potential physical and health benefits of exergames, as well as some research on their design, comparatively little research addresses the issue of the effects of feedback on exergaming, particularly on the accuracy of performing a rehabilitation motor task. Approaches to exergaming can be broadly split into two categories - those that aim to promote physical activity and those that are designed for rehabilitation purposes. Included in the former group are exergames that aim to tackle obesity in children for example, by combining a passion for video games with exercise. In such cases, it is physical movement that is the main goal, and such exergames typically integrate feedback to motivate physical exercise [3], [4]. Nintendo's Wii, and more recently Microsoft Kinect are probably the best known commercial exergaming technologies, and an example of those that encourage physical activity through gaming. Therapeutic exergaming typically addresses physical rehabilitation or motor control training through the use of

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video game play [5]. Some applications include recovery following stroke, muscle injury rehabilitation and balance training [6], [7].
'Play, Mate!' is a design that aims to reduce sedentary activity in game play in children by introducing motivators to perform physical activity while playing [4]. In a controlled experiment with 180 children playing the Neverball game integrating the Play, Mate! design and wearing activity monitors, one group was provided with a direct motivator to perform jumps during game play so as to increase the number of coins they collected and the amount of time they had to finish the level. Only 76.01% of this group's game playtime was sedentary, compared to 96.75% in the control group who didn't have a motivator. Furthermore, there were no negative effects on perceived enjoyment reported in the group who had to perform physical activity.

Whether an exergame is designed for rehabilitation purposes or simply as a fun way to promote physical activity, design considerations are similar. Sinclair et al [3] outline some considerations for designing exergames, focusing on 2 desired outcomes of exergame technology - attractiveness to players and effectiveness as an exercise. They state feedback should be unambiguous so that the player's behaviour can be adjusted as needed. Sweetser & Wyeth describe a model for evaluating player enjoyment in games [8]. The authors outline 8 elements for achieving enjoyment in games: concentration, challenge, skills, control, clear goals, feedback, immersion and social interaction. Consolvo et al [9] identified 4 key design requirements for technologies that encourage physical activity - give users proper credit for activities; provide personal awareness of activity level; support social influence; consider the practical constraints of users' lifestyles. Maitland & Siek stress the importance of explicit value as feedback in encouraging physical activity in a low-income population [10]. Jung et al highlight two advantages of integrating virtual reality technology into stroke rehabilitation - interactive video and audio feedback motivate stroke patients and therapists have the ability to manipulate and tailor treatment sessions to each individual patient and to increase task complexity as appropriate [11].

Much of the design guidelines/requirements for feedback in exergames simply state that players should receive appropriate feedback at appropriate times [8]. Appropriate is generally understood to mean direct and immediate [3]. When exergames are used to promote physical activity, the main goal is for games to be fun, engaging, attractive and challenging. Such games do not typically address the accuracy of the exercise. Usually the motor task/exercise itself is secondary to the game, in which the participant is typically fully immersed, requiring a certain amount of cognitive processing on the part of the person playing the game. Thus, for therapeutic exergaming an additional design requirement is ensuring that visual feedback assists the patient in maintaining correct exercise technique.

There have been a number of studies on the effects of visual feedback on the performance of motor tasks, though not necessarily within exergames. It has been observed that visual feedback is critical in movement rehabilitation and motor skill learning [12]. A study conducted by Hou et al. demonstrated a correlation between visual feedback and motor skill by showing that increased visual feedback can improve a person's regulation of force production [13]. Similarly, Prodoehl & Vaillancourt showed that increases in visual gain led to improvements in the steadiness of force output at both the elbow and the ankle [14]. As such, there exists evidence that visual feedback helps people to adjust their movements in a force production task.

A study carried out by O'Huiginn et al. to investigate the training effect of an exergaming system compared to a conventional exercise training approach over a four-week period, found similar effects in terms of physical function with both methods [5]. However, reported levels of interest and enjoyment were significantly higher within the exergaming group, which is an encouraging result in terms of motivation to adhere to a rehabilitation programme. A study by Fitzgerald et al. aimed to compare exergaming and conventional approaches to wobble board postural stability training [15]. They found similar clinical improvements in the exergaming group to the conventional group, with a greater self-reported level of interest and enjoyment when using the exergaming system.

