Serious Games for the Rehabilitation of Disabled People: Results of A Multilingual Survey

Marion Hersh[1] and Barbara Leporini[2]
[1]Biomedical Engineeriung, University of Glasgow, Glasgow G12 8LT, Stotland
Email: marion.hersh@glsgow.ac.uk
ISTI – CNR, Via G. Moruzzi, 1, 56124 – Pisa, Italy
Email: barbara.leporini@isti.cnr.it

Abstract. The paper reports the results of an original mixed-methods survey on the experiences and attitudes of disabled people to digital games in rehabilitation. Serious games are very widely used, but there is currently no research from the perspective of disabled people on their use in rehabilitation. A majority of participants were found to consider games in rehabilitation useful or very useful, with particular interest in games with a camera and sensors. Some statistically significant differences were found between the experiences and attitudes of blind and other disabled people and under and over 40s, but the results were found to be male-female gender independent. Several theories of technology use were applied to interpret the findings. The results were used to provide recommendations for the development and implementation of serious games in rehabilitation and suggestions for further work.

Keywords: Serious games; accessible games; disabled people; older people; rehabilitation; human-centred design

1 Introduction

Serious games are widely used in many different applications, including education and training. However, there has been limited research on serious games for disabled and older people, despite their potential and the popularity of digital games with players over 50, who range from 14% of the total in Germany to 29% in the USA [38]. For instance, surveys on game accessibility [40] have focused on entertainment rather than serious games, with the difference understood as serious games not having entertainment as their main purpose.

The term disabled people will be used within the framework of the social model of disability as resulting from social, environmental and attitudinal barriers. However, rehabilitation has normally been understood within a medical model framework as improving or 'restoring' function to be closer to that of a non-disabled person. Improving skills and abilities is always valuable. For instance, after a stroke most people will want to improve their speech and control and range of movement. However, there is need for a definition aligned with the social model of disability, which includes, but is not restricted to improving skills and abilities. One approach involves examination and making paralles with the literature on independence and disability which rejects definitions of independence in terms of the ability to carry out basic tasks, as this leads to many disabled people being treated as dependent.

Alternatively, independence can be understand in terms of autonomy and self-determination. Self-determination is about having agency in one's life and being able to take action to maintain or improve its quality [37] and involves making choices and decisions, setting and attaining goals, solving problems, and self-awareness, advocacy and efficacy [39]. Autonomy is about being self-governing and having control of life and choosing how to live it [6]. This then allows rehabilitation to be defined as training of disabled or older people or following an accident or illness with the aim of increasing independence understood as autonomy and self-determination.

Both competitive and cooperative games have been found to increase motivation [4]. Serious games can also engage attention, reduce boredom in repetitive activities by providing appropriate challenge, adapt to motor skills, provide meaningful tasks and appropriate feedback, and possibly distract attention from pain, [17, 30, 32]. This makes them potentially very useful in repetitive rehabilitation activities, for instance to improve physical condition after a stroke [1]. Motion capture systems can support game-based rehabilitation by obtaining data which is fed back to the user to support relearning correct movement patterns [32]. However, the privacy management issues raised by data collection have not been discussed. Mini games lasting a few minutes can provide relatively low cost development approaches for games generally covering a specific exercise [28]. There is some evidence that games can help to promote higher order thinking and soft and social skills [13] and entertainment games can improve attention and visual perception [4]. This could be helpful in both skils training and the wider aspects of rehabilitation that go beyond it. Games involving virtual reality systems e.g. [11, 33] have considerable potential to provide interesting story lines and options for practising a range of skills in a safe environment.

Accessibility relates to the environmental characteristics of the system input and output which enable particular (groups of) users to access and use all the facilities of the system [16]. Game accessibility has been improved by using user profiles to customise the user interface, alternatives to visual feedback for blind people [18] and alternatives to auditory feedback for deaf people. These alternatives need to cover any special effects to ensure that the game does not become less interesting.

