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Differences in hand acceleration and digital reaction time between different skill levels of Counter Strike players

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ABSTRACT

Due to the international prominence that eSports are acquiring, it is necessary to study their effects on human behavior. Specifically, the difference between the motor skills of players with different levels of experience. Therefore, the main objective of this work is to observe whether there are differences in hand accelerations (mouse handling) and digital reaction time between different skill levels. 21 subjects participated and were grouped according to their skill level (Low, Intermediate and Elite levels). The results showed greater hand accelerations in the Elite and Intermediate Skills players than Low-Skill players ($p < 0.05$). The hand-eye reaction time was lower in the Elite-Skill group than in the Low-Skill group ($p = 0.008$). Those with a Low-Skill had a higher dots per inch (DPI) than those with Intermediate and Elite Skills ($p < 0.05$). Elite-Skill players used larger screens than Low-Skill players ($p = 0.034$). The results suggest that players with better skills have better hand acceleration and shorter hand-eye reaction time.

1. Introduction

In recent years, the culture of video games and the competitive phenomenon of eSports (electronic sports) has grown exponentially, becoming a field of special interest [15,24]. Therefore, as it has grown, the study of its effects on people has increased. For example, scientific literature shows how exposure of the organism to visually altered environments (e.g., video games) often results in a modification of the visual system itself [9,22,25]. Normally, the use of any type of video game produces improvements in the task or objective of the video game being played [14,22]. Specifically, focusing on action video games, it can also be found that they are capable of altering a wide range of visual abilities, such as selective visual attention, visual short-term memory, or visual dissociation [11,18]. According to Bavelier, Achtman, Mani and Föcker [3], this could be understood as a greater efficiency among active players to filter relevant and irrelevant information and place greater attention towards certain aspects in a more automated way [5].

When entering the genre of First Person Shooters (FPS) video games, it is observed how different actions and strategies are required in their players to react quickly to the visual and auditory stimuli presented and to adapt and control the responses in a context of permanent change. The practice of this type of game, in addition to the alterations at the visual level, reports improvements in the performance of intermittent and fast tasks.

Studies carried out with the video game *Counter-Strike: Global Offensive* (CS:GO), which is the most popular FPS and, in addition, is one of the pioneering games with the largest player base worldwide [28], have shown that regular players could have improvements in hand coordination in tasks where precision, control, direction and rhythm of execution prevail [7]. It should be noted that CS:GO is dominated by hand-eye coordination, the level of which is directly proportional to accuracy. Therefore, studies have been interested in the variables related to hand-eye reaction time and visual coordination and precision, which have been analyzed in many ways in the field of sports performance and motor control learning [8,26].

This type of study has shown that eye movements and hand movements are related in terms of speed and precision as well as the time a player spends using one instrument or another during the game (i.e.,

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mouse and keyboard scroll buttons) and his or her skill level [19].

The aforementioned work on the interaction between eye movement and hand movements is key in CS:GO, as the game is played using the mouse, moving it towards the visual stimuli occurring on the screen. Even so, these studies have not considered certain factors that could be relevant when obtaining the results, such as the number of accelerations and displacements generated by the hand or the configuration of the instruments. For example, although it is known that there are different screen sizes in gaming peripheral monitors and that the mouse sensitivity setting during scrolling can vary, no studies have been found to date that can provide information in this regard.

In summary, although recent literature has shown that people with high level and/or experience in action games, such as CS:GO, show improved cognitive and motor skills, such as processing speed, visual search, spatial memory, or response inhibition [4,12,17,20], differences in hand accelerations (handling the mouse) and digital reaction time between different skill levels have not yet been observed. That is why this is the main aim of the present work.

Differences between levels in other aspects that could be of interest, such as the configuration parameters of the game itself or the size of the peripheral monitor screens, have also been explored since these are factors that can influence the magnitude of the accelerations.

2. Methods

2.1. Design and participants

For our study, we opted for a simple prospective design in which the formation of groups was based on the range of play possessed by everyone in competitive games. This contains a total of 18 ranks to differentiate the level of the players (Fig. 1). This factor was used as an independent variable and is determined by a complex mathematical calculation performed by the game based on the number of victories, the rank of the other players you have defeated, and parameters such as the victim/death ratio (times you kill, times you are killed). It could be said that the rank is a faithful indicator of the level of skill in the game.

Through non-probabilistic convenience sampling 21 subjects were recruited. These subjects aged 18–35 years (Mean = 27.6; Standard Deviation = 1.9) were distributed into 3 groups, one group with an Elite Skill (ranges Master guardian elite to The global elite), one Intermediate Skill group (ranges Gold nova I to Master guardian II), and Low Skill group (ranges Silver I to Silver elite master) as has been recommended previously [26].

