Impact of an exergame-based didactic intervention on supplementary motor area activation during motor coordination in primary school students: a pilot study

Juan Carlos Bustamante

Profesor contratado doctor de la Facultad de Educación de la Universidad de Zaragoza

jbustama@unizar.es

Alejandro Quintas Hijós

Profesor contratado interino de la Facultad de Ciencias Humanas y de la Educación de la Universidad de Zaragoza

quintas@unizar.es

Manuel Segura Berges

Estudiante del programa de doctorado en Educación de la Facultad de Educación de la Universidad de Zaragoza y maestro del Colegio Compañía de María de Zaragoza

manuelseguraberges@gmail.com

Carlos Peñarrubia Lozano

Profesor ayudante doctor de la Facultad de Educación de la Universidad de Zaragoza

carlospl@unizar.es

José Luis Antoñanzas Laborda

Profesor contratado doctor de la Facultad de Educación de la Universidad de Zaragoza

jlantona@unizar.es

Abstract

Our study investigated the effect of an exergaming didactic intervention in Physical Education (PE) on brain functioning associated with motor coordination. Five students formed the control group (received traditional didactic intervention) and four made up the experimental group (received exergaming didactic intervention). Functional near-infrared spectroscopy (fNIRS) measures were acquired at two time points (before and after intervention) by a 64-channel NIRScout system covering the supplementary motor area (SMA) while performing a bimanual digital flexion-extension coordination task. The results showed a more efficient activity pattern for the group that performed the gamified exergaming intervention than for the control group (traditional didactic intervention). In conclusion, our study reports neurofunctional evidence for effects of exergames on motor coordination.

Keywords: exergame; primary school; supplementary motor area (SMA); functional near-infrared spectroscopy (fNIRS); neuroeducation.

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Impacto de una intervención didáctica basada en el uso de un *exergame* en la activación del área motora suplementaria durante procesos de coordinación motora: un estudio piloto en primaria

Juan Carlos Bustamante

Alejandro Quintas Hijós

Manuel Segura Berges

Carlos Peñarrubia Lozano

José Luis Antoñanzas Laborda

Extracto

Este estudio busca analizar el efecto de una intervención educativa, basada en el uso de un *exergame*, sobre la actividad cerebral relacionada con procesos de coordinación motora. Cinco alumnos formaron parte del grupo control (fueron los que recibieron la intervención didáctica tradicional) y cuatro alumnos formaron parte del grupo experimental (recibieron la intervención educativa basada en el uso del *exergame*). Las medidas de espectroscopía funcional de infrarrojo cercano (fNIRS) se recogieron en dos momentos diferenciados (antes –medida PRE– y después –medida POST– de la intervención) con un sistema NIRScout de 64 canales, cubriendo el área motora suplementaria (SMA) durante la realización de una tarea de coordinación bimanual de flexión-extensión digital. Los resultados mostraron que parece existir un patrón de actividad más eficiente en el grupo que realizó la intervención de *exergaming* gamificada en comparación con el grupo que realizó la intervención didáctica tradicional. En conclusión, nuestro estudio muestra evidencia neurofuncional sobre los efectos de los *exergames* en la coordinación motora.

Palabras clave: primaria; área motora suplementaria (SMA); espectroscopía funcional de infrarrojo cercano (fNIRS); neuroeducación.

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Summary

Nota: este trabajo se enmarca dentro de la Convocatoria de Ayudas a Proyectos de I+D+i 2017 de la Fundación Hergar (categoría: Investigación aplicada y tecnológica en Ciencias Sociales, Jurídicas y Humanidades). Este estudio ha recibido el apoyo de la Fundación Bancaria Ibercaja (JIUZ-20170-SOC-06), del Fondo Europeo de Desarrollo Regional (FEDER) (Programa Operativo 2014-2020) y del Gobierno de Aragón (INFR2016_UZ_SOC_05). Finalmente, Alejandro Quintas Hijós agradece la ayuda recibida por el Ministerio de Educación, Cultura y Deporte para poder disfrutar de un contrato predoctoral que le ha permitido desarrollar esta investigación.