Viau et al. conducted a study comparing movements made to virtual objects in a virtual environment with movements made to real objects in real environments [16]. They found no differences in movement characteristics between both environments, suggesting that VR and reality provide similar, effective, training environments. However, a similar study did find significant differences in reach performances when performed in a VR environment compared to a real environment [17]. When reaching for objects in the VR environment, both young and old adults reached significantly further than in reality. The authors suggest that within the VR environment, participants' focus was drawn away from the potential for losing balance. In one way, this can have negative effects as if balance is lost, injury can occur. However, the authors also note that on the other hand, participants may have had an increased fear of losing balance in the real environment, resulting in an underestimation of their ability. Thus finding the correct balance to ensure rehabilitation is effective is crucial.

Thus, as is evident from the literature, feedback is an essential component of exergaming and has many purposes, such as to be fun, challenging, motivating, informative etc. However, where the literature is still lacking is how best to design feedback for *therapeutic* exergaming, where additional feedback parameters, such as accuracy of movement, are likely required, but where caution is needed so as not to detract focus from the primary, physical task. In the remainder of the paper we describe our research in this field and how we are making steps towards identifying solutions to this issue.

## III. The Exergaming Application

The system we are designing has three main patient-focused goals:

1. To assist the patient in carrying out their rehabilitation programme accurately.
2. To increase the patient's motivation to adhere to the exercise programme, by making the exercise task enjoyable.
3. To increase the patient's sense of competency in correct completion of their exercise programme.

With regard to other design elements, the system eliminates the need for direct supervision by providing real-time feedback to the patient on their accuracy as they exercise. The application has both physiotherapist and patient interfaces, presented on a laptop. An iPhone strapped to the body acts as the single sensor input to the game. The 3-axis accelerometer in the iPhone is used the measure the angle of the phone with respect to gravity.

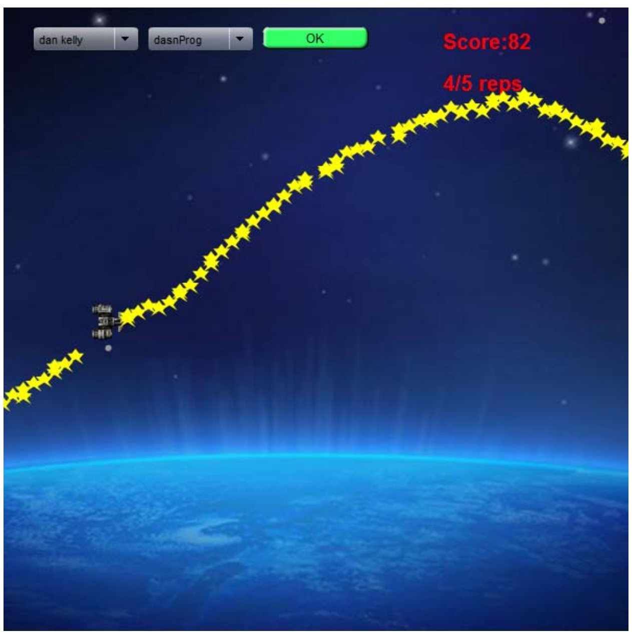


**Fig. 1. The game used in the study required the user to maintain a spaceship on the correct path with their movement. The shape of the path is determined by the user's baseline repetition of the exercise**

The premise behind the game used in our study is that the patient is presented with a moving spaceship on screen, which they control with their body movement (Figure 1). The patient's goal is to move the spaceship along a certain trajectory, which represents their baseline exercise recorded under clinical supervision, so that it follows a sequence of stars. If the patient's movement is in line with their baseline movement, the spaceship clears the stars. If the patient makes an incorrect movement, such as not maintaining a regular pace or not achieving the correct angle of movement, one or more stars will not be cleared. This prompts the patient to correct their movement, to return the spaceship to its correct trajectory. At the end of the exercise session, the user receives an accuracy score as a percentage. Thus, in addition to real time feedback to support technique correction, the game aims to provide a level of increased enjoyment over exercising alone, in addition to promoting a sense of increased confidence that the user is performing the exercise correctly. Movement data is uploaded to a remote server once the user's exercise session is complete. This data can then be viewed by the physiotherapist.