There are advantages in a design for all approach [10, 12] to make games playable and enjoyable for as diverse a population as possible. However, games have generally been aimed at disabled people with a particular impairment, frequently physical, and a design for all approach rarely used [40]. This includes several games for post-stroke rehabilitation, generally to improve arm movements [7, 8, 26, 31]. Studies show that both non-disabled and post-stroke participants generally enjoy them [7] and challenge is provided by varying the pace and associated difficulty [31]. However, they have minimal storyline or fantasy and create interest through the use of audio and visual feedback. The Wii gaming control, which requires players to use movements to play games, has been used in operational therapy with positive responses from clients and therapists [19].

A few games, including puzzle games, interaction with an intelligent agent and movement games, have been developed to support social skills development or improve attention and coordination of autistic children [2, 3, 29]. Rehabilitation games have been developed to improve the cognitive skills of children and adults with cognitive impairments [11, 14, 23, 34]. In one case, an accessible interface in a game for children with cognitive impairments involved square tiles with force resistive sensors that they step on to initiate the games [14]. Several games e.g. [9] have been developed to support people with intellectual disabilities learning to use public transport. There are a few smart phone games to teach blind children, but not adults, Braille [27]. They include games for identifying and writing Braille symbols and a 'hangman' type word identification game. An interactive game to teach Deaf children American Sign Language [5, 20, 25] includes a child signing short phrases to an on-screen cat avatar. Serious games have also been used to improve balance, provide therapeutic support for eating problems, gambling and other behavioural issues [30], as well as in the rehabilitation of people with various health conditions [22, 38].

Thus, there is a small body of work on rehabilitation games. However, most of the literature focuses on specific games and does not investigate wider issues of game design, design for all approaches and what disabled people want from them. It also generally considers rehabilitation solely in terms of improving skills and functioning and not in terms of improving independence, as defined here. This chapter aims to meet some of these gaps. In particular its aims are (i) investigating the attitudes to, knowledge of and experiences of disabled people of the use of digital and interactive games in the rehabilitation of disabled people and (ii) obtaining suggestions for improving game design and use. It will do this in a framework of the social model definition of rehabilitation presented above, an understanding of disabled people as experts on their own experiences, design for all principles and technology use theories. The technology acceptance model (TAM) [36], according to which usefulness and ease of use are the main drivers of technology use is one of the most commonly used technology use theories Other relevant theories are based on motivation with the four components of attention gaining, relevance, confidence building and satisfaction [35] and the impact of the context and structures [15]. With regard to context the availability or lack of support could be an important factor [21].

2. Methods

The study involved a questionnaire for disabled people and parents of disabled people under 16 to complete on their behalf. It has three sections. Section A covers personal information on gender, age and impairment. Section B investigates the frequency and type of use of information technology, digital games and apps. Section C investigates the use of games in rehabilitation, views on their usefulness for different age groups, activities that could be supported and comments and suggestions.

English and Italian versions were produced and care taken to ensure their equivalence. Both authors speak both languages. The questionnaire could be completed anonymously online or as a word file. The online questionnaire site was chosen to be accessible and have a good privacy policy. The links to the online version of the questionnaire were circulated to organisations of disabled people, through email lists and forums, to the authors' contacts and by other researchers and disabled people. The Fisher exact test with software developed by Langsrud [24] was used to determine statistical significance at the 0.05 level.

3. Results

Percentages are given to the nearest integer and may not add to 100% due to rounding. 44 responses were obtained, 43 from disabled people with 23 Italian and 20 English speaking and one from an English speaking parent of a disabled child under 16. 45% were female, 45% male, 2% other (and 7% unstated). There was a good age distribution, with 25% between 41 and 50 and 14-20% in each of the other decades between 20 and 70. 59%, including all the Italian participants, were blind or partially sighted, a third physically disabled, 9% deaf or hard of hearing and 5% autistic. 14% had mental health conditions, 5% specific learning difficulties, 2% general learning difficulties and 2% sensory processing difficulties. Some participants had more than one impairment.