1. Introduction

Researchers have been investigating the benefits of game and game-based approaches in education from the 1980s (Borges, Durelli, Reis and Isotani, 2014). Exergames are digital motor games that aim to stimulate players' motor skills that have been popular on the global market and have gained more attention by academic research (Lin, 2015; Quintas, 2019). Understood as a type of games, exergames applied to PE can simultaneously provide the benefits of both motor games and video games (Gee, 2003; González and Navarro, 2015). Although much about the physical benefits of exergaming has been proven, less is known about psychological benefits at primary schools that enable exergames to become an effective and applicable educational tool (Li and Lwin, 2016).

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Recent studies conclude that incorporating active video games into the teaching system improves students' physical, cognitive and motivational elements (Gao, Lee, Pope and Zhang, 2016; Li and Lwin, 2016, Nguyen *et al.*, 2016; Nyberg and Meckbach, 2017). Some research on active video games in PE has focused on learning fundamental motor skills (Sheehan and Katz, 2010), and on motor control (Vernadakis, Papastergiou, Zetou and Panagiotis, 2015) and motor learning (Di Tore and Gaetano, 2012). However, Di Tore and Gaetano (2012) concluded that the verification of the effectiveness of active video games in relation to learning motor skills is not definitive. In fact, previous literature considers how active video games present many potential advantages in the field of motor activities and acquisition of specific motor skills; but, at the same time, other studies have led to less positive results (Di Tore and Raiola, 2012; Hsu *et al.*, 2011; Tanaka *et al.*, 2012).

In line with this, another area associated with PE is to work and develop coordinated body movement. The ability to acquire and rapidly reproduce new motor skills is a characteristic feature of human behaviour (Smethurs and Carson, 2001). Thus according to these same authors, intermember coordination is an adequate framework to study and analyse the processes of acquiring new coordinated motor skills. The learning and development of motor coordination is «effector-independent» and is really a neural representation of a higher level that governs coordinative processes (Kelso and Zanone, 2002). There are functionally and anatomically heterogeneous regions that are related to multiple aspects of sensory processing and sensorimotor integration, suggesting differential networks that are flexibly and dynamics during motor sequence learning (Bo, Peltier, Noll and Seidler, 2011). If so, the learning effects that occur with dance practice to coordinate knee movements can be transferred to the coordination of the fingers, or vice versa (Miura, Fujii, Okano, Kudo and Nakazawa, 2016).

The neuromuscular system is key for the coordinated human body movement, and can produce a wide diversity of motor patterns of bimanual coordination that can change in their spatio-temporal organisation according to the demands of the task being performed (Daza, 2007). Given a classical computational approach in cognitive neuroscience based on a basic, localist and deterministic information processing, which evolves to a connectionist approach based on a distributed and interactive pattern in brain functioning, Kelso (1995) stated that the human brain involves dynamical self-regulated systems. Specifically, Kelso, Scholz and Schoner (1986) showed that repetitive bimanual movements, especially fingers, naturally tend to be performed in a symmetrical mirror pattern as frequency of movements increases. Accordingly, asymmetric patterns in such movement imply higher demands of a cognitive type to maintain this motor coordination (Zanone, Monno, Temprado and Laurent, 2001). The SMA is involved in bimanual coordination and has functional specialisation in motor behaviour planning processes and in executing movements (Duque, Lew, Mazzocchio, Olivier and Irvy, 2010; Nachev, Kennard and Husain, 2008; Wilson, Kurz and Arpin, 2014). The SMA is associated with coordination regardless of whether it is bimanual or auditory-motor coordination (Miura, Kudo and Nakazawa, 2013). In addition, performing bimanual finger coordination tasks implies greater activity in the SMA compared to unimanual tasks (Ryan, Schranz, Duggal and Bartha, 2019). Thus sophisticated motor coordination patterns are related to SMA activity (Wilson *et al.*, 2014). Moreover, the SMA is involved in a dance network, and is critical for motor planning as it is active during both motor execution and imagery in tasks accompanied by music or in musical performances (De Manzano and Ullén, 2012; Olshansky, Bar, Fogarty and DeSouza, 2015). The SMA mediates beat perception, which is an essential component of dance (Grahn and Brett, 2007).

