Distinguishing Aging Clusters and Mobile Devices by Hand-Wrist Articulation: A Case of Study

Daniel Palacios-Alonso[1,2](✉), Carlos Lázaro-Carrascosa[1,2], Raquel Mas-García[1], José Manuel Ferrández Vicente[3], Andrés Gómez-Rodellar[2], and Pedro Gómez-Vilda[2]

[1] Escuela Técnica Superior de Ingeniería Informática, Universidad Rey Juan Carlos, Campus de Móstoles, Tulipán, s/n, 28933 Móstoles, Madrid, Spain
daniel.palacios@urjc.es

[2] Neuromorphic Speech Processing Lab, Center for Biomedical Technology, Universidad Politécnica de Madrid, Campus de Montegancedo, 28223 Pozuelo de Alarcón, Madrid, Spain

[3] Universidad Politécnica de Cartagena, Campus Universitario Muralla del Mar, Pza. Hospital 1, 30202 Cartagena, Spain

Abstract. Nowadays, video games are not considered only mere hobbies. The use of these tools is increased in last years. On the other hand, gamification and usability techniques have empowered the improvement of communication between player/user and Aided Communication Devices (ACD). New ACDs provide a novel approach to capture biomechanical features or indicators. This work consists of a novel methodology development to capture biomechanical indicators throughout multiplatform video games. The present work has an exploratory nature to measure, hand-wrist articulation features estimated from the smartphone's accelerometer. The intention of the study is to answer some hypothesis for instance, if the device is crucial to evaluate player's movement capabilities or if the age of the person as a key biomarker. Once these indicators have been tested, it will be able to use them in studies of neurodegenerative diseases, where involuntary tremor is one of the most important observable correlates.

Keywords: Hand-wrist articulation · Video games · Gamification · Mobile devices · Neurodegenerative diseases

1 Introduction

When speaking about a case of study or proof of concept, one of the aims is to find an objective method which produces always consistent results. However, some well-known scales, such as Hoëhn-Yahr [9] or UPDRS [7], which are used to diagnose the grade or level of symptom severity in Parkinson's Disease (PD) patients do not satisfy this premise because two raters could produce different

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scores for the same patient using the same rating scale. This methodology is based on the subjective opinion of the clinician. The rater is going to review a list of items where each item has a lower and upper limit. That is where a subjective decision of the professional comes in. This decision could be crucial due to the waiting list in health services. Depending on the speciality and clinical diagnosis, patients must wait between four and eighteen months for their next clinical revision. Furthermore, it must also be remembered that posology and dosing must be subject to frequent revision and updating. For this reason, it is necessary to design and develop a methodology reproducible, simple and ubiquitous to assess the conditions of the patient in any circumstance.

According to the results of Tardon's work [8], the serious video games and gamification are a powerful tool for direct social transformation in several fields: health improvement [4], learning [10], work performance [11], etc. Furthermore, as is well known, the industry of video games has clearly grown fast in last years and the use of video games in biomedical research has been notable [17] but not without critical voices in this approach [2,3]. On the other hand, the use of video consoles such as Wii of Nintendo® in biomedicine is a reality [14]. Moreover, in the rehabilitation area, video games are a novel approach and are used as well [16,18].

The contribution of this work is to propose and assess a methodology to capture and monitor biomechanical features throughout the use of a hand-held video game. The calculated trait and the hand-wrist articulation, were estimated from the smartphone's accelerometer through a video game using a mobile device.

This paper is organized as follows. In Sect. 2, we introduce the proposed methods. The following section, the materials used. Results are shown and discussed in Sect. 4. And finally, conclusions are presented in Sect. 5.

