A WebGL Virtual Reality Exergame for Assessing the Cognitive Capabilities of Elderly People: A Study About Digital Autonomy for Web-Based Applications

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Abstract. Exergames and Virtual Reality are positive technologies which can be effectively used for the assessment and the training of cognitive capabilities in elderly population. The current COVID-19 pandemic and a consistent number of people living in small villages far from big city centers make necessary to develop applications which can be used remotely at the users' homes. Web-based applications, and in particular WebGL, are a promising technology to cope with such needs and to design instruments for active ageing. Here, we propose a WebGL exergame for the assessment of cognitive capabilities of elderly people, and a web-based procedure to offer the game and to collect data. In this paper, we assess (i) the digital autonomy of a group of volunteers who tested the web-based exergame, and (ii) the potentiality of Unity WebGL build to create non-immersive Virtual Reality environments.

Keywords: Cognitive assessment · Web-based virtual reality · Human-computer interaction · Positive technology · Serious games

1 Introduction

The continuous growth of the population average age can produce a stress of the socio-health structures that in turn can negatively affect the wellbeing of elderly people. The information and communications technology (ICT)-based applications can be a tool that on the one hand helps therapists and doctors in their activities and on the other hand provides assessment techniques that are more acceptable by elderly people [9,10]. By considering the incidence of neurodegenerative diseases that are specific of aging and the impact on the fragile individuals and their family [13,15], the cognitive assessments are an important part of the medical activities. As a consequence, there is the need of changing the usual methods of performing the cognitive assessment of elderly people, since such methods are nowadays mainly based on paper-pencil tests. Such kind of tests are time consuming for the medical staff and can produce discomfort to

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the fragile individual. A solution based on human-computer interaction (HCI) in non immersive virtual reality (VR), as a exergame, can solve both problems: it can be carried out without a full commitment of the doctor (i.e. the elderly individual can perform the task in an autonomous way) and can be experienced by the elderly person as an enjoyable activity. In this context, VR can be seen as a positive technology [16].

We can also consider another important aspect that starting from February 2020 became more evident, due to the COVID-19 pandemic: the need of performing medical assessment possibly without the physical presence of the doctors. Relevance of such techniques is however general, e.g. persons living in rural and alpine areas not well connected with villages nearby [8].

Related Work. To have mobile and wearable technologies in healthcare for the ageing population is an emerging need of the modern society [10]. Recently, reviews highlighted the fact that ICT technologies can be a new promising tool for managing the frailty [4,7]. Indeed, the use of exergames and new interactive technologies, such as VR, has increased in the last few years [14]. Several cognitive functions are addressed by using different devices. By exploiting PCs, working memory, attention, and problem solving are considered, e.g. in [3]. Recognition, orientation and reasoning are addressed, e.g. in [1], by using tablet. VR has been employed to consider executive functions and spatial abilities, e.g. [5]. Recent studies take also into account the involvement of the elderly people in design of the service in order to increase their engagement, e.g. [17].

Aims of this Paper. In this paper, we propose a cognitive assessment tool, implemented through an exergame, that can be performed remotely on the web by using commonly available devices. Our tool provides an easy access to an application that can be used by elderly people without specific devices and with a minimum support by the doctor. Moreover, such an application could provide a continuous assessment of the elderly individuals instead of the sporadic assessment of the traditional tests, by producing more information for the medical service. It is worth noting that such approach can be without stress for elderly people, since they play a game at their own home or in a familiar context (without the presence of a doctor or in a clinic). To this aim, we extend and improve an exergame, a Virtual Supermarket, which has been presented in [2] for assessing people with Mild Cognitive Impairment (MCI) [6]. In this pilot study, we want to assess whether people (both elderly and not) are able to use a web-based exergame in an independent way, thus providing information about their autonomy in using ICT applications and the knowledge for developing games with specific medical targets. Indeed, few works are aimed to assess on how ICT application are used by fragile people [4]. Web-based application have several advantages with respect standard applications, in particular they do not need installation and configuration, but they are directly accessible trough the web. Moreover, web-based games are easier to update than traditional applications for specific devices.

2 Materials and Methods

2.1 The Virtual Supermarket Environment

As a followup of an already assessed exergame, we have implemented a web-based version of a Virtual Supermarket [2,11,12]. The exergame mimics the steps necessary to buy items at a supermarket. The user receives a list of items he/she should buy, and he/she has to find them in three shelves. Once the correct item has been found, it could be added to the basket by clicking on it. At any time, the user can see the content of the basket, possibly removing undesired items. The last step is to pay the total due amount, by choosing the right banknotes and coins.

In the previous works, we have assessed several interaction techniques, to find the most suitable one for elderly people, and we compared the quantitative results obtained with the exergame (e.g. total time to complete the task) with the scores provided by some state-of-the-art paper and pencil tests for MCI evaluation. In all the previous experiments, an experimenter, expert in the field, was always present to help subjects with practical issues. In this work, we are focusing on the web-based interface and on the possibility of collecting data without the physical presence of an experimenter.