In the present study, given the neuroeducational perspective which establishes that neuroimaging can also offer information to optimise and guide educative intervention, but seems most likely to assure theoretically sound (Howard-Jones, 2007; Howard-Jones *et al.*, 2015), we investigated the effect of an exergaming didactic intervention in PE, compared to a traditional didactic intervention, on brain functioning associated with motor coordination. As Daniel (2012) warns brain science findings do not necessarily translate to the context of the classroom, Howard-Jones *et al.* (2015) state that greater dialogue between the two disciplines is necessary to bridge the gap between scientific research and classroom application, and also some «brain based» education programmes have

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never been evaluated or are «unscientific» (Goswami, 2006) we try to give neuroscientific evidence that support the efficacy of our intervention. Thus, given the exploratory and preliminary nature of our fNIRS study, we hypothesised that an exergaming intervention, in comparison with traditional didactic intervention, would produce different SMA oxygenated hemoglobin (oxy-Hb) concentration level while performing a task involving bimanual finger coordination related to exergame motor-related benefits for primary students while they learn dancing.

2. Methods

2.1. Participants

Participants were recruited from the students enrolled in a non-public school in the city of Zaragoza, Spain. Five students (3 girls, 2 boys and mean age = 10.20; *SD* = 0.45) formed the control group (received traditional didactic intervention). Four students (3 girls, 1 boy and mean age = 11.25; *SD* = 0.50) formed the experimental group (received exergaming didactic intervention). All the participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). Both groups were matched for general intellectual functioning, which was assessed with Culture Fair Intelligence Tests (Spanish adaptation, scales 2 and 3; Cordero, De la Cruz, González and Seisdedos, 2009) ($p > 0.05$). No history of head injury with loss of consciousness was reported. Informational letters and informed non-consent forms were sent to all the parents or guardians of the eligible students. All the schoolchildren had access to didactic treatments, but only the participants whose parents or guardians agreed to collaborate in the study were included. This research was approved by the Ethical Committee of Clinical Research of Aragon (Spain) with statement number: 10/2017.

The control treatment (traditional didactic intervention) was designed according to the usual didactic teaching of dance in Spanish PE (Larraz, 2012). The control group learnt dance without the exergame being present and with no gamification resource. Another experimental treatment was designed similarly to the control treatment, except that an exergame was involved (gamified exergaming intervention). Each treatment lasted 12 sessions or 9 hours and was applied for 4 weeks during curricular PE classes. Both the traditional didactic intervention and the gamified exergaming intervention were applied in the same way by the same teacher. Treatments were applied to the year-6 and year-7 students at primary schools.

At the end of each intervention, the same final dance performance evaluation test that consisted in creating and representing group choreography in groups of 5-7 people was used in both groups to measure the dance task execution level. This measure represented academic PE-related performance and was based on the following criteria:

- **Expressivity.** Implies that the student continuously performs and perfects the expression of movements during the dance.

- **Interaction during the dance.** It implies that the student dances in coordination with the rest of his/her classmates.
- **Expressive quality of the dance.** It implies that the student participates in the elaboration of a choreography rich in expressive resources.
- **Rhythm.** It implies that the student controls musical and corporal rhythm while performing a dance with musical support.
- **Concatenation.** It implies that the student performs the dance movements in a chained manner. That is, (s)he has the ability to anticipate the rhythmic steps that must be done to adapt and adjust coordinated body movements.

Each criterion had a scale ranging from 1 to 5, being 5 the best quality of execution and 1 the worst quality of execution. All performances were filmed. Then, the evaluation of each criterion was subsequently carried out, observing each student one by one. Thus, not all students in each group were tested at the same time.

The Just Dance Now exergame was used because it is compatible with the facilities of the participating schools and is based on accessible materials (screen projector, laptop, smartphone and the internet). Its use is justified by its huge commercial success worldwide and its extensive use for youths' leisure (Allsop, Rumbold, Debuse and Dodd-Reynolds, 2013), and because it has been scientifically studied (Gao *et al.*, 2016; Lin, 2015; Li and Lwin, 2016; Nyberg and Meckbach, 2017; Thin, Brown and Meenan, 2013). Playing with a smartphone is a strategy to help acquire a good psychological attitude and young people are used to employing it (Beltrán-Carrillo, Beltrán-Carrillo, González-Cutre, Biddle and Montero-Carretero, 2015). The experimental treatment design allowed all the students to dance several times during all sessions.

