Borrowing a Virtual Rehabilitation Tool for the Physical Activation and Cognitive Stimulation of Elders

Alberto L. Morán[1], Felipe Orihuela-Espina[2], Victoria Meza-Kubo[1],
Ana I. Grimaldo[1], Cristina Ramírez-Fernández[1], Eloisa García-Canseco[1],
Juan Manuel Oropeza-Salas[2], and Luis Enrique Sucar[2]

[1] Facultad de Ciencias, UABC, Ensenada, B.C., México
[2] Instituto Nacional de Astrofísica, Óptica y Electrónica, Tontanzintla, Puebla, México
{alberto.moran,mmeza,ana.grimaldo,al302126,
eloisa.garcia}@uabc.edu.mx
{f.orihuela-espina,juan.oropeza,esucar}@inaoep.mx

Abstract. We explore the use of a virtual rehabilitation platform as the interaction means for physical activation and cognitive stimulation of elders. A usability evaluation of actual and projected use of the tool suggests that this could be feasible to perform. Elders perceived the use of the evaluated tool as useful (93.75/100), easy to use (93.75/100) and pleasurable to use (91.66/100) during an actual activation and stimulation session. Previous experience on the use of computers by the participants did not significantly impact on their usability perception for most of the included factors, with the sole exception being the perception of anxiety. This is an encouraging result to reuse and adapt technologies from "close" domains (e.g., virtual rehabilitation). In addition, this can reduce development times and cost, and facilitate knowledge transfer into the domain of physical activation and cognitive stimulation of elders.

Keywords: Usability study, virtual rehabilitation, cognitive stimulation, physical activation, elders.

1   Introduction

Life expectancy of human beings has increased over the past few decades. However, longer living impacts the quality of life at an old age, as an increased age is usually associated with a decline in the physical and cognitive abilities of elders. This decline may be due to, or aggravated by, the existence of wear or disease. Technology can potentially help alleviating the decline in innovative ways [e.g. 2, 9, 10].

Under this latter goal we are interested in investigating the development of technology that supports the physical activation of the elderly and their cognitive stimulation in order to meet both the physical and the cognitive aspects concurrently. In this paper, rather than developing new technology, we explore an alternative approach; reusing existing exogenous technology. We present an exercise that takes a virtual rehabilitation system of the upper limb, and evaluates its usability as an interaction means for the physical activation and cognitive stimulation of the elderly. If

succeeding, that will open the door for cross-breeding technologies across domains. In particular, in this first study we are interested in usability; i) obtaining the elders' perception regarding the use of the rehabilitation tool as an interaction means for an activation and cognitive stimulation application, and ii) whether the novelty of the device and application has an effect on the perception of users that have (or have not) experience on the use of this or similar technology.

2   Background

Virtual Rehabilitation. Brain injury resulting from stroke or palsy often leaves patients with motor impairment. Several rehabilitation therapies are available for motor restoration [1]. Among them, virtual reality based therapies have recently become a valid alternative, an option that is now known as virtual rehabilitation [2]. Virtual rehabilitation commonly involves concealing rehabilitation exercises as serious games. By now, a few tens of virtual rehabilitation platforms have been developed [3]. For the experiments presented in this work we rely on Gesture Therapy (GT) [3, 4], a low cost virtual rehabilitation platform for the upper limb illustrated in Figure 1. GT has demonstrated clinical value similar to occupational therapy in two different trials but with an edge on motivation [4, 5].

Fig. 1. The Gesture therapy virtual rehabilitation platform for the upper limb. Gesture Therapy characteristic gripper permits controlling of the user avatar through tracking of the colorful ball as well as monitoring gripping forces by an incorporated pressure sensor. Serious games of the platform as the one pictured encourage repetitive exercises beneficial for motor rehabilitation.

Cognitive Stimulation for the Elderly. Some age-related diseases, such as Alzheimer, are accompanied by the patient's cognitive decline. Cognitive decline is characterized by difficulties in one of the following: memory and learning, attention and concentration, problem solving and abstraction, language comprehension and word finding and/or visual functioning [6]. Cognitive stimulation is a non-pharmacological intervention for people with dementia by which a range of enjoyable activities bring forth general stimulation for thinking, concentration and memory usually in a social setting, such as a small group [7]. Frequent participation in cognitive stimulation

activities reduces the risk of suffering a cognitive decline related disease, improving the patient's cognitive functioning and behavior [8]. To deliver cognitive stimulation activities, a number of platforms use serious games as a mean [9, 10, 11], thus being an ideal environment for testing transference from virtual rehabilitation technology. We have chosen cognitive stimulation as a target application to integrate with physical activation (through virtual rehabilitation games) because the population affected by cognitive decline, i.e. elders, is also the population most affected by stroke.

