Using an Aging Simulator Suit for Modeling Visuo-Motor Limitations of Elderly Users Interacting with a Mobile Application: Feasibility Study

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Abstract. With the rapid ageing of the population, designing inclusive mobile interfaces that match accessibility requirements is an important challenge. Here, we report results of an exploratory study, which investigated the feasibility of using an "aging simulator suit" for modeling the sensorimotor limitations of elderly users interacting with a tablet application. The study involved one experimental group ("simulated ageing" condition, SA) and two normative comparison groups ("elderly control" condition, EA; and "young control" condition, YC). In the SA condition, a group of young adults (N = 60; mean age = 26.1, s.d. = 4.0) carried out a visuo-motor task while wearing the aging simulator suit, which reproduced three levels of visuo-motor impairment: (i) visual; (ii) motor; (iii) visual and motor. In the EC condition, the same visuo-motor task was executed by a sample of healthy elderly individuals (N = 20; mean age = 73.5, s.d. = 6.3). In the "young control" (YC) condition, the task was executed by a sample of young adults (N = 40; mean age = 24.6; s.d. = 4.7). Results showed that accuracy and speed of YC outperformed performance of EC and SA. Furthermore, SA approximated EC performance, suggesting that aging simulator suit may provide a reliable model of visuo-motor limitations of the normative-aged group. Implications of these findings for design practice are discussed.

Keywords: Inclusive design · Accessibility · Aging simulator suit Visuo-motor limitation · Mobile applications

1 Introduction

According to a recent UN report [1], in the next fifteen years, the number of people in the world aged 60 years or over is projected to grow to 1.4 billion, reaching nearly 2.1 billion by 2050. As the senior population progressively increases, it will also increase the proportion of elderly individuals using mobile and ubiquitous computing devices.

P. Cipresso et al. (Eds.): MindCare 2018, LNICST 253, pp. 24–33, 2018.
https://doi.org/10.1007/978-3-030-01093-5_4

Therefore, designing universally accessible mobile applications has become an important challenge to address in order to ensure that elderly individuals can exploit the full range of opportunities offered by the mobile digital revolution. In this context, the concept of accessibility refers to the discriminatory aspects related to equivalent user experience for people with disabilities, including people with age-related impairments [2]. A key requirement for improving the accessibility of products is to put the user at the center of the design process, which is the core principle of the so-called "universal design". According to Christophersen [3], universal design involves three knowledge processes: (i) user-designer interaction: any tool or technique that designers apply in order to align the requirements of the end-user with the characteristics of the product; (ii) understanding people: to collect information that allows deepening the understanding of the target user group (including i.e., range of abilities, potential impairments, contextual factors etc.); (iii) evidence-based findings: to analyze previous experiences (both positive and negative) of existing products to inform the design of future products. Within the context of universal design, a significant challenge concerns how to create reliable and informative model of end user abilities, which is even more relevant when dealing with elderly users interacting with mobile applications. User modeling has a significant role in enhancing the accessibility of user interfaces since it allows defining them by taking into consideration the needs and eventual limitations of the target. Here, we report results of an exploratory study, which investigated the feasibility of using an "aging simulator suit" as a new approach for modeling the sensorimotor limitations of elderly users interacting with a mobile device application. Aging simulators are wearable devices that are designed to generate embodied models of physical and sensorial limitations of an elderly individual. These tools have been applied in education and health disciplines [4] while their use in universal design is still very limited. Specifically, our research examined the effects of ageing simulator on sensorimotor performance of young adult participants under three different simulated impairment levels (visual, motor, and visuo-motor), using two simple visuo-motor coordination tasks, which participants were asked to execute as quickly and accurate as possible on a tablet device. Performance in this experimental condition was contrasted with two control conditions: a normative elderly group; and a young adults group, who executed the same tasks without wearing the ageing suit.