In order to gamify learning contents, 10 exergame dances were previously selected from 300 dances. The selection criteria were motor difficulty, the dance's cultural variety, and the adjustment of values to Primary Education: Level 1 «Rasputin»; Level 2 «Crazy Christmas»; Level 3 «Boogie Wonderland»; Level 4 «Aquarius»; Level 5 «Let's Groove»; Level 6 «#thatPOWER»; Level 7 «Hungarian Dance no. 5»; Level 8 «I Will Survive»; Level 9 a dance chosen by the group of students; Level 10 «Jambo Mambo». All the dances are available on the official exergame website (<https://justdancenow.com/>). To make the intervention sessions gamified, the ClassDojo virtual platform was used.

2.2. Paradigm

The participants performed a bimanual coordination digital flexion-extension task adapted from Wilson *et al.* (2014). They had to be seated with their arms in a comfortable and neutral position, with their elbows bent at a 90 degree angle so that their thumbs pointed upwards. During the baseline period without movement, the participants were asked to keep their index fingers extended and their other fingers flexed into a fist. Once prepared, they were instructed to remain immobile and to be attentive to the reproduction of two differentiated instructions that each indicated a different condition. These conditions were presented in a pseudo-random order:

- The condition «anti-phase» consisted of the participants alternately flexing their index finger on one of their hands in unison with extending the opposite index finger (asymmetrically).
- The condition in parallel or «in phase» consisted of the flexion and extension of both index fingers in unison (symmetrically).

In any case, the frequencies of the respective movements of the coordinated fingers were maintained at a pace set by the participants themselves and remained constant throughout both conditions. Each condition was constituted by five trials, and each trial involved making bimanual movements for 15 seconds, followed by a 25-second baseline without movements. Each trial lasted 40 seconds.

2.3. fNIRS recording

fNIRS measures were acquired at two different time points (before and after intervention) by an NIRScout system (NIRx Medical Technologies LLC, Glen Head, New York, USA) of 64 channels (with 8 sources of light and 8 detectors) covering the SMA. The sources and detectors that formed part of the cap (or NIRScap) were separated by a distance of 30 mm, and a wavelength frequency of between 750 nm and 2,600 nm was used. The signals obtained in the different channels were measured at a sampling rate of 7.81 Hz. The software NIRStar (version 14.2, NIRx Medizintechnik GmbH, Berlin, Germany) was used for data collection.

2.4. fNIRS data analysis

The obtained signal was analysed and transformed offline using the nirsLAB toolbox software (version 2016.01, NIRx Medical Technologies LLC, Glen Head, New York, USA), according to its wavelength and location, which resulted in values for changes in the concentrations of oxy-Hb and deoxygenated haemoglobin (deoxy-Hb) for each channel. The raw data for oxy-Hb and deoxy-Hb were digitally band-pass filtered at 0.01-0.2 Hz and converted into this using Beer-Lamberts law (Delpy *et al.*, 1988). A statistical analysis was conducted on changes in oxy-Hb.

For this purpose, the SMA oxy-Hb concentrations under both «In-phase» conditions and «anti-phase» conditions were extracted as GLM coefficients (betas) for each participant and each channel (at each acquisition time, for example, before and after intervention). Then betas were averaged by condition (also at each acquisition time) to increase the signal-to-noise ratio.

A repeated-measures ANOVA was conducted with the fNIRS SMA oxy-Hb concentration level as the dependent variable, and acquisition time (2: before the intervention, after the intervention) and task condition (2: in-phase condition, anti-phase condition) as the repeated factors, and intervention (2: traditional didactic intervention, gamified exergaming intervention) as the between factor. Significant interaction effects were followed up using paired t-tests.

The correlation analyses (bivariate Pearson correlational values) were applied to test the relation between academic PE-related performance and change in the SMA oxy-Hb concentration level due to intervention. This change was calculated for each condition (in-phase condition and anti-phase condition) by subtracting the concentration level of oxy-Hb at the post-intervention time, minus the level before the intervention. Thus when the difference value was more negative, it meant that greater SMA deactivation resulted from the intervention. Likewise, correlations were conducted with the quantitative assessment of the criteria rhythm and concatenation given the study's rationale (see table 1 for performance data for each intervention group).

Table 1. **Performance data related to rhythm and concatenation (the scale ranged from 1 [worst quality of execution] to 5 [best quality of execution])**

	Rhythm	Concatenation
Traditional didactic intervention group	2.80 (1.30)	2.40 (1.14)
Gamified exergaming intervention group	4.75 (0.50)	4.00 (0.82)

Note: mean (standard deviation).