2 Methods

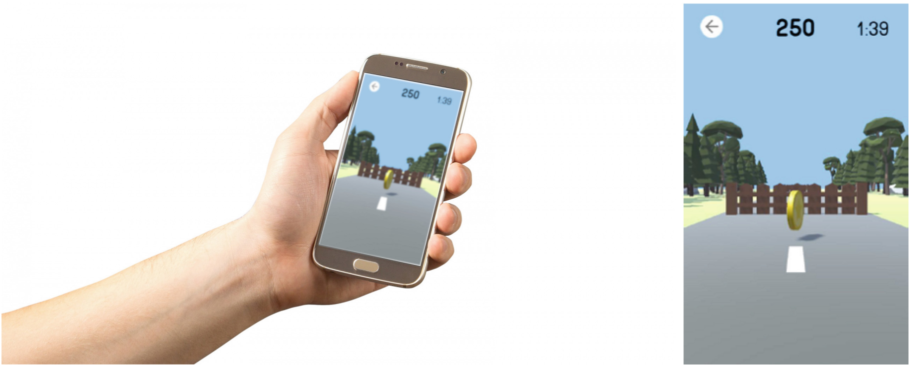
2.1 Objectives

In what follows, the objectives that are to be achieved at the beginning of this work will be presented. To monitor player's activity it is necessary to design and develop two questionnaires. The first one is based on an enrolment form to know the initial conditions of the user, and consists of items such as user code, age, gender, region, country, current diseases, and in its case, prescriptions and dosage in the moment of the enrolment. This form is presented only the first time. The second one is the dialy questionnaire, which must take into account occasional data, as the circumstantial use of a painkiller, antihistaminics, antibiotics, etc., to have into account any possible factors which could alter patient's neuromotor conditions beforehand at each session start. Once the state of the player is assessed, the a priori conditions of the hand-wrist articulation will be monitored using the smart device accelerometer, to be saved in the server database.

2.2 Methodology

The experiment consists of three stages: Home, Game and Scores. During the Game, the player must turn the wrist from the right to left, and vice-versa, as in driving a car in both directions. This movement is similar to turn the steering wheel in a car. In Fig. 1a an example of the game interface is illustrated.

The experiment is based on the development of a first-person racing video game, where the player has to collect the highest number of coins on the road, as it may be seen in Fig. 1b. The number of coins collected is an indication of the ability of the player to stay within the road limits, if this number is below a given value, an alarm will warn the players to improve their performance. Furthermore, the game has some props for a high quality immersive experience, for example, trees, road, grass, and other details. On the other hand, there are distractor objects such as stones and fences. The last ones are obstacles that slow down the race. If the player crashes with these objects, the car stops. However, if the players pulls back the mobile device towards their chest, the car jumps these obstacles and continue the race. In every single moment of the game, the device captures the accelerometer's outcomes. This information is sent via a 4G connection to the database server.



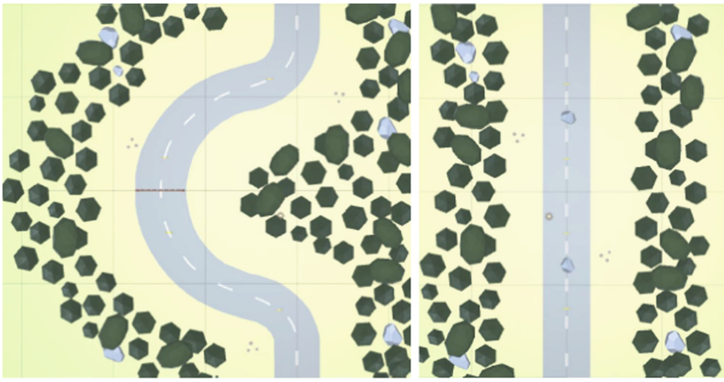
(a) Mode of use the device. (b) Screenshot of racing game.

Fig. 1. Capture of racing video game.

2.3 Technical Description of Video Game

The game controller is in charge of starting the game, managing the objects and ending the game. This controller generates the roadmap dynamically in real time, using eleven different roads aspects as the ones depicted in Fig. 2a and b, respectively. It was necessary to create checkpoints, which informed the controller when it had to draw the next road. The checkpoints are hidden to players.

Simple and little overloaded interfaces have been contemplated because the target user may not be familiar with video games lore. Big font sizes to facilitate the reading and large buttons were used as well. The naming of the screens and texts were very descriptive.



(a) Curved road with fence. (b) Straight road with two stones.

Fig. 2. Kind of roads for the racing game.