3.1 Use of Computers and Tablets/Smartphones

All the participants used computers and 98% a smartphone or tablet. The overwhelming majority spent between 1-3 and over eight hours a day using both computers and smartphones/tablets (both 89%) (table 1). Considerably, but not statistically significantly more of them (23% compared to 12%, p=0.18) used computers for over eight hours a day and smartphones/tablets for 1-3 hours a day (48% compared to 30%, p= 0.26). Thus, computers are still the most frequently used device, but tablets/smartphones are catching up.

The most popular applications were internet and email (table 2), with nearly universal use of both on computers (98%) and 71% and 81% respectively on tablets/smartphones with the differences statistically significant (p=0.0007 and 0.0009). Computers were used considerably, but not statistically significantly more often for both work (56% cf. 36%, p=0.08;) and formal education (26% cf. 17%, p=0.4) than smartphones/tablets. Other frequent uses of computers were producing documents (77%) and finance and budgeting (35%) and of smartphones/tablets phone calls (88%) and travel (63%) and other (33%) apps. Participants mainly used digital games for entertainment (53%), followed by personal learning (37%), professional training (19%) and rehabilitation (14%), with only 7% using them in formal education. Other uses provided in the comments included with children in an educational setting, fitness, coordination, 'brain training to improve memory' and 'mental distraction'.

Table 1: Frequency of use of computers and smartphones/tablets

	Never	Very occasionally	Once a month	2-3x/ week	< 1hour /day	1-3h /day	4-8h /day	>8h /day
Computer	0	0	2%	2%	7%	30%	36%	23%
Phone or tablet	2%	2%	0	0	7%	48%	30%	11%

Table 2: Use of computers and smartphones/tablets

	Internet	Email	Producing Documents	Work	Games	Finance	Formal Education	Phone calls	Travel apps	Other Apps
Computer	98%	98%	77%	57%	39%	34%	25%			
Phone or tablet	70%	80%		34%	36%		16%	86%	64%	32%
Stat sig p	0.0007	0.01		.053			0.43			

3.2 Uses of digital games

55% (31) provided their uses of games on computers and/or tablets/smartphones, so the additional 11 presumably used games on another device than a computer or tablet/smart phone. The main application was enjoyment (77% of 31), followed by personal learning (52%), professional training (26%) and rehabilitation (19%) (table 3). Suggested additional uses of games related to improving mental and physical functioning, specifically 'fitness and brain training to improve memory' and 'mental distraction and coordination'. 16 participants commented on their use of games. They named types of games, including puzzle, brain training and word games and specific games, including solitaire, sudoko, pokemon go, scrabble bridge and bingo rather than discussing their use.

Table 3: Types of uses of games

Use	Enjoyment	Professional training	University courses	College	School	Personal learning	Rehabilitation
%	77	26	6	0	6	52	19

13 participants commented on their use of digital games in rehabilitation, with three others commenting they did not use them. Presumably seven participants used digital games in rehabilitation on other devices than computers and smart phones/tablets. They were used for a mixture of physical and mental rehabilitation and relaxation, with several participants mentioning memory. Other applications included coordination, fitness,

occupational therapy and problem solving. Approaches to improving memory included 'using the games before I go to sleep helps the following day, since playing the word games I have improved my memory which helps me talk and not 'lose' words quite as much'; and 'I use word games to try to keep my vocabulary'. Luminosity was used multifunctionally to 'track my performance in memory, coordination, concentration to track my progress against tiredness (sleep), MS relapses and stress'. Comments about physical rehabilitation included 'Timmoco is a game that enables my kid to move his hands in order to gain some precision in his movements' and 'I use Fitbit to track how far I can walk and my sleep patterns with regard to pain'. Comments on games for relaxation included ' I play solitaire because I don't have to think about anything ... I don't even have to concentrate and I don't care what my score is.'