The inclusion criteria were: i) to be older than 18 years of age; ii) not to suffer neurological or other diseases that could affect their motor control, iii) not to have functional or motor disability; iv) not to have suffered upper limb injuries during the last 6 months; v) not to suffer any other alteration or pathology that could affect hand-eye coordination, vi) to have played *Counter-Strike* for more than 10 h, and to belong to one of the skill ranges granted by the game. In addition, they were asked not to consume any stimulant substance 24 h before the measurements. In addition, they were informed of the anonymity of the experiment and gave their written consent to the processing of the data derived from their performances. All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Experimental procedure

Before starting, the participants were informed of the characteristics of the measurement, and it was emphasized that the players should naturally play the game without considering the observation that was being made.

First, the eye-hand reaction time test on a mobile device was performed by the Reaction Time application (Banensoft, Alicante, Spain). This consisted of pressing the green circle appearing on the screen as quickly as possible. The circle appeared on whatever place on the screen after a random period of time between 3 and 5 s. Some previous variations and adaptations of this type of test have been successfully used to measure reaction time in different studies [1,10,16]. Each subject performed five attempts of the test.

Once the test was completed, the value of the mouse sensitivity or dots per inch (DPI) used by participants during the CS:GO was annotated as well as the size of the screen they were playing with. These variables are to some extent related to the magnitude of the accelerations since the lower the DPI and the higher the screen size, the higher the accelerations should be produced to reach a point in the screen with the mouse.

In the next step, a glove with a Metawar accelerometer (100 Hz) (MbientLab Inc., San Francisco, USA) was placed on each participant's mouse-holding hand. The sensor was linked to its own application, MetaBase v3.4 (MbientLab Inc., San Francisco, USA), on the mobile

Fig. 1. Competitive ranks, CS:GO.

device via a Bluetooth connection. Subsequently, the experiment proceeded by playing in the *Deathmatch* game mode of the CS:GO by each participant's own computer equipment. The sensor data recording was activated at the start of the 10-minute countdown of the game.

2.3. Data analysis

In each trial of 10 min, accelerometer signals were registered at a frequency of 40 Hz. The analysis of the acceleration signals was performed with the Matlab 2018a program (Mathworks Inc., Natick, USA). On the one hand, the signals were filtered with a Butterworth high-pass filter with a cutoff frequency of 0.5 Hz to remove noise. Then, the following variables were calculated using the ten minutes of signal for each space axis: i. Root Mean Square (RMS), ii. Median Frequency (MF) (Eq. (2)) and iii. Sampling Entropy (SE) (Eq. (3)). The RMS was calculated by Eq.1, where N is the number of data points in the time and x every point. To calculate the MF, the signal spectrum was obtained using the 'periodogram' function of the Signal Processing Toolbox package. The Eq.2 is applied by this function, where $P(f_i)$ is the power spectral density at frequency f_i, and n is the number of frequencies in the spectrum. Finally, the SE was obtained using 0.3 standard deviations as the tolerance parameter and 3 samples as pattern length. On the other hand, the mean reaction time was obtained as the average of the 5 attempts made by each subject and was expressed in milliseconds. In Eq.3 it can be seen observed, where N represents the quantity of data points over time, A signifies the count of comparable vector lengths ($m + 1$) lying within a relative tolerance threshold (r times the standard deviation of the time series), and B denotes the count of comparable vector lengths (m) within the tolerance threshold [23,29].

$$RootMeanSquare = \frac{\sqrt{x_1^2 + x_2^2 \cdots x_3^2}}{N} \tag{1}$$

$$MedianFrequency = \frac{1}{2\pi}\frac{\Sigma_{i=1}^{n} P(f_i)}{\Sigma_{i=1}^{n} P(f_i)/f_i} \tag{2}$$

$$SamplingEntropy(m, r, N) = -\ln\left[\frac{A^{m+1}(r)}{B^{m}(r)}\right] \tag{3}$$

2.4. Statistical analysis

Statistical analysis was performed with the software SPSS 20 (IBM, Armonk, USA). Since the sample size was small, nonparametric tests were applied. A Kruskal-Wallis test was applied to establish differences according to player skill in the variables of mean reaction time, RMS, MF, SE, DPI, and screen size. In the case of finding significant effects, pairwise comparisons with Dunn-Bonferroni adjustment were requested. In addition, Spearman correlations were performed between the dependent variables. The significance level was set at $p = 0.05$ in all analyses.