2.4 Framework and Hardware

The application has been developed as a 3D project in Unity [1]. The version used was 5.6.1 because of its stability, fixed bugs, and online documentation. The operative system used in the laptop was Windows 10. Considering that the application was addressed to mobile devices (smartphones and tablets), the use of external libraries of Android and Java was required. Therefore, Android version 24.4.1 of the Software Development Kit (SDK) and Java Development Kit (version 1.8.0) were included. On the other hand, e-mail management required the use of a Dynamic Link Library (DLL) as a project dependency.

Two groups were involved in the proof of concept: end-users and contrast-users. Each group tested the proof in different devices. The first group used a smartphone Huawei P8 Lite with two GB of RAM, sixteen GB of memory, octa-core, a screen of 5.2 in., and Android version 6.0. The contrast group used a tablet Bq Elcano with a GB of RAM, sixteen GB of memory, dual-core, a screen of seven inches, and Android version 4.1.2.

2.5 Statistical Methods

One-Sample Kolmogorov-Smirnov Test is a non-parametric statistical test which is used to assess if a variable follows a given distribution in a population [13]. The null hypothesis for the Kolmogorov-Smirnov test is rejected if its $p{-}value < 0.05$, this means that the data is normally distributed, otherwise, the distribution is not normally distributed [5]. The K-S test measures the largest distance between the empirical distribution function(EDF) $F_{data}(x)$ and the theoretical function $F_0(x)$ [19]. Let $F_0(x)$ is the cumulative distribution function (cdf) of the hypothesized distribution and $F_{data}(x)$ is the EDF of your observed data. The expression of KS-test:

$$D = sup_x|F_0(x) - F_{data}(x)| \tag{1}$$

Parametric test: t-Student is a statistical test which is used to compare the mean of two groups of samples, assessing if the means of the two sets of data are significantly different from each other [5]. The unpaired two sample T_test has been used, used to compare the mean of two independent samples, where its expression is given in Eq. (2) X and Y represent the two groups to compare; m_X and m_Y being the means of groups, respectively. Finally, n_X and n_Y represent the group sizes.

$$T = \frac{m_X - m_Y}{\sqrt{\frac{\sigma^2}{n_X} + \frac{\sigma^2}{n_Y}}} \tag{2}$$

Non-Parametric test: Mann-Whitney U test is the non-parametric alternative to the independent T-test [12]. The test compares two distributions. If these samples are part of the same population, the null hypothesis is not rejected. Otherwise, an alternate null hypothesis is that the two samples belong to the same distribution, that is to say, both samples have the same median. Let X and Y are the distributions, respectively. R is the sum of ranks in the sample, and n is the number of items in the sample.

$$U_1 = R_1 - \frac{n_X(n_X+1)}{2}; U_2 = R_2 - \frac{n_Y(n_Y+1)}{2} \tag{3}$$

Cohen's Coefficient or Size effect is determined by calculating the mean difference between two groups M_1 and M_2, respectively, and then dividing the result by the standard deviation of the pooled population [6,15]. This coefficient is used to measure the differences among samples when the T-Student or U-Mann-Whitney tests are used.

$$d = \frac{M_1 - M_2}{\sigma} \tag{4}$$

3 Materials

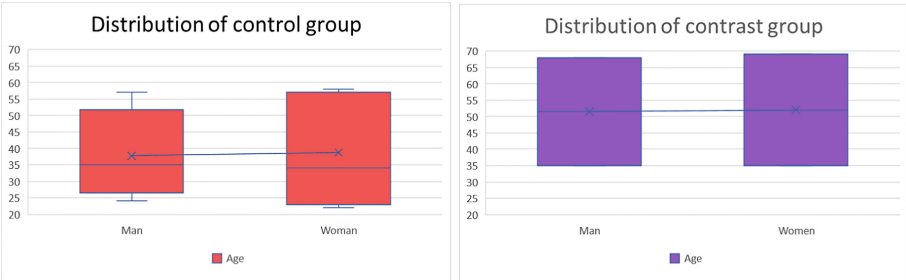
3.1 Corpora

The corpus consists of two groups, control (nine volunteers) and contrast (four volunteers). The number of participant users was thirteen of different ages and genders and they did not have any neurodegenerative disease at the moment of the experiment. The *Kolmogorov-Smirnov test* was used to assess the distributions and it was concluded that both distributions are normal as their p-values were higher than 0.05 as shown in Fig. 3. In Fig. 4 the boxplots of both datasets are shown.