The main negative comment was from a participant using games 'to improve my memory and problem solving' following a therapist's recommendation. They 'prefer a book or person ... Find them hard to do ... get easily bored if I don't progress and forget to do them', indicating that games are not a universal solution. Four participants commented positively on other uses, including learning languages, entertainment and 'pass[ing] the time'. One participant deplored the lack of 'digital ... games that kids with quadriplegia can play. 'We are in need for more games that are switch or eye gaze friendly'.

3.3 The Usefulness of Games in Rehabilitation

Nearly 60% considered digital games useful (41%) or very useful (16%) in rehabilitating someone with similar impairments (table 4). A camera or sensors that could track movements considerably increased game usefulness in rehabilitation to 80%, though the difference narrowly missed statistical significance (p=0.08). However, this raises privacy management issues.

Table 4: Usefulness of digital games in rehabilitation

	Not at all useful	Not useful	Neither useful nor not useful	Useful	Very useful	No response
Games	0%	20%	20%	41%	16%	2%
Games with camera and sensors	0%	9%	11%	64%	16%	0%

35 participants (80%) commented on game usefulness. Several of them commented that they did not 'know of any games that could be helpful in my rehabilitation', though some of them considered 'if there are games for rehabilitation, ... then they might be useful. I would be curious.' There were also positive comments on motivation and

making learning easier: 'a motivational tool for rehabilitation and entertainment for kids at the same time' and 'Could provide opportunities to support rehabilitation in ways that are engaging and/or enjoyable'; However, the importance of an appropriate degree of challenge was noted: 'If the targets are too hard I would not do it. If it becomes tiresome I would not do it. ... a small challenge'. On the negative side 'they require too much concentration for my mental health problems'.

Digital games were considered useful for learning or improving skills, including 'identifying sounds for mobility training', motor skills and sign language and 'the option of doing exercises at home', though one participant did 'not see why games would help with mobility'. There was a fun aspect, including 'collaborative enjoyment', as well as improving 'well-being' and 'state of mind'. Participants also noted games were currently little used in rehabilitation and the need for accessible games. Negative comments included preference for rehabilitation 'in person with a real person' and that games would be used to make up for the lack of therapists. 'I feel they are being used because therapists of all sorts can't see patients quick enough or as often as they would like.'

At least 32% of participants considered digital games suitable for the rehabilitation of people of all ages from preschool to over 70. The largest numbers considered them suitable for the rehabilitation of 18-30 year olds (74%), 6-12 year olds (72%) and teenagers (65%) (table 5).

Table 5: Ages rehabilitation games considered suitable for

Age	Preschool	6-12 years	Teenagers	18-30 years	31-70 yrs	70+ years
%	39	73	66	75	52	32

35 participants (80%) commented on the ages games were suitable for, though several of these comments purely noted their inability to comment. The comments mainly divided into two groups, those who thought games suitable or potentially 'fun, educational and self directed' for all ages' and those who considered them better adapted to younger people. The first category included 'Everyone can get something from them' and 'There are word games that can help all ages from co-ordination for preschool to crossword type and word search games for the over 70's'. They also rejected the idea that technology could act as a barrier: 'while older people may not be as familiar with technology they could be shown', One participant specifically mentioned the benefits to an older relative: 'My Mother finds digital games entertaining at 89'.

Several comments in the second category related to younger people's greater perceived ability and liking for technology: 'I think younger people would prefer to use them or anyone who is really into phones and computer games' and ' Younger people understand the tech better and are usually more dexterous'. There was also a belief that learning was age dependent: 'probably the greatest level of learning takes place at a young age ... I find it difficult to imagine game which old people can easily use'. Other comments related to school integration: 'at primary school age it could also support integration with non-disabled peers'; and sensory compensation: 'in the first years of life games could be useful to compensate for missing senses or develop residuals.'