2.2 The Software Framework

The Virtual Supermarket exergame is developed in Unity 3D (2020.1.6f1), by exploiting WebGL (Web-based Graphics Library) build. WebGL[1] is a JavaScript API for rendering high-performance interactive 3D and 2D graphics within any compatible web browser without the use of plug-ins. WebGL does so by introducing an API that closely conforms to OpenGL ES 2.0 that can be used in HTML5 <canvas> elements. This conformance makes it possible for the API to take advantage of hardware graphics acceleration provided by the user's device. Unity 3D can directly publish a WebGL build, i.e. the HTML5/Javascript program. Unity WebGL content is supported in the current versions of most major browsers on the desktop. Mobile devices are not supported by Unity WebGL, thus our analysis has been performed on PC desktops, only, despite the results discussed in [12], showing that some people would prefer a touch based interaction.

The application runs on the client side, thus we expect differences in the graphic quality of the exergame. In order to collect and analyze the recorded data (time to complete the task and errors in the number or kind of items put in the basket), we have implemented a method to send such data to the server. In WebGL applications, due to security implications, JavaScript code does not have direct access to IP Sockets to implement network connectivity. As a result, the .NET networking classes (i.e., everything in the System.Net namespace, particularly System.Net.Sockets) are non-functional in WebGL. For

[1] https://www.khronos.org/webgl/.

this reason, we used the UnityWebRequest systems, which allows us to post a message to the HTTP server.

2.3 Collected Data

The Virtual Supermarket exergame records and stores the following data: the ID associated to the user, the list of items provided to the user, the final list of items put in the basket by the user, the number of changes in the basket (added and removed items), the total amount to be paid, and the amount actually paid.

In addition, we store the answers to a questionnaire, specifically designed for the experiment presented in this paper, whose required information are:

- Age, Gender, Qualification, Current occupation
- Familiarity with gaming (10-point Likert-scale)
- Familiarity with shopping (10-point Likert-scale)
- Satisfaction with the Virtual Supermarket game (10-point Likert-scale)
- Easiness of interaction (10-point Likert-scale)
- Difficulties in finding items on the shelves
- Free comments.

2.4 Experimental Procedure

We have set up a web page with all the steps necessary for participating to the experiment. The procedure is shown in Fig. 1. First, the user is instructed about the purposes of the study and about the rules of the VR game, then he/she is asked to fill the privacy consensus, accordingly to the General Data Protection Regulation (GDPR). A random number is shown to the user, then he/she is asked to open the web page of the game. The given number must be inserted in a form, then the game begins, and proceeds like previously explained. At the end of the game, recorded data (see Subsect. 2.3) are sent to the server and the evaluation questionnaire is shown to the user. The experiment lasts about 20 min (depending on the time to fill the basket, since there are no timing constraints).

2.5 Data Analysis

For the purposes of this work, we analyze and discuss the following measurements:

- Total time to complete the shopping and the payment task. In a previous work [11] we discussed the relationships among these values and the scores of the questionnaires used to evaluate the cognitive impairment. Nevertheless, such values are also related to the technical skills of the users and with his/her familiarity with the use of PCs. In our case, all the participants are not affected by MCI, thus we expect that only the technical skills affect the measured values.
- Satisfaction with the Virtual Supermarket game and easiness of interaction, with respect to age, familiarity with games and with shopping in real supermarkets.
- Qualitative discussion of the free comments.

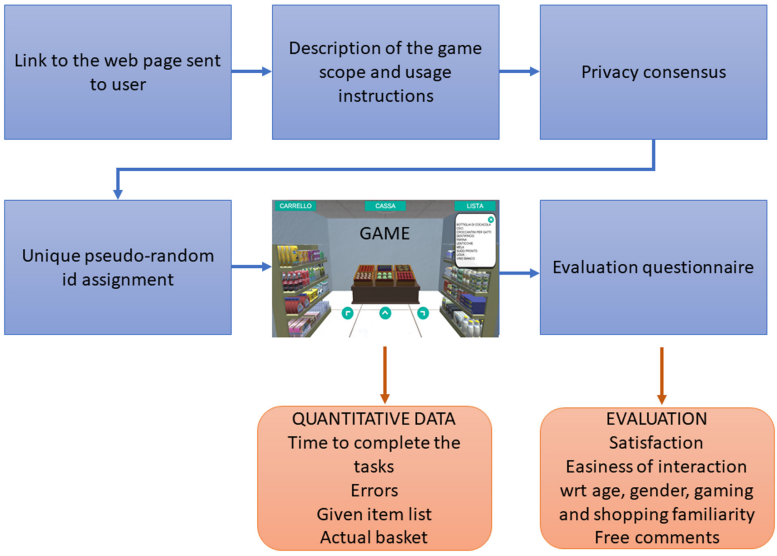

Fig. 1. The experimental procedure (blue boxes) and the collected data (orange boxes). (Color figure online)

3 Results

Participants. 19 people participated to the experiment (8 males, 11 females, mean age 44.3 ± 18.6) They were recruited through messages sent to friends. All the instructions were written in a dedicated web page, no other hints were provided to the participants. 5 more potential participants were not able to complete the experiment, due to technical problem (e.g., poor connection or not sufficient skills to understand the procedure).