One-Sample Kolmogorov-Smirnov Test

		AVERAGE
N		13
Normal Parameters(a,b)	Mean	1,80581681
	Std. Deviation	,889302271
Most Extreme Differences	Absolute	,226
	Positive	,226
	Negative	-,196
Kolmogorov-Smirnov Z		,814
Asymp. Sig. (2-tailed)		,521
a Test distribution is Normal.		
b Calculated from data.		

Fig. 3. Summary of one-sample Kolmogorov-Smirnov test with 95% confidence interval.



(a) Distribution of control group. (b) Distribution of contrast group.

Fig. 4. Capture of both datasets.

3.2 Control Group

The control group was composed of the nine volunteers (familiars and friends) with ages between 22 and 58 years old, five of whom were women and four men. The details are shown in Table 1.

3.3 Contrast Group

The contrast group was composed of four volunteers (relatives and friends) with ages between 35 and 69 years old, of whom two were women and two men. The details are shown in Table 2.

Table 1. Corpus of control group.

ID	Age	Gender	Competence in video games
A1	24	Male	High
A2	22	Female	Medium
A3	23	Female	High
B1	34	Female	Medium
B2	36	Male	High
B3	34	Male	High
C1	56	Female	High
C2	57	Male	Medium
C3	58	Female	Low

Table 2. Corpus of contrast group.

ID	Age	Gender	Competence in video games
ContrastB1	35	Male	High
ContrastB2	35	Female	Medium
ContrastC1	68	Male	High
ContrastC2	69	Female	Low

4 Results

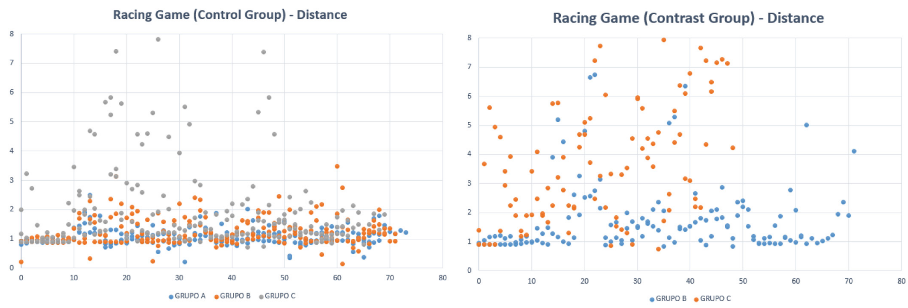
The results presented in this paper are extracted from a game session with a duration of 2 min. The volunteers did not know this game in advance. In this way, all participants had the same opportunities and level of knowledge about the test, game, and the scenario at the beginning of test.

As it was explained before, the statistical tests used in the evaluation were T-test, U-test and Cohen's Coefficient. Given the number of samples in both dataset it was necessary to check the values with parametric and non-parametric approaches, because parametric methods assume a statistical distribution in data. However, non-parametric techniques do not require these initial conditions.

The outcomes of the test are depicted in the following pictures Fig. 5a for the control group and Fig. 5b for the contrast group, respectively.

The results are divided into three categories, such as *aging test, smartphone tests, and tablet tests*. Cluster A includes people between 20 and 30 years old. The second cluster (B) includes volunteers between 31 and 50 years old. Finally, the last cluster is composed of players between 51 to 70 years old.

The outcomes are depicted in Table 3 for women and men, regardless of the specific device used. Analyzing the results, it may be noticed that the significant results were obtained in comparing cluster C with A and B, being both tests, parametric and non-parametric, the null hypothesis being rejected with 95% confidence interval. Furthermore, Cohen's coefficient reveals a negative value



(a) (b)

Fig. 5. Results to a session of racing game. Left (a): values of distance respect the middle of road of control group. Cluster A (blue), Cluster B (orange) and Cluster C (grey). Right (b): values of distance respect the middle of road of contrast group. Cluster B (blue) and Cluster C (orange). (Color figure online)

greater than −1.15 (kappa value), in others words, the distributions can be considered different.