3.4 Games with a camera and sensors

28 participants (64%) proposed a wide range of activities that they considered could be usefully practiced or carried out with the help of games with a camera and sensors to detect movement. One participant stated that 'the limits are determined by your imagination'. Participants were generally interested in rehabilitation related to their specific impairments. The blind participants were particularly interested in mobility, including tele-guidance via a camera and learning about the environment. Several Italian blind participants were interested in learning foreign languages, sports and dancing. The other disabled participants were interested in movement, including reaching, grabbing, coordination, walking and physiotherapy, and also mentioned sign language and sound identification.

Several comments on the usefulness of games with cameras and sensors related specifically to the value of cameras e.g. 'a game with a camera could be very useful'. Others were about rehabilitation but not specifically games e.g. 'I think a camera is fundamental, as only this way can you know whether you are doing the exercise correctly'. Practical suggestions for the use of a camera included 'to use a camera to remind people of what an item is called ... it can be very frustrating not ... to find the word to describe something'. One blind participant considered a camera more useful for people with other impairments, though 'with a distance connection to a sighted person it could help a blind person find something in the house'.

Concern was expressed about sensor sensitivity: 'they would need to accommodate individuals with impairments which means ... their movement ability, is restricted. Therefore sensors would need to be sensitive enough to detect subtle movements'. Other comments related to making games accessible to more people. 'It would enable people who lack the dexterity ... to participate in online gaming.' Other positive comments involved improving the abilities to walk in a straight line and identify sounds and use with existing equipment: 'I use adaptive equipment that reads the screen. To add a form of movement detection would be a great feature'. Several participants considered that usefulness depended on the type of game, or the user and their impairment(s). Other participants considered that they were not particularly relevant to them; and one participant was sceptical about their usefulness in mobility other than for encouraging exercise.

3.5 Reasons for not using games, types of output and suggestions

While most participants were relatively positive about serious digital games, including their use in rehabilitation, a significant minority (27%) did not like games (table 6). The main reasons for not using games in rehabilitation were not knowing they were available (43%) and not participating in rehabilitation (39%) and being unaware of suitable games

(39%). Lack of accessibility was an issue for a fifth and 16% considered them not useful. Several participants provided more than one reason.

Table 6: Reasons for not using games in rehabilitation

Reason	Not like games	Not participated in rehab	Not know games used in rehab	Unaware of suitable games	Not consider useful	Digital games not accessible	Other
%	27	39	43	39	16	20	7

Overall participants considered sounds the most useful output from a digital game (4.4 out of 5), followed by speech (3.5) and vibration (3.4) with pressure or tapping (2.5) and other tactile indications (2.7) considered the least useful (table 7). Most of the differences were statistically significant e.g. p=0.0001 for sound and speech and p=0.001 for speech and pressure or tapping. Statistically significant differences between blind and other disabled people included other disabled people considering pressure or tapping (3.6 cf 2.1) and other tactile input (3.2 cf. 2.1) more useful than blind people and vibration less useful (2.4 cf. 4.2). The differences between under and over 40s were small.

Table 7: Attitudes to different types of output

	Vibration	Press/tapping	Other tactile	Speech	Sounds
Overall (%)	3.7	2.7	2.5	3.8	4.4
Blind (%)	4.2	2.1	2.1	3.4	4.6
Other disabled	2.4	3.6	3.2	3.9	4.1
P	10^{-7}	0.00003	0.004		

29 participants (66%) commented on the use of sources of information other than sounds, speech, vibration, tapping/pressure or other tactile. A blind participant commented that 'any type of information could be useful'. Other comments by blind people suggested a combination of sound and vibration e.g. 'for speed of operation the combination sound-vibration is superior to speech' or a combination of sound, speech and vibration e.g. 'sound, vibration and spoken comments ... when combined ... can ... make the difference in using a game, whether for fun, education or rehabilitation'. The other disabled participants either focussed on their specific requirements or the importance of considering the needs of users with different impairments. The latter included 'different needs, different ways of information so universal design should be applied'; 'all of the above are necessary, and this includes sound, particularly for those with visual or learning difficulties.' The need for silent devices was recognised: 'for sound should not be the only

criteria for entry (e.g. if disabled people require their device to be on silent)' and 'vibration is useful, as it is discrete and practical'. The need of sensory development to enjoy games was also suggested: 'The senses that are engaged using games need to be educated in order to gain any gratification'.