3 Usability Evaluation

Participants were 32 elderly (age mean±std: 64.96±6.31 years) recruited from a local municipal third age support group in Ensenada, Mexico. They live an independent life and have no apparent cognitive problems. The cohort was exposed to a subset of three games of the GT platform (steak cooking, window cleaning and fly killer), and asked to evaluate them in terms of perceived usefulness, ease of use and user experience. Our main goal was to assess usability aspects of the recycled technology. In addition, their previous experience, or lack of it, with technologies was logged to use it as a factor for explaining the evaluation results. The hypothesis was that older adults with previous experience with technology were to perform better in the serious games, and consequently, likely evaluate the games more graciously.

After a brief explanation of the experiment objectives, participants signed a consent form. Upon commencing the experimental session they answered a questionnaire regarding their demographic data and their familiarity with technologies. A 2-minute demonstration of the use of the platform followed by a 3-minute free playing familiarization (training) was given to each participant. Afterwards, the subjects played the games for 15 minutes each. The order in which the games were played was randomized. User interaction with the games was monitored with software tool Camtasia (TechSmith, USA). Finally, participants were asked to fill a 29-element extended TAM-based questionnaire [12]. The questionnaire addresses 5 sections: perception of usefulness, perception of ease of use, intention of use (should the system be available), anxiety experience during system usage, and user experience. Most elements of this questionnaire (22 items) are 5-point Likert scales. The remaining 7 items have a 3-option answer where the preference of games has to be ranked.

4 Evaluation Results

4.1 Performance on the Game

The average scores per game and category (technology experienced and inexperienced) are presented in Table 1. As expected, subjects that reported having previous experience on computer or game console use slightly outperformed those reporting lacking experience. Independent-samples *t*-tests were conducted to compare the performance on each game of the two groups of subjects.

There were no significant differences in the scores for any of the performed games for experienced subjects and inexperienced subjects, conditions; steak cooking: $t_{30} = 0.52$, $p = 0.303$; window cleaning: $t_{30} = 0.9$, $p = 0.187$; and fly killer: $t_{30} = 1.07$, $p = 0.146$. This suggests that previous technological experience does not give an edge start when using GT that reflects significantly on performance. Thus, we consider that the proposed games and controller gripper allow experienced and inexperienced subjects to achieve similar performances while conducting this experiment.

Table 1. Score averages per game and previous experience with technology category

Experienced Subjects (ES) (N=17)				Inexperienced Subjects (NES) (N=15)			
	Steak cooking	Window cleaning	Fly killer		Steak cooking	Window cleaning	Fly killer
Avg.	141	789.35	58.64	Avg.	128	739.26	50.6
S.D.	76.89	142.86	20.86	S.D.	63.23	173.48	21.83

4.2   Overall Usability Perception

To evaluate the perception of usefulness, ease of use and user experience, we scored the questionnaire items of each category following an approach similar to that used in the System Usability Scale (SUS) [13]. This way, scores greater that 62.5 will indicate a trend towards users agreeing (75) or completely agreeing (100) that the proposed feature is present or supported by the application under evaluation.

Table 2. Evaluation results concerning the overall usability perception of subjects per groups using the 22 Likert scale items only

Overall Usability Perception *(alpha = 0.05, p = 0.065)*			
Experienced Subjects (ES)		Inexperienced Subjects (NES)	
Median	94.32	**Median**	88.63
IQR	6.81	**IQR**	21.59
Mean Rank	18.9	**Mean Rank**	13.8

Table 2 presents a summary of the results categorized according to participants' having or not experience using the computer. As hypothesized, technology experienced subjects granted higher notes (median = 94.32 (Interquartile Rank (IQR) = 6.81)) than inexperienced subjects (median = 88.63 (IQR = 21.59)); however, the effect was found to be marginally not significant at the 0.05 level (Mann-Whitney U: p=0.065). These results suggest that a) most subjects tend to agree (A) or completely agree (CA) that the application provides or promotes each of the evaluated factors (i.e. usefulness, ease of use, etc.), and b) that previous experience on computer or game console use does not have an effect on the subjects' overall usability perception of the platform.