Source: own elaboration.

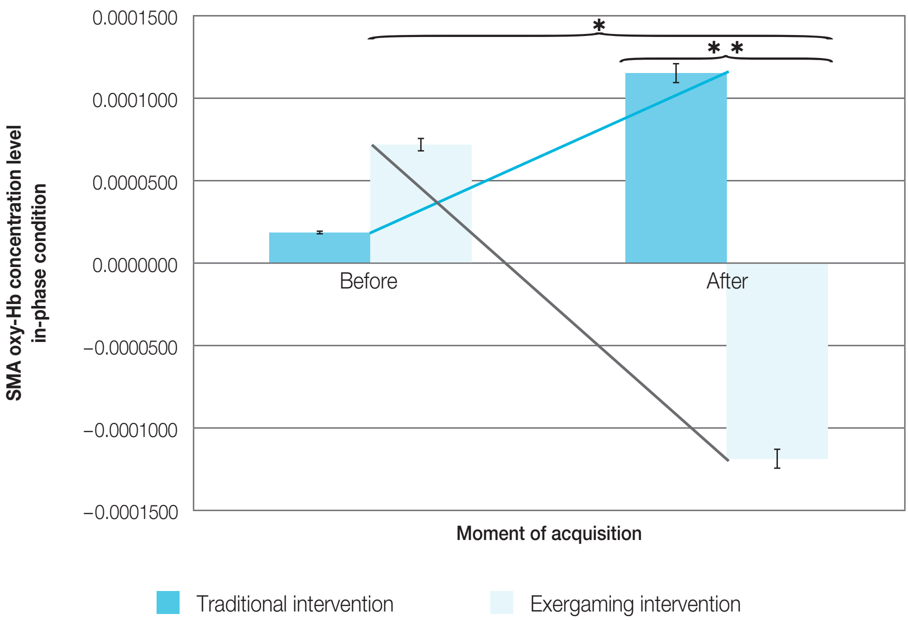
All the statistical analyses were performed using SPSS (version 22.0 <https://www.ibm.com/es-es/analytics/spss-statistics-software>) and the ANOVA analysis threshold was set at ≤ 0.008 with Bonferroni adjustment (Bland and Altman, 1995). For any ANOVA significant effects, the effect size was also reported (partial eta-squared, η_p^2). The threshold was set at ≤ 0.05 for the other analyses.

3. Results

The ANOVA performed on the SMA oxy-Hb concentration levels showed non significant acquisition time effect ($F_{1,7} = 0.37$; $p = 0.854$), non significant task condition effect ($F_{1,7} = 4.64$; $p = 0.068$) and non significant intervention effect ($F_{1,7} = 1.12$; $p = 0.324$). But, analyses showed a significant interaction effect for acquisition time X intervention ($F_{1,7} = 14.38$; $p = 0.007$; $\eta_p^2 = 0.067$)

(see figure 1). Specifically, in the control (traditional didactic intervention) group, no statistically significant differences appeared considering acquisition time factor (before *versus* after) for any task condition ($p > 0.05$). In the gamified exergaming intervention group, statistically significant differences appeared considering acquisition time factor for the in-phase condition ($t_3 = 8.08$; $p = 0.004$) (see figure 1), but not for the anti-phase condition ($p > 0.05$). Thus under the in-phase condition, there were no between-group statistical significant differences for the acquisition time before the intervention ($p > 0.05$), but there were statistically significant between-group differences for the acquisition time after the intervention ($t_7 = 2.60$; $p = 0.035$) (see figure 1).

Figure 1. **Between-groups and within-group differences in the SMA oxy-Hb concentration level under the in-phase condition for acquisition time**



Notes:

* Within-group differences in the exergaming intervention group in the SMA oxy-Hb concentration level under the in-phase condition when comparing the before intervention acquisition time to the after intervention acquisition time.