A parent commented on their hearing impaired son's need for visual, including sign language information: 'my son has hearing loss, in that case a sign language information or symbols, or pictures would be useful'. Participants with impairments affecting tactile perception and dexterity were unsure about the usefulness of tactile information and preferred speech. 'I have difficulties to concentrate feeling vibrations. I don't know what other tactile information can be useful' and 'As someone with very limited dexterity I would find games where I could complete actions via two word speech commands "shoot B" (for example)'. Users with sensory processing issues needed carefully managed input: 'I've got sensory processing issues ... I can tap on a screen and I can read text/look at images, but please don't talk to me or expect me to get more from auditory information than "there's a sound!" when I am playing a GAME'.

Suggestions for the use of digital games to support rehabilitation or education included the need for games with a single switch; the use of sound and vibration, for instance to learn about space, and maps and Braille labels on CD boxes. Several participants stressed the importance of making existing games for non-disabled people accessible for everyone, if appropriate with the use of assistive technology, and the need to make games usable and simple. The appropriate use of games with attention to both their advantages and disadvantages was recommended. 'Games are good for improving concentration but also as a distraction. I am not sure if they are the be all and end all to disability but I am sure they could improve situations for most people.' Suggested uses included improving memory and motor rehabilitation.

3.6 Comparisons for gender, age and type of impairment

The data was found to be male-female gender independent with similar values for frequency and type of use of both computers and tablets/smartphones, game applications, the perceived usefulness of rehabilitation games for different ages and with and without cameras and sensors. As an example usefulness of rehabilitation games is given in table 8.

Table 8: Gender similarities in game usefulness

	M/F	Not at all useful	Not useful	Neither useful nor not useful	Useful	Very useful
Games (%)	F	0	20	10	35	30
Games (%)	M	0	20	10	35	25

The main differences in the responses of blind and other disabled participants, and participants over and under 40 are discussed briefly below. Almost all participants in these four groups used computers for both internet and email. Fewer blind than other disabled participants played games on both computers (31% cf. 50%, p=0.22) and tablets/smartphones (23% cf 56%, p=0.054) with the latter difference close to statistical significance. The main other differences were greater use of computers for finance and budgeting and statistically significantly greater use of other apps on tablets/smartphones by other disabled than blind people (50% cf. 19%, p=0.049). More under 40s used computers in formal education and over 40s for finance and budgeting, but the differences were not statistically significant, Similar numbers of over and under 40s used tablets/smartphones for education. More over 40s used other apps on tablets/smartphones and more under 40s travel apps (82% cf. 52%, p=0.056), with the later difference close to statistical significance.

Approximately equal numbers of blind (59%) and other disabled people (56%) considered games to be useful or very useful in rehabilitation and somewhat more blind people (85% cf. 72%) considered games with sensors and cameras useful or very useful in rehabilitation. However, in both categories more blind people considered games useful and more other disabled people very useful. More under than over 40s considered games with (88% cf. 75%) and without (71% cf. 58%) a camera and sensors useful or very useful.

More blind people used games for personal learning (50% cf. 17%, p=0.03) and professional training (23% cf. 11%, p=0.03) and fewer for rehabilitation (8% cf. 22%), with the first two differences statistically significant. More under than over 40s used games for enjoyment (76% cf. 41%, p=0.03) and personal learning (52% cf. 26%, p=0.11) and fewer for rehabilitation (0 cf. 22%. p=0.002), with the first and last differences statistically significant. The difference in use for enjoyment may be indicative of different attitudes to games.