2 Method

2.1 Participants

All participants involved in the study were unpaid volunteers. Informed consent was obtained after the nature of the procedures had been fully explained. In overall, the study involved 120 participants, of which 100 young adults and 20 healthy elderly individuals. Young adults participants were included in the study if they matched the following inclusion criteria: age $\geq$ 21 years; normal vision or corrected-to-normal with glasses or contact lenses; absence of motor impairments on the dominant hand. Elderly adults participants were included in the study if they matched the following inclusion criteria: age $\geq$ 65 years; age-related (expected) decline of vision loss, or near-normal vision (in the better eye, with best possible glasses correction); age-related (expected) decline of bimanual and uni-manual motor skills. Exclusion criteria included: abnormal vision changes caused by disorders of the visual system; evidence of medical, neurologic, or psychiatric conditions that could adversely affect motor function; evidence of cognitive impairment (Mini-Mental Status Examination cut-score of 24 or below). A test of hand dominance was performed on all participants. Summary statistics for demographic variables across conditions are shown in Tables 1 and 2.

Table 1. Descriptive statistics for demographic variables across conditions

Condition	N	F	M	Mean age	S.D.
EC	20	10	10	73.050	6.2616
YC	40	20	20	24.575	4.7116
SA-V	20	10	10	27.450	4.2361
SA-M	20	10	10	24.600	3.7892
SA-VM	20	10	10	26.250	3.9719
Total	120	60	60	33.417	18.4166

SA = simulated ageing group (overall); SA-V: simulated ageing group (visual impairment); SA-M: simulated ageing group (motor impairment) SA-VM simulated ageing group (visual and motor impairment).

Table 2. Descriptive statistics for hand dominance across conditions

Condition	Right	Left	Total
EC	20	0	20
YC	35	5	40
SA-V	19	1	20
SA-M	17	3	20
SA-VM	20	0	20
Total	111	9	120

SA = simulated ageing group (overall); SA-V: simulated ageing group (visual impairment); SA-M: simulated ageing group (motor impairment) SA-VM simulated ageing group (visual and motor impairment).

2.2 Apparatus and Materials

2.2.1 Aging Simulator Suit

The GERT aging simulator suit [5] (Fig. 1) includes several components, which can be used either alone, or in combination in order to make the user experiencing the sensorimotor limitations of older persons.

Since the present study focused on the modeling of visuo-motor coordination ability in interacting with a tablet-based app, only the functionalities of the GERT suit that could potentially interfere with this ability were selected; more specifically, the impairments selected were:

Fig. 1. The GERT ageing simulation suit used in this study.

– opacity of the eye lens and narrowing of the visual field (caused by the special glasses);
– head mobility restrictions (caused by the cervical collar);
– restricted joint mobility (caused by the elbow wraps);
– sinking strength and changed coordination (caused by the weight cuffs);
– restricted grip ability and reduced tactile perception (caused by the special gloves).

Young adults participants assigned to the SA-V condition worn the special glasses only; participants assigned to the SA-M condition worn only the components of the GERT that were expected to cause limitations of the motor function in the upper limb and torso; finally, participants assigned to the SA-VM condition performed the tasks wearing both the special glasses and the components of the GEAR suit that limited the motor function in the upper limb and torso.

2.2.2 Tablet Applications Used for the Visuo-Motor Tasks

The mobile device used to perform the visuo-motor task was an Apple iPad 2. The task was performed on two commercial applications available on the Apple Store: "Finger Balance" e "Tap the Dots". The first application challenges the player with a fine motor coordination task, consisting in balancing a ball on a rod. Task difficulty can be gradually increased during the gameplay, i.e., by changing the inclination of the rod. The "Tap the Dots" application requires the player to tap as many buttons as possible within 60 s. The target button flashes within a grid, in a random way. Game configuration options allow setting the task difficulty by increasing or decreasing the speed of the gameplay.

For both applications, users' performance was assessed in terms of speed and accuracy, following the arrangement outlined in Table 3.

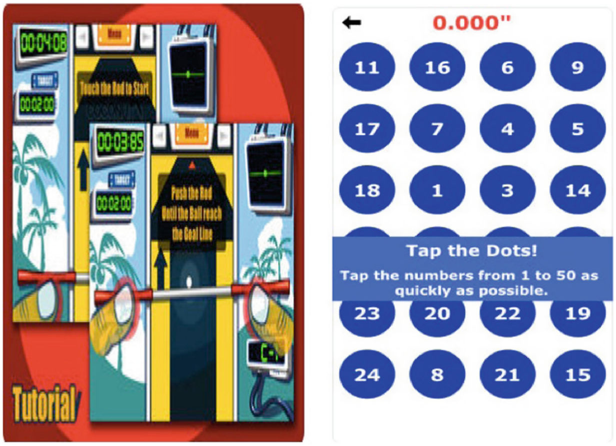

Fig. 2. Screenshots of the tablet applications selected to implement the visuo-motor tasks. Left: the Finger Balance application; Right: the Tap the Dots application.