3. Results

3.1. Player level and reaction time

We found an effect of player level on mean reaction time ($H_2 = 9.34$; $p = 0.009$; ε^2=0.467). Pairwise comparisons showed that reaction time was significantly higher in the Low Skill group than in the Elite Skill group ($p = 0.008$). Descriptive data can be seen in Fig. 2A.

3.2. Player level and accelerations during the game

An effect of player level on RMS was found on all three axes of space (Table 1). However, this effect was not significant on MF or SE on any of the axes (Table 1). Pairwise comparisons showed that players with Intermediate and Elite Skill obtained a higher RMS on all three axes of space than players with Low Skill (Fig. 3). Pairwise comparisons of RMS, MF, and SE are observed in Fig. 3.

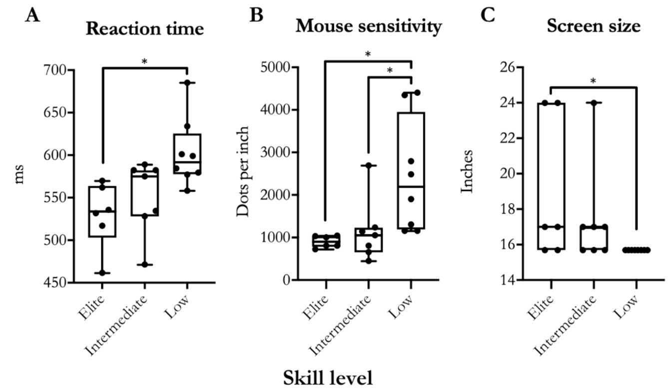

Fig. 2. Descriptive statistics of reaction time (A), mouse sensitivity (B), and screen size (C) were used as a function of player level. * Indicates significant differences.

3.3. Player level and peripheral configuration

Moreover, an effect of player level on DPI ($H_2 = 11.2$; $p = 0.004$; ε^2=0.56) and on the screen size used ($H_2 = 7.47$; $p = 0.02$; ε^2=0.374) was found. It was observed that players with a Low Skill obtained a higher mouse sensitivity or DPI than Intermediate and Elite Skill players ($p < 0.05$) (Fig. 2B). In addition, Elite Skill players used larger screens than Low Skill players ($p < 0.05$) (Fig. 2C). Finally, Spearman correlations showed a significant relationship between DPI and screen size with the RMS value on all three axes of space (Table 2).

4. Discussion

Considering the unpublished nature of the study, the results open a great front of action to further investigate the relationship between the skill level of the CS:GO video game and the level of human motor skills. The evidence found in the study shows that players with better skills have better hand acceleration and shorter hand-eye reaction time in response to visual stimuli.

On the one hand, the increase in the RMS value for Elite Skill players in the three axes of space in the hand accelerations could be interpreted as a greater number of interactions with the mouse of these players during the task, in order to solve the situations that arise during the video game action in a satisfactory manner [19]. However, these interactions should not necessarily be a higher number of accelerations, since the frequency on the three axes of space was not affected by the skill level of the players. We understand, therefore, that the magnitude of the acceleration differentiates one group from another.

Moreover, although in previous studies it was mentioned that players of FPS games prefer to adjust and customize the mouse pointer sensitivity [2], the difference in DPI between different levels has not been observed so far. Through the results of this study, it can be highlighted that higher level players use lower DPI and, therefore, may need a higher magnitude of accelerations to generate cursor (weapon sight) displacements with the mouse. Therefore, it can be stated that, typically, higher-level players prefer to have a lower mouse sensitivity at the cost of generating higher accelerations with the hand in the three axes (i.e., X, Y, and Z). This could help them to be more accurate in placing the weapon sight on the target they are aiming at. To some extent, this strategy could be related to the results obtained in previous studies, where it was shown that Elite Skill players use the mouse to a greater extent than the rest of the players [19], which could be produced by supposedly more efficient fine motor skills, on the part of the former mentioned, to use this instrument [7,27]. Moreover, if we add to this

Table 1
Results of the Kruskal-Wallis test for acceleration parameters.

Variable	Descriptive data *Median (IR)*			Axis	H_2	p-value	ε^2
	Elite	Intermediate	Low				
RMS	0.62 (0.04)	0.5 (0.08)	0.37 (0.03)	X	11.04[a]	0.004	0.507
	0.16 (0.14)	0.11 (0.25)	0.06 (0.05)	Y	12.02[a]	0.002	0.585
	0.89 (0.05)	0.07 (0.08)	0.05 (0.04)	Z	11.72[a]	0.003	0.561
MF	3,06 (1.38)	3.56 (7.36)	2.81 (5.37)	X	1.43	0.49	0.072
	2,61 (1.87)	2.98 (2.21)	3.26 (5.61)	Y	0.68	0.71	0.034
	2,9 (2.45)	3.61 (1.76)	2.88 (6.34)	Z	1.70	0.43	0.087
SE	0.32 (0.21)	0.26 (0.27)	0.24 (0.19)	X	4.93	0.09	0.239
	0.21 (0.09)	0.17 (0.2)	0.21 (0.21)	Y	0.87	0.65	0.047
	0.18 (0.17)	0.16 (0.16)	0.19 (0.22)	Z	0.53	0.77	0.028

RMS = Root mean square; MF = Median frequency; SE = Sampling Entropy.
[a] Indicates significant differences between skill levels ($p < 0.05$).