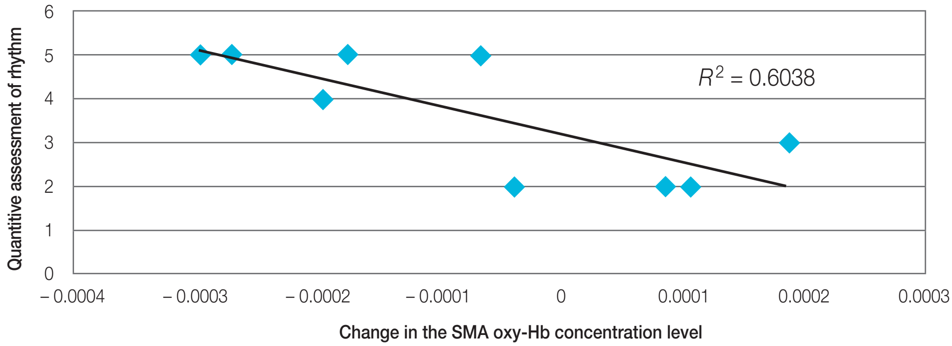
** Between-groups differences in the SMA oxy-Hb concentration level for the in-phase condition at after intervention acquisition time.

Lines representing acquisition time X intervention interaction effect. The blue line represents the tendency of the SMA oxy-Hb concentration level in traditional didactic intervention group when considering both the before intervention and after intervention acquisition times for the in-phase condition of the task. The gray line denotes the tendency of the SMA oxy-Hb concentration level in the gamified exergaming intervention group when considering both the before intervention and after intervention acquisition times for the in-phase condition of the task. Bar plots represent standard error (SE).

Source: own elaboration.

For the correlations analyses, given that there were no between-group statistical significant differences for the criteria concatenation ($p > 0.05$) but there were statistically significant between-group differences for the criteria rhythm ($t_7 = -2.80$; $p = 0.027$), a significant negative correlation between change in the SMA oxy-Hb concentration level due to intervention (in the in-phase condition) and the obtained rhythm score was found ($r = -0.78$; $p = 0.014$) (see figure 2). Likewise, we obtained a coefficient correlation of – 0.61 ($p = 0.08$) when we conducted a correlational analysis between change in the SMA oxy-Hb concentration level due to intervention (in the in-phase condition) and the obtained concatenation score (see figure 3). We did not obtain any other correlational effect.

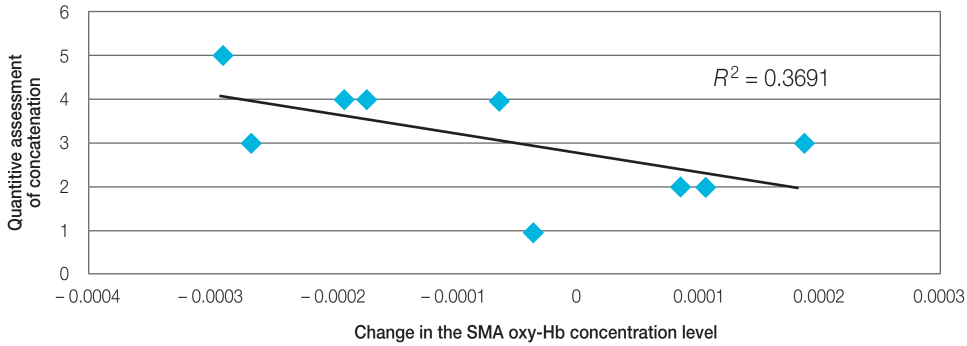
Figure 2. **Negative correlation between change in the SMA oxy-Hb concentration level due to intervention (in the in-phase condition) and the obtained rhythm score ($p = 0.014$)**



Note: R^2 represents coefficient of determination.

Source: own elaboration.

Figure 3. **Correlational analysis between change in the SMA oxy-Hb concentration level due to intervention (in the in-phase condition) and the obtained concatenation score ($p = 0.08$)**



Note: R^2 represents coefficient of determination.

Source: own elaboration.

4. Discussion

The literature shows that exergames are considered a valuable component in programmes to enhance psychomotor functioning (Gioftsidou *et al.*, 2013; Peng, Crouse and Lin, 2013; Vernadakis, Gioftsidou, Panagiotis, Ioannidis and Giannouisi, 2012). Hence some evidence indicates a positive impact of exergames on children's motor skill acquisition (Verdanakis *et al.*, 2015). The use of exergames as a form of exercise incorporates fundamental motor learning elements (Yen *et al.*, 2011). The physical activities performed in these games include motor tasks that involve a wide range of sensory feedback, adjustable motor amplitudes, speed and precision levels, and the incorporation of a variety of visual-spatial, cognitive and attention tasks (Salem, Gropack, Coffin and Godwin, 2012). Specifically, the study shows differential changes in the brain activity pattern of the SMA in view of the demand to perform bimanual digital flexion-extension coordination exercises when comparing both the control and experimental groups before and after performing the intervention based on using the exergame and gamification. The results show that the pattern of activity seemed more efficient for the group that performed the gamified exergaming intervention than for the group that performed the traditional didactic intervention. This result might reveal some type of neurofunctional effect on motor processes in relation to SMA activity due to using a gamifier educational resource in PE classes.