Table 3. Structure of visuo-motor tasks and performance measures

Application	Difficult levels	Number of trials for each level	Total number of trials	Performance measures
Finger Balance	5	3	15	Task completion time (sec) and number of errors
Tap the Dots	1	3	3	Task completion time (sec) and number of correct choices

2.3 Procedure

Participants signed the informed consent and filled the demographic questionnaires. Next, they received the experimental instructions: participants were explained the two games and asked to be fast and accurate in solving the tasks. After the briefing, the experimenter assisted participants in the SA condition in dressing the components of the GERT age simulator suit and provided them with safety guidelines. Next, participants were given the iPad tablet with the pre-installed applications to begin the experiment. The order of the tasks performed with the two applications was counterbalanced across participants at each condition. The overall experimental procedure lasted about 35–40 min for each participant.

3 Data Analysis and Results

All participants successfully completed the experimental procedures. Data were analysed by mean of statistical software package IBM SPSS Statistics v. 21. We first performed a correlation analysis of accuracy and speed variables across selected tasks. Results of correlation analysis on performance variables is reported in Table 4.

Table 4. Correlation analysis of accuracy and speed variables across selected tasks

		FB Mean errors	FB Mean total time	T+ Mean hits	T+ Mean response time
FB Mean errors	Pearson correlation	1	.417**	−.407**	.598**
	Sig. (2-tailed)		.000	.000	.000
	N	120	120	120	120
FB Mean total time	Pearson correlation	.417**	1	−.387**	.540**
	Sig. (2-tailed)	.000		.000	.000
	N	120	120	120	120
T+ Mean hits	Pearson correlation	−.407**	−.387**	1	−.652**
	Sig. (2-tailed)	.000	.000		.000
	N	120	120	120	120
T+ Mean response time	Pearson correlation	.598**	.540**	−.652**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	120	120	120	120

FB = *Finger Balance* application; T+: *Tap the Dots* application
*p < 0.05 and **p < 0.01

As predictable, accuracy and speed measures were positively correlated within each task. Furthermore, a positive correlation was found between measures of accuracy and speed across the two different tasks. This finding suggests that the selected tasks provided an independent, but related measure of participants' visuo-motor performance.

Two repeated-measures ANOVA were carried out to determine the effects of condition type (EC, YC, SA-V, SA-M and SA-VM) on accuracy of task execution and time (see also Table 3). The first ANOVA was carried out on the Finger Balance task data. Condition served as a between-subjects factor and trial repetition (3 levels) and degree of difficulty (5 levels) served as within-subject factor. The second ANOVA was carried out on the Tap the Dots task data; again, condition type served as a between-subjects factor, and trial repetition (3) served as within-subject factor.

3.1 Results of Repeated ANOVA for Finger Balance Task

Results showed a significant effect of condition on number of errors ($F(4; 115) = 21.791$, $p < 0.01$). Post-hoc comparisons were carried out using Bonferroni adjustment for correcting the significance level, showing that the EC group made significantly more errors than each of the other conditions; none of the remaining contrasts were significant.

The effect of condition on response time was also significant ($F(4; 115) = 19.422$, $p < 0.01$). Post-hoc contrasts revealed that the EC group was significantly slower than