Table 3. Summary of Mann-Whitney U Test results on the perception of usefulness, ease of use, intention of use, user experience and anxiety by category

Experienced Subjects (ES)		Inexperienced Subjects (NES)	
Perceived Usefulness *(alpha = 0.05, p = 0.153)*			
Median	93.75	Median	100
IQR	12.5	IQR	6.25
Mean Rank	14.9	Mean Rank	18.3
Perceived Ease of Use *(alpha = 0.05, p = 0. 254)*			
Median	93.75	Median	93.75
IQR	12.5	IQR	25
Mean Rank	17.6	Mean Rank	15.3
Perceived Intention of Use *(alpha = 0.05, p = 0. 173)*			
Median	100	Median	100
IQR	12.5	IQR	25
Mean Rank	18	Mean Rank	14.8
Perceived User Experience *(alpha = 0.05, p = 0. 440)*			
Median	91.66	Median	95.83
IQR	4.16	IQR	33.33
Mean Rank	16.8	Mean-Rank	16.2
Perceived Anxiety *(alpha = 0.05, p = 0. 017)*			
Median	100	Median	87.5
IQR	4.16	IQR	29.16
Mean Rank	19.8	Mean Rank	12.8

4.3 Perceived Usefulness, Ease of Use, Intention of Use and User Experience

To further scrutinize usability aspects we further analyzed perception of usefulness, ease of use, anxiety and user experience of elders (see Table 3). As can be seen in Table 3, both groups of participants perceived high values for the aspects considered in this study. On the one hand, contrary to hypothesized, the inexperienced group (NES) granted higher notes than the experienced group (ES) on the perceived usefulness (NES: Median = 100 (IQR = 6.25), ES: Median = 93.75 (IQR = 12.5)) and on the perceived user experience (NES: Median = 95.83 (IQR = 33.33), ES: Median = 91.66 (IQR = 4.16)). Furthermore, both groups granted very similar notes on the perceived ease of use (ES: Median = 93.75 (IQR = 12.5), NES: Median = 93.75 (IQR = 25)) and on the perceived intention of use (ES: Median = 100 (IQR = 12.5), NES: Median = 100 (IQR = 25)). However, subsequent Mann-Whitney U tests showed no significant differences at the 0.05 level for any of the four described aspects: perceived usefulness (p=0.153), perceived ease of use (p=0.254), perceived intention of use (p=0.173) and perceived user experience (p=0.440). These results suggest that experience on computer or game console use does not have an effect on any of these aspects regarding the use of the GT platform.

4.4 Perceived Anxiety

Subjects from both groups reported low levels of anxiety while using the GT platform as shown in Table 3. As hypothesized, experienced subjects granted higher notes on

low levels of anxiety (Median = 100 (IQR = 4.16)) than inexperienced subjects (Median = 87.5 (IQR = 29.16)). The results of a Mann-Whitney U test suggest that the mean ranks differ in the same directions as the medians, and that the effect was found to be significant at the 0.05 level (p=0.017), which suggests that prior experience affects subjects' anxiety perception when first confronted with the GT platform.

4.5   Participants' Thoughts on the Provided Technology

Usefulness. Subjects were also asked to categorize the games regarding the usefulness they perceived after playing with them (items 5 and 6). Overall, fly killer was perceived as the most useful (41.74%), followed by steak cooking (31.11%) and window cleaning (27.15%). A possible explanation could be that elders from both groups perceived fly killer as the game that put more challenges on them (discussed in the next subsection). Interestingly, in private communications a rehabilitation consultant already told us he perceives the fly killer to be the most useful for rehabilitation.

Ease of Use. Subjects were also asked to categorize the games regarding the ease of use they perceived after playing with them (items 11 and 12). Overall, window cleaning was perceived as the most ease to play game (40.13%), followed by steak cooking (32.71%) and fly killer (27.16%). Not surprisingly in the light of the higher scores, despite the similar scoring system across games, however unexpected since window cleaning is arguably the hardest task being the only requiring bidirectional movements, a game designed for advanced stages of motor rehabilitation therapies. A possible explanation could be that elders from both groups perceived window cleaning as the game with the most familiar activity (e.g. Inexperienced Subject 10 (NES10) said that cleaning the window "is something that I usually do, but I am not used to kill mosquitoes that way"), and that they perceived fly killer as the most-challenging game (e.g. NES15 said "it is the hardest game to play, […] you are required to move the sprayer towards the mosquito and press ["the handle"] to actually spray it").