Significantly more other disabled than blind people considered games suitable for the rehabilitation of preschoolers (61% cf to 23%, p=0.015) and people over 71 years (61% cf. 12%, p=0.0009). More under than over 40s considered games suitable for each age group, with the total differences (p=0.0001) and those for teenagers (88% cf. 52%, p=0.02) statistically significant.

More blind than other disabled people did not use games in rehabilitation, because they did not like them, had not participated in rehabilitation, did not know games were used in rehabilitation, were unaware of suitable games and found digital games inaccessible with the overall (p=0.004), but not individual differences statistically significant. However, fewer blind than other disabled people did not consider games useful in rehabilitation, but the difference was not statistically significant. More under than over 40s did not use games in rehabilitation as they had not participated in rehabilitation (71% cf 19%, p=0.0003) or did not know that games could be used in rehabilitation (76% cf. 22%, p=0.0005). More under than over 40s were unaware of suitable games and considered them not useful and more over 40s did not like games, but the differences were not statistically significant. Approximately equal numbers (18% cf. 22%) of both under and over 40s considered that digital games were not accessible.

4. Discussion and Conclusions

The results of the survey show that a diverse group of disabled people are very frequent users of both computers and smartphones/tablets for a range of applications. While they currently use computers more, the relative closeness of the figures indicate that smartphones/tablets may soon take over. This increasing popularity is probably due to their easy portability and indicates that many disabled people are able to overcome the potential accessibility barriers resulting from their small size.

Over half the participants used digital games for enjoyment and just over a third for personal learning, and a significant minority (14%) already used them in rehabilitation. Over 60% of participants considered games useful in the rehabilitation of someone with similar impairments and this increased to over 80% for games with cameras and sensors to track movement. [Most people think that games in the rehabilitation can be mostly useful for young users (from 16 to 30), but only a small sample considers such a valuable support for prescholar individuals.] Thus there is a considerable gap between the percentage of participants who considered games useful in rehabilitation and those who actually used them. While just over a quarter of participants did not like digital games, the main reasons for not using games in rehabilitation, each held by about 40% of participants, were lack of knowledge of their potential and lack of knowledge of suitable games and not having participated in rehabilitation. This indicates the potential for the use of games in rehabilitation, as well as need to develop additional games. While nearly a third of participants considered digital serious games suitable for rehabilitation for all ages, nearly two thirds considered them most suitable for children, teenagers and young adults.

From the responses participants' understanding of rehabilitation seems to generally be the traditional one of improving skills and functioning rather than the wider social model understanding proposed here. Thus participants considered games to be useful in mobility training, motor skills, sign language and exercising at home, and games with a camera to remind people of object names. The expressed interest in games for learning languages could be related to the social model understanding of rehabilitation or indicate a misunderstanding of the concept.

There were some interesting differences and similarities between the different groups of participants. In particular, the results on device frequency, games applications and the perceived usefulness of rehabilitation games for different ages and with and without cameras and sensors were male-female gender independent. This is interesting, as gender is generally considered to be an important variable in technology use. Participants under 40 were more aware than over 40s of the potential of digital games for rehabilitation for older age groups, indicating the need for both appropriate design and awareness raising. The main game related differences and similarities are summarised below:

- Game playing: fewer blind than other disabled played games on both tablets/smartphones (close to statistical significance) and computers.
- Useful or very useful in rehabilitation: equal numbers of blind and other disabled people; more blind people for games with camera and sensors; more under than over 40s for games with and without sensors and camera.
- Game applications: significantly more blind people for personal learning and professional training and fewer for rehabilitation; significantly more under than over 40s for enjoyment and personal learning and significantly fewer for rehabilitation.
- Reasons games not used in rehabilitation: more blind people do not like them, not participated in rehabilitation, not know games used, not aware of suitable games and have accessibility issues (overall statistically significant); more under 40s have not participated in rehabilitation, not know games could be used (both statistically significant), unaware of suitable games and not consider them useful; more over 40s did not like games; about the same under and over 40s found games inaccessible.