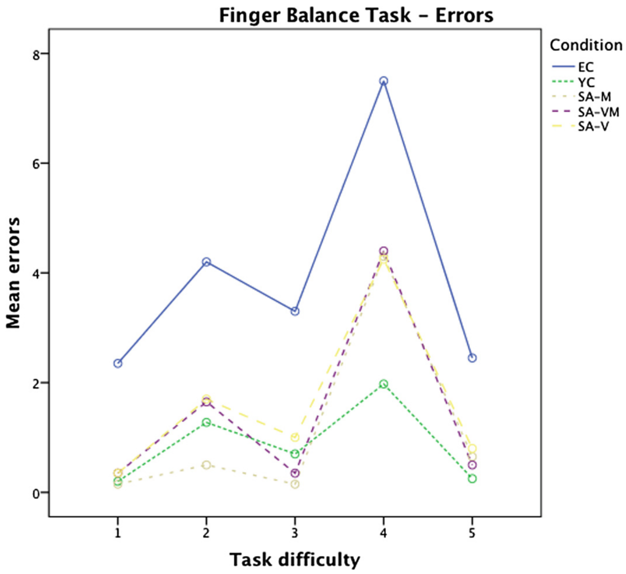

Fig. 3. Mean errors for each experimental condition, on five increasing task difficulty levels (Finger Balance task).

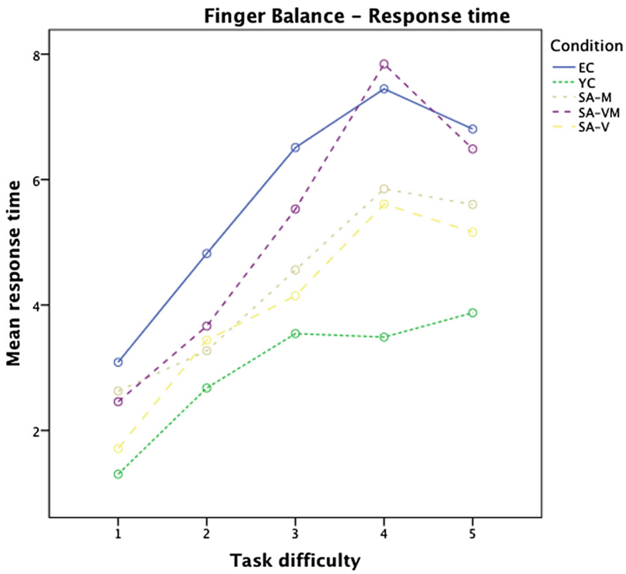

Fig. 4. Mean time response for each experimental condition, on five increasing task difficulty levels (Finger Balance task).

each of the other conditions, with the exception of SA-VM. The following graphs depict mean errors (Fig. 2) and time (Fig. 3) for each experimental condition, on five increasing task difficulty levels.

3.2 Results of Repeated ANOVA for Tap the Dots Application

Results of the second repeated ANOVA showed a significant effect of condition on number of target hits ($F(4; 115) = 21.791$, $p < 0.01$). Post-hoc comparisons (with Bonferroni adjustment) revealed that the EC group hit significantly less targets than the remaining conditions. In addition, the YC condition produced significantly more hits than SA-VM, which was also significantly less accurate than SA-V and SA-M (see Fig. 4).

ANOVA conducted on response time for Tap the Dots application showed a significant effect of condition on response time $F(4; 115) = 44.432$, $p < 0.01$). Post-hoc contrasts showed that the EC group was significantly slower than each of the other conditions, while the YC condition performed significantly faster than SA-VM. In addition, the SA-VM condition was significantly faster that EC but also significantly slower than SA-V, SA-M and YC (see Figs. 5 and 6).

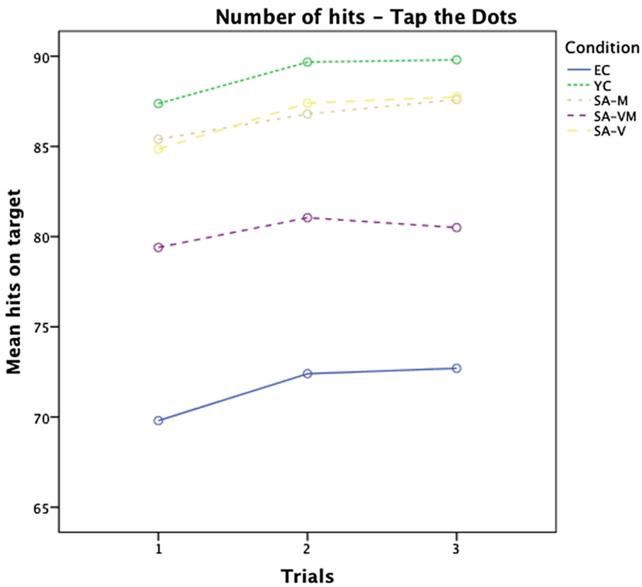

Fig. 5. Mean hits on target for each experimental condition, on three consecutive trials (Tap the Dots application).