## IV. User Feedback

In this section we focus on feedback from users of the game who participated in a study to determine the effects of exergaming on enjoyment and perceived competence under three different conditions:

1. **Control** – no feedback.
2. **Video** – limited feedback in the form of a demonstration video shown prior to the participant performing their exercise task.
3. **Exergame** – visual feedback (i.e. the exergame) which provides real time feedback on the participant's accuracy in performing the task.

A total of 8 healthy participants (3F, 5M; mean age 28) took part in the study. The experiment took place over two days in a research laboratory. Day one involved a training session with a physiotherapist and the recording of the participant's baseline data under supervision. On day two, participants returned and repeated the exercise they were taught under the three conditions outlined above.

Study equipment/apparatus consisted of a single iPhone 3GS attached to the participant's thigh and a laptop providing visual feedback. A double leg squat exercise was chosen as the test motor task in this study as it is a relatively simple exercise yet one that is frequently performed incorrectly in terms of depth of squat and rhythm of repetitions. After each condition, participants answered the Interest/Enjoyment and Perceived Competence subscales from the Intrinsic Motivation Inventory. We also measured exercise accuracy in each condition (as compared to the participant's baseline exercise). There was a significant difference observed across the three conditions, with participants performing significantly more accurately under the Exergame condition. Further detail on these results can be found elsewhere [18]. In this section we present participant feedback in terms of Interest/Enjoyment and Perceived Competence.

### *A. Interest/Enjoyment*

Looking at Figure 2 below we observe the following:

- All 8 participants scored higher in the Exergame condition than in the Control condition. Thus all 8 participants found the game more interesting or enjoyable than exercising without feedback. Results of a paired 2 samples t-test reveal this is a significant result (p=0.001, df=7).

- 7 participants scored higher in the Exergame condition than in the Video condition. 1 participant scored the same. Results of a paired 2 samples t-test reveal this is a significant result (p=0.009, df=7).
- 5 participants scored higher in the Video condition than in the Control condition; 1 participant scored them the same. Results of a paired 2 samples t-test reveal no significant difference (p=0.08, df=7).

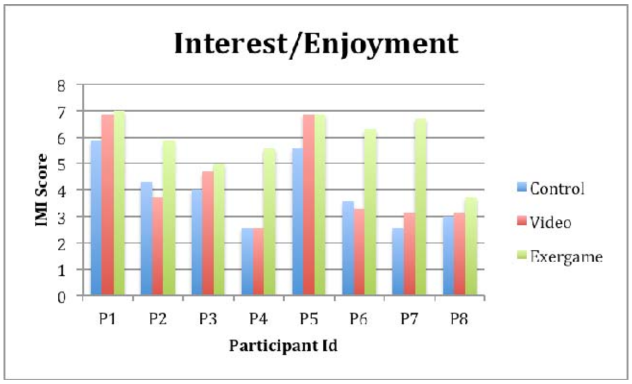


**Fig. 2. Participant scores for the interest/enjoyment subscale of the Intrinsic Motivation Inventory, across the three experimental conditions**

### *B. Perceived Competence*

Looking at Figure 3 below we observe the following:

- Only 4 participants scored higher in the Exergaming condition than the Control condition. That is, half of the participants felt more competent at performing the task without the game. While this result is not significant (p=0.25, df=7), it is of some concern.
- Only 3 participants scored higher in the Exergame condition than in the Video condition; 1 participant scored the same. This result is not significant (p=0.03, df=7).
- 6 participants scored higher in the Video condition than in the Control condition. This result is not significant (p=0.17, df=7).

While the perceived competence results are not significant they require consideration. When the exercise session is complete, participants are provided with an on-screen score based on their accuracy. We had felt that this combined with the on-screen feedback on accuracy, would help to increase participants' perceived competence. Indeed, results of previous usability testing during the design process of the game had indicated that the game was easily understood and easy to follow along with. We had not examined perceived competence at that time, however, nor had we examined exercising under different feedback conditions. The results as seen in Figure 3 suggest that participants felt most competent at exercising under the Video condition. Post-task interviews with these participants suggest that they found that the game somewhat distracted them from concentrating on the exercise technique that the physiotherapist had taught them the previous day.