User Experience. When asked to categorize the games considering which was the most fun to play (item 29), overall, fly killer was perceived as the most fun to play game (41.50%), followed by steak cooking (31.43%) and window cleaning (27.07%). Perhaps, elders felt a sense of satisfaction after killing the mosquito (e.g. NES6, while playing, said "take that! you won't be able to bite me anymore!"); that they did not perceived window cleaning as a fun activity (e.g. NES1 said "I like to cook, but I don't like to clean the windows!"); and that being fly killer perceived as the most challenging activity, participants were proud of their scores, and interested in knowing how they have done in comparison to the others (e.g. after finishing the game, subject ES3 said "72 mosquitoes, wow! … what is the highest score?").

Intention of Use. Regarding projected frequency of use and session duration (items 15-16) 29 participants (90.6%) said that they would use it at least twice or thrice a week (Figure 2.A), and 27 participants (84.3%) declared that they would use it for 10 minutes or more during each projected session (Figure 2.B).
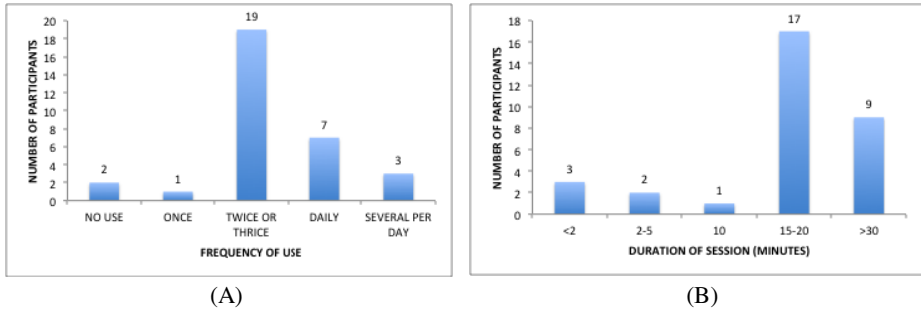
(A)   (B)

Fig. 2. Participants' intention of use regarding frequency of use (A) and duration of session (B)

Anxiety Levels. Anxiety levels could be inversely related to the subject's familiarity with controllers such as the proposed one (i.e. gripper), which in turn may influence the subject's expectations regarding the use of and interaction through the device. Although subjects from both groups found the system easy to use, experienced subjects were more at ease with the device (e.g. Experienced Subject 5 (ES5) said that "the gripper is similar to the Wii[mote] controller", and ES14 said that s/he has "already used this [a similar] controller with his/her grandson's [PlayStation] game console"), while some inexperienced subjects did not knew what to expect or what to do with the proposed device (e.g. NES15 said "In the beginning I did not know what this thing [referring to the gripper] was for or how to use it … that made me nervous, but once I understood how to use it, I felt much better", and NES8 said "I did not knew what to expect").

5   Discussion and Conclusions

Regarding the reutilization of a virtual rehabilitation tool as the interaction means for the physical activation and the cognitive stimulation of elders, our main findings are that i) subjects perceived the proposed games as useful, easy to use and capable of generating a pleasurable or fun user experience with a low anxiety level, and (ii) that subjects expressed their intention to use the games if available. This is an encouraging result to recycle technologies from "close" domains, which can reduce development times and cost, as well as facilitating knowledge transfer. Furthermore, we found that experience on the use of computer and game consoles does not impact the user's overall usability perception of the platform, nor on the specific factors; with the exception of the anxiety level.

Concerning the particular approach, we consider that i) GT activities foster the elderly upper limb physical activation and their cognitive stimulation (at an initial level); ii) the proposed application allows for assessing the elders' performance on the activity and provides feedback to render them aware of how they did in the exercise; iii) the elements (contents) of the activity are presented to them in an appropriate manner (metaphors) that eases their perception and learnability; and iv) the proposed device (gripper) provides the elderly with a simple but effective interaction channel.

These results provide promising evidence towards the feasibility of integrating virtual rehabilitation and cognitive stimulation technologies to concurrently support the physical (re) activation of the elderly and their cognitive stimulation. However, it is necessary to further identify specific elements from each domain and to determine how they relate among them in order to generate a more general design solution that aids in the development of useful, easy to use and pleasurable physical activation and cognitive stimulation applications. We aim to address this in our future work.

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