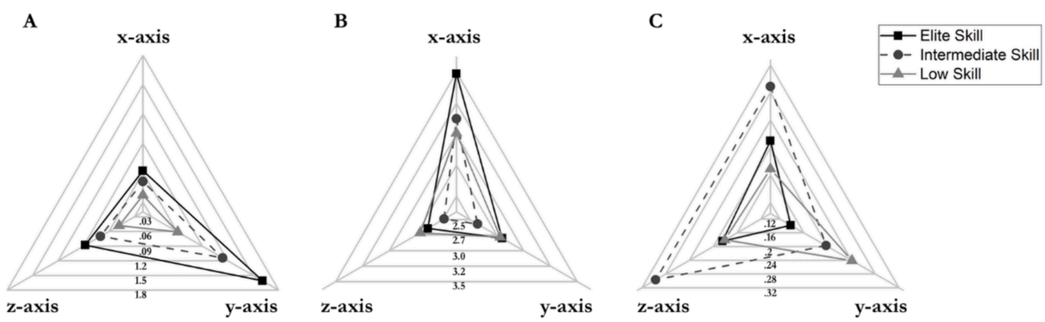

Fig. 3. Pairwise comparisons of accelerations during the game. A = Root Mean Square; B = Sampling Entropy; and C = Median Frequency.

Table 2
Relation of RMS with DPI and the Screen Size.

Variable	Axis	DPI	Screen Size
RMS	X	−0.80[a]	0.72[a]
	Y	−0.91[a]	0.61[a]
	Z	−0.87[a]	0.58[a]
MF	X	0.07	0.3
	Y	0.36	−0.16
	Z	0.01	0.25
SE	X	−0.44[a]	0.3
	Y	0.25	0.16
	Z	−0.06	0.15

RMS = Root mean square; MF = Median frequency; SE = Sampling Entropy.
[a] Indicates significant differences between accelerations and peripheral configuration ($p < 0.05$).

that Elite Skill players have a higher hand-eye reaction speed than the rest of the players [26–27], as corroborated in this study, it could be interpreted that they can perform larger mouse movements without facing a significant loss of time and performance.

Finally, it has been observed that higher-level players use larger screens. For this reason, the authors propose to further investigate this field by replicating this study with peripherals of the same characteristics (DPI and screens) for all gamers, although it seems that this is an aspect that does not have a considerable influence [13]. Nevertheless, we consider it as a limitation of the present study. If the proposal is carried out, it will be possible to observe whether the DPI setting and screen size are chosen by the player's skill level or whether, on the contrary, the player's level is altered by the DPI setting and screen size.

The parameters studied can be used to know approximately the level of a player and, in a way, to predict the degree of evolution in the skill level of a given individual, as well as the characteristics that should be trained or modified to increase their level, because as some authors have commented, eSports training should be specific to each game and, therefore, it should deepen the skills of each of them [21]. However, it should be taken into account that in this video game, the skill level or rank is not something exclusive to the precision in motor skills. Still, mental processes related to tactical aspects and group decision-making among the members of the team come into play, because the configuration of team members is also important to performance in this game [6,21,30]. These phenomena should be studied in the future to have a better general knowledge of the issue.

As mentioned above, the limitations of the study include the fact that standard computer equipment was not available for all participants, which could affect the external validity of the study, and the small sample size, which could lead to a type II error. It would be prudent for forthcoming studies to consider these limitations.

5. Conclusions

The evidence found in the study shows that players with better skills have enhanced hand acceleration and shorter hand-eye reaction time in response to visual stimuli. In addition, new relationships have been obtained in variables that, a priori, were not considered significant, such as the fact that players with a higher level of skill make use of larger monitor screens or that the sensitivity of their mouse or DPI is lower.

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CRediT authorship contribution statement

Jose Luis Casado Rico: Writing – original draft, Methodology, Investigation, Conceptualization. **Israel Villarrasa-Sapiña:** Writing – review & editing, Writing – original draft, Investigation. **Xavier García-**

Massó: Investigation, Formal analysis, Conceptualization. **Gonzalo Monfort-Torres:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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