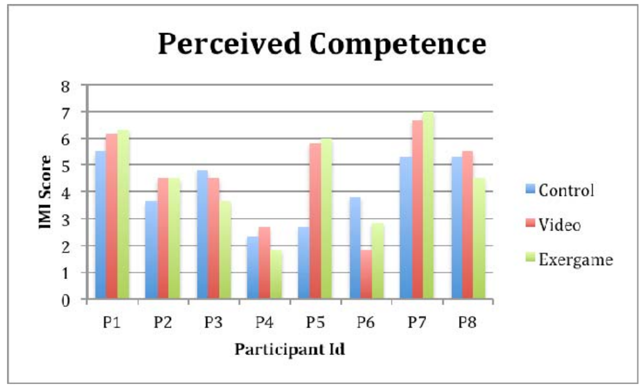


**Fig. 3. Participant scores for the perceived competence subscale of the Intrinsic Motivation Inventory, across the three experimental conditions**

## V. DISCUSSION

The research we have conducted to date, alongside related work in the field, confirms that therapeutic exergaming systems are useful in training situations; they can support the maintenance of quality of exercise and have potential to promote adherence due to supporting increasing levels of intrinsic motivation. However, a number of requirements emerge that need to be integrated into exergaming applications as feedback to ensure therapeutic exergames foster these properties. Generally, the majority of such feedback is visual, with audio and haptics also playing smaller roles. As such, a conflict of sorts arises. While various visual feedback parameters undoubtedly have the potential to increase motivation to exercise, it is necessary within *therapeutic* exergaming to ensure that visual feedback does not detract focus from the physical task. For example, with the game Dance Dance Revolution, the input device is a foot mat and users must concentrate on their foot movements on the mat rather than focusing on the visuals on screen. Therefore visual feedback in DDR is relatively simple so as not to distract from the physical task. Similarly, an interactive exercise application that aimed to improve lower limb balance and strength in older adults found that for certain exercises audio feedback was more beneficial than visual [7]. Such exercises included elements of walking forwards, backwards and heel-to-toe, during which it was observed that many participants would look at their feet while also trying to concentrate on the on-screen visual feedback. Given that this exercise programme was aimed at older adults and was to be carried out in the home, unsupervised, visual feedback alone was a potential fall risk.

As we saw from the results of our study presented in this paper, visual feedback can negatively affect a person's feeling of confidence in performing an exercise correctly, due to the engaging nature of on screen feedback. Furthermore, visual feedback in our system was deliberately simple, as we wanted to start with the minimum amount of visual feedback and build on this as required. Other research has suggested that participants themselves often request more feedback, likely because it is more engaging and enjoyable [19], [20]. Thus balancing feedback is an important research topic that merits further work. In terms of our study, adding audio feedback may address the issue of low perceived competence. Audio feedback can encourage participants throughout their exercise, without being intrusive or requiring much effort on the part of the participant to process it. For example it might provide pointers on correct technique, such as correct placement of the feet, how the back should be positioned etc. either before or during exercise.

While reported levels of enjoyment were high in our study, it is important to remember that in a home environment when exercises are bring carried out repetitively over long periods of time, the same game will quickly lose its appeal. Thus providing a selection of games is necessary. A number of games are currently available on our therapeutic exergaming application, and each can control a large number of both upper and lower body rehabilitation exercises.

As a result of our research, some requirements have emerged for the design of therapeutic exergames:

- Applications should be general enough that they can support a wide range of both upper and lower limb rehabilitation exercises.
- Interaction should be hands free to remove interaction complexity and allow the user to focus on their exercise movement.
- The number of sensors should be minimised to avoid a lengthy set-up procedure, which could have negative effects on adherence.
- It should be easy to add or remove feedback components from the system interface to suit a wide range of user preferences and needs. For example, our previous work with older adults indicates that feedback that is overly-engaging can have safety implications.
- Feedback in therapeutic exergaming should be integrated as a response to specific design requirements and user needs. Feedback should address maintaining quality of exercise, encouraging adherence while not cognitively overloading the user so as to distract from the primary physical task.
- A one-size-fits-all policy does not apply. What one person finds encouraging and helpful in terms of feedback, another might find annoying or obtrusive. It is necessary to work closely with patients when designing therapeutic exergaming applications and to support personalised feedback parameters.

These are a short list of requirements for integrating feedback into therapeutic exergaming. Further research is necessary to move the field forward and to ensure that home-based therapeutic exercise programmes are both motivating and physically effective.

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