Table 3. Summary of results according to the age of volunteers.

Test	T-student	Mann-Whitney test	Cohen coefficient
Cluster A vs B	0.057 (No)	0.101 (No)	
Cluster A vs C	**0.021 (Yes)**	**0.025 (Yes)**	**−1.762**
Cluster A vs (B U C)	0.101 (No)	0.028 (Yes)	−1.10
Cluster B vs C	**0.042 (Yes)**	**0.016 (Yes)**	**−1.515**
Cluster B vs (A U C)	0.260 (No)	0.380 (No)	
Cluster C vs (A U B)	0.032 (No)	0.005 (No)	−1.98

Table 4 shows results using only the smartphone. Once again, cluster C seems to be different in both techniques and Cohen's coefficient asserts this condition with respect to cluster A and B even when the third cluster is compared with the union of both.

Table 4. Summary of results from the smartphone.

Test	T-student	Mann-Whitney test	Cohen coefficient
Cluster A vs B	0.215 (No)	0.275 (No)	
Cluster A vs C	**0.015 (Yes)**	**0.05 (Yes)**	**−5.06**
Cluster A vs (B U C)	0.078 (No)	0.071 (No)	
Cluster B vs C	**0.012 (Yes)**	**0.05 (Yes)**	**−2.86**
Cluster B vs (A U C)	0.411 (No)	0.606 (No)	
Cluster C vs (A U B)	**0.006 (Yes)**	**0.02 (Yes)**	**−4.15**

Table 5. Summary of results according to the tablet.

Test	T-student	Mann-Whitney test	Cohen Coefficient
Cluster B vs C	**0.008 (Yes)**	0.121 (No)	**−13.45**

Table 6. Summary of results according to devices and age.

Test	T-student	Mann-Whitney test	Cohen coefficient
Smartphone vs Tablet	0.097(No)	**0.045 (Yes)**	**−1.76**
Smartphone vs Tablet with Cluster B	**0.033 (Yes)**	0.083 (No)	**−2.15**
Smartphone vs Tablet with Cluster C	**0.002 (Yes)**	0.083 (No)	**−7.61**

The test results obtained with the tablet are given in Table 5, where T-Student rejects the initial hypothesis with a rather low value (0.008). However, the U-test does not reject the hypothesis. Nevertheless, Cohen's coefficient returns a high negative value (−13.45), being the lowest value obtained for all tests.

Finally, Table 6 describes the results having into account the devices and the age of players. In this case, T-Student rejects the initial hypothesis in two tests and the U-test only on one occasion. However, both tests have never coincided.

5 Conclusions

The use of video games in biomedical applications is a hot topic. Through the present exploratory study a first approach to this problem under a systematic methodology has been presented. Although limited by the small number of samples included, the most relevant findings derived are the following:

- The third cluster, the elder players, had produced the highest difference respect to the two other groups, that is to say, the young and middle-aged populations. This fact is illustrated when the tests reject the null hypothesis with a p-value less than 0.05 and with a rather high Cohen's coefficient.
- It seems that the devices are a key point in producing this kind of results. The use of a tablet or smartphone produces distinct outcomes. Of course, there are several factors to be taken into account such as weight, performance, and size of devices. It is worth to highlight that the smartphone used is a medium-range device but the tablet is a bottom-range device. Nevertheless, this fact allows a further reflection: it is not necessary to use a top-range device to produce significant results in this type of study.
- Although the outcomes of this research are very promising, a drawback in this exploratory study is the number of samples. For this reason, the continuation of the study foresees two main ideas: Firstly, increasing the number of samples with both devices using another game mode, for example, a third-person mode, where the player can visualize the car instead of being inside the car. Secondly, releasing the video game in Play Store (Android) or App Store (Apple) to recruit more samples.

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