Total Time. The mean time to complete the shopping task (i.e. to localize and put all the items in the basket) is $4\,\mathrm{m}\,1\,\mathrm{s} \pm 2\,\mathrm{m}\ 22\,\mathrm{s}$; the mean time to complete the payment task is $22\,\mathrm{s} \pm 7\,\mathrm{s}$.

Task Errors. Almost all the users did no errors in the shopping task. By analyzing the provided list and the list of items actually out in the basket is clear that errors are due to misunderstanding in the visual representation of the items. This may be caused by a poor quality of the textures for certain devices, or by a misleading choice of elements (e.g. the difference between olive oil and white wine which have similar shapes and colors). All the users did no errors in the payment task. We expected this results, since the users do not have any cognitive impairment, and the game implements an easy task for cognitive healthy people.

Satisfaction and Easiness. On a Likert-scale from 1 to 10, the mean score for the satisfaction is 8.0 ± 2.4, the mean score for the easiness of interaction is 7.3 ± 2.5.

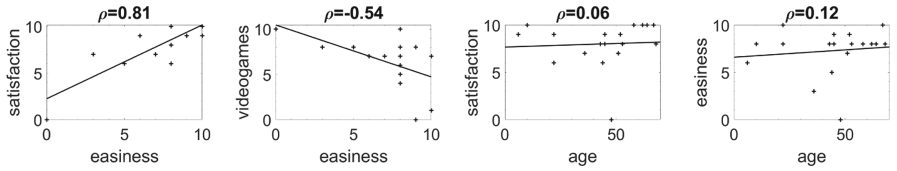

Fig. 2. Correlation among age, familiarity with videogames, perceived satisfaction in using the exergame and perceived easiness of interaction. Values on axes are the scores given on a Likert-scale from 1 to 10.

53% of the users found some difficulties in finding the right items on the shelves, 1 person reported serious problems in solving the shopping task. 89% of the users found the instructions clear. To understand whether there are correlation among the age of the participants, their familiarity with videogames, the perceived satisfaction from the game and the perceived easiness of interaction, we plot the scores and the associated correlation (Pearson) values. Figure 2 shows that a positive strong correlation exists between easiness of interaction and satisfaction ($\rho = 0.81$), a mild negative correlation is present between familiarity with videogames and easiness of interaction, probably due to higher expectations from gamers, and no correlation has been found with ages. Finally, no strong correlation has been found between the score given to the easiness of interaction and the total time necessary to complete the task ($\rho = 0.17$).

Free Comments. In the free text comments, people described the encountered difficulties, which are the following: difficulties in detecting the correct item due to poor quality of the textures (this is also related to the resolution of the display), or to the small dimension of the objects. Most of the problems are HCI issues, such as wrong double clicks on objects, or bugs in the visualization due to the behaviour of WebGL with non-conventional display resolutions. Sometimes, delays caused the insertion of multiple copies of the same item, the cause of this is under investigation, and it might be due to network problem as well to slow PCs. Some comments suggested improvements in the layout of the supermarket, asking for a more realistic layout to improve navigation among shelves.

4 Discussion and Conclusions

With respect to the paper aims, the results of this pilot study allow us to draw the following conclusions:

(i) The pipeline for collecting data without the assistance of the experimenter works, but about 20% of the recruited participants encountered problems, which did not allow them to complete the task. This could be due to the chosen platform (WebGL which does not have full supports for some devices, e.g. mobile ones) or to misleading and not precise written instructions. This aspect should be carefully addressed in order to effectively use the web-based instruments in hospitals, retire homes or directly at elderly houses.

(ii) The Unity WebGL build allowed us to distribute a previously developed game with few modifications. The game worked properly in most cases, nevertheless some participants had technically problems, which hampered the correct fruition of the game. Most of the problems were due to display resolution settings, or out-of-date browsers.
(iii) The usability of the Virtual Supermarket was already assessed in [2,12]. Here, we focused on the usability by considering the WebGL build. One of the main issues was the poor quality of the textures, this may be due to the rendering limits of WebGL applications. Items could be dynamically enlarged, thus allowing a better visualization, but the cost of adding a new feature, in terms of usability, must be evaluated.
(iv) The collected data and feedback allow us to devise the future improvements of the Virtual Supermarket, e.g. to re-arrange shelves to facilitate the research of items or to enlarge items.

As a final remark, data were collected in a time span of 24 h, thus demonstrating the possibility of reaching a large number of participants in an easy way. This would have interesting and useful implication for all the research activities involving human participants during the COVID-19 pandemic.

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