While the majority of participants considered games useful, a significant minority was sceptical about the usefulness of games in rehabilitation. More over than under 40s did not consider them useful, though statistically significantly more over 40s used them in rehabilitation. In addition, fewer blind than other disabled people used them in rehabilitation.

From table 6 of the reasons for not using games in rehabilitation, usefulness and ease of use in line with TAM [36] are clearly important factors. However, lack of usefulness is measured here more strongly by non-participation in rehabilitation than perceived non-usefulness. The lack of knowledge that games are used in rehabilitation and awareness of suitable games is in accordance with the attention gaining component of motivation theory, whereas not liking games is an element of lack of satisfaction [35]. However, TAM was not able to explain the experience of under and over 40s: the over 40s were using games more in rehabilitation, but considered them less useful. In terms of motivation [35] over 40s experienced some lack of satisfaction and relevance due to not liking games and not considering them useful, though there was reasonable 'attention' to games in terms of awareness of suitable games. The reduced serious game use by blind people, both in general and for rehabilitation is in accordance with both TAM and motivation theory. Blind people had reduced participation in rehabilitation (usefulness), though they considered games for rehabilitation equally useful, did not like games (satisfaction), and were not aware games were used or of suitable games (attention gaining).

The numerical data and comments indicate some of the factors to be taken into account in game development and lead to the following design and implementation recommendations:

1. Where feasible include cameras and sensors in games, with sensors sufficiently sensitive to track faint movements.
2. Make games accessible and easy to use.

3. Modify existing games to make them fully accessible, possibly through the use of assistive technology.
4. Apply design for all approaches whenever feasible.
5. Design games for neglected groups e.g. switch and eye gaze technology users
6. Make game design age appropriate and pay particular attention to the needs of older players.
7. Use games to complement other approaches rather than to replace therapists
8. Publicise the potential of rehabilitation games, particularly for older people.

The main limitations of the study are the relatively small sample size, though studies of disabled people are generally smaller than of non-disabled people, not asking about a wider range of output formats than those of interest to blind people and omitting question on country and ethnicity/race However, the results indicate the value of continuing the survey, possibly in additional countries, with the aim of obtaining more respondents and including this data.

Although feedback and comments are generally positive about technology use in rehabilitation, but some of the comments and opinions expressed indicate that particip;ants may not fully understand the potential of technology to support disabled people. They may still consider games purely as a form of entertainment and not fully understand their potential in education training, including rehabilitation. Further research is required to investigate this.

Other avenues for further work include:

1. A survey on the use of games in rehabilitation from the perspective of professionals and a comparison of the experiences and attitudes of disabled people and professionals
2. An investigation of the potential of sensors of different types in providing feedback on user behaviour and enabling adaptive learning and users' preferences for games with sensors in addition to a camera.
3. An in-depth investigation of privacy management issues associated with data collection and the trade-offs users are willing to make.
4. An investigation of the impact of the context, including available support, and surrounding structures on the use of games in rehabilitation in line with the theory of structurisation [15].

In summary the study has indicated the potential of games in rehabilitation and made a number of recommendations for their design and implementation, as well as suggestions for further work. It has also shown the importance of the involvement of end-users in the process to both ensure that their requirements are met and to enable them to understand the potential of rehabilitation games.

Acknowledgements We would like to thank everyone who completed a questionnaire or helped distribute them. We are very grateful for their assistance. Ethical Approval was obtained from the Ethics Committee of the College of Science and Engineering at the University of Glasgow. There are no conflicts of interest. An earlier version of the paper was published as Serious Games for the Rehabilitation of Disabled People in Rehab 2016 Workshop, ACM Digital Library.

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