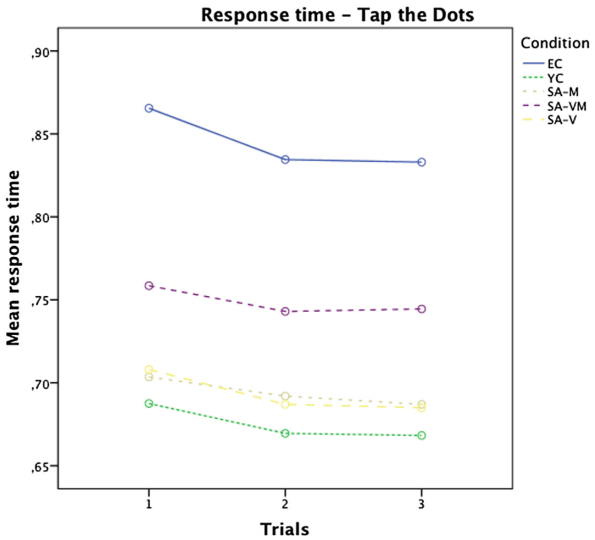

Fig. 6. Mean time response for each experimental condition, on three trials (Tap the Dots application).

4 Discussion and Conclusion

Results indicated that speed and accuracy measures were highly correlated within each task and across tasks, suggesting that the selected tasks were reliable proxies of participants' visuo-motor coordination performance. In the Finger Balance task, participants in the SA-VM sub-condition (combining visual and motor impairment simulation) were significantly slower than participants in the SA-V (only visual) and SA-M (only motor) sub-conditions. In the Tap the Dots task, participants in the SA-VM were significantly less accurate and slower than participants in the SA-V and SA-M sub-conditions. Overall, these results indicate that within the experimental condition, the combination of simulated visual and motor impairment was more detrimental to performance than simulated visual and simulated motor impairment alone. Results of the repeated measure ANOVA revealed a main effect of condition indicating that, as predictable, the elderly group performed at the worst level, while the young adult group performed at the best level. Noteworthy, the young adult group wearing the GERT suit performed on both tasks at intermediate level, indicating that the ageing simulator decreased their visuo-motor coordination performance. Furthermore, the post-hoc contrasts revealed that for both tasks, the combination of simulated visual and motor impairment determined the best approximation of the performance of the normative elderly group, indicating that the visual and motor modules of the GERT had an additive detrimental effect on users' speed and accuracy. Overall, these preliminary findings suggest that the ageing simulator suit could be used to model, at least in an approximate order, the effects of age-related visuo-motor impairments on interactive tasks involving mobile applications. The "first-person" experience of sensory and physical challenges associated with aging generated by the GERT (or by devices alike) could help designers in gaining a better understanding of these limitations and provide them with new insights concerning the development of more inclusive and accessible user interfaces. Furthermore, the age simulation suit could be potentially used for carrying out preliminary usability tests to evaluate perceptual and motor issues of users' accessibility in mobile interfaces for older people.

Acknowledgments. This work was partially supported by the MIUR grant CTN01-00128-297089 Design4All and by the MDS grant Frail-VR (PE-2013-02355948).

References

1. United Nations: Department of Economic and Social Affairs, Population Division. World Population Ageing (2015)
2. Web Accessibility Initiative: Accessibility, Usability, and Inclusion: Related Aspects of a Web for All. https://www.w3.org/WAI/intro/usable. Accessed 15 Sept 2017
3. Christophersen, J. (ed.): Universal Design: 17 Ways of Thinking and Teaching. Husbanken, Norway (2002)
4. Cannon-Diehl, M.R., Rugari, S.M., Jones, T.S.: High-fidelity simulation for continuing education in nurse anesthesia. AANA J. **80**(3), 191–196 (2012)
5. http://www.age-simulation-suit.com/ Accessed 15 Sept 2017