The results show that the pattern of activity seemed more efficient for the group that performed the gamified exergaming intervention than for the group that performed the traditional didactic intervention

The experimental group showed less SMA activation during the bimanual coordination task after the exergaming didactic intervention compared to the before intervention acquisition time. This effect was not obtained in the control group. This result could be associated with the fact that exergaming has a positive effect on brain functioning related with movement, which involves lower activation and less effort to perform coordination tasks. As in previous studies, less SMA activation took place when raising the motor skill level (Ross, Tkach, Ruggieri, Lieber and Lapresto, 2003). «Economy of effort» is also a feature of skilled psychological performance (Hatfield and Hillman, 2001). However, with higher cognitive demands the effects of exergaming may not come over clearly. Thus no significant differences were observed herein between the before and after intervention times in the intervention group for the anti-phase condition. This result could be related to the fact that anti-phase patterns are less stable and require much more attention (Zanone *et al.*, 2001). Likewise, our

The experimental group showed less SMA activation during the bimanual coordination task after the exergaming didactic intervention compared to the before intervention acquisition time. This result could be associated with the fact that exergaming has a positive effect on brain functioning related with movement, which involves lower activation and less effort to perform coordination tasks

in-phase condition effect could be also associated with functional aspects. The SMA could be subdivided into SMA proper and a more anterior part (for example, the pre-SMA) (Nachev *et al.*, 2008). SMA proper is activated in motor control task of movement initiation and temporal triggering, and pre-SMA seems to be related with cognitive control functions (Hertrich, Dietrich and Ackermann, 2016; Van Gaal, Scholte, Lamme, Fahrenfort and Ridderinkhof, 2011). It might be possible that tasks with also higher cognitive demands would involve the pre-SMA too, showing different effects of the intervention on SMA. There is also evidence reporting that activation magnitude in the SMA correlates positively with healthy participants performing antiphase trials (Goble *et al.*, 2010). But also with participants who have age-related motor declines. These results show that recruiting the SMA more leads to improved antiphase coordination.

Therefore, our results could be related to the fact that exergaming intervention involves efficient SMA functioning for motor preparation during coordination that requires no complex cognitive resources

The SMA shapes an appropriate motor plan in a task-specific manner during motor execution (Sarfeld *et al.*, 2012; Welniarz *et al.*, 2019). Indeed interhemisferic communication is involved in motor execution, even during the period preceding movement made up of different steps ranging from decision-making to movement execution (motor preparation), and is properly modulated by the SMA (Welniarz *et al.*, 2019). Therefore, our results could be related to the fact that exergaming intervention involves efficient SMA functioning for motor preparation during coordination that requires no complex cognitive resources. In fact, Hatfield, Haufler, Hung and Spalding (2004) determined that elite motor performance is associated with diminished cortical activation.

Likewise, our correlational results could support the notion that those subjects who present reduced SMA activation could display efficient motor preparation, which could be associated with better dance task execution that involves rhythmic and motor preparing components. Our participants specifically showed a lower oxy-Hb SMA level after the intervention and better rhythmic performance during the final dance performance evaluation test. This is a correlational effect that considers a brain area to be related to the fact that preparing timely motor actions needs predictions of future events (Cadena-Valencia, García-Garibay, Merchant, Jazayeri and De Lafuente, 2018). A major change in SMA activation due to the exergaming intervention could be associated with students' efficient preparatory motor activity capacity to perform a dance properly in the classroom as an academic task. This result could be associated with previous evidence determining that reduced brain activity during motor learning reflects neural efficacy improvements (Gobel, Parrish and Reber, 2011; Reithler, Van Mierand Goebel, 2010).

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This study has some limitations given its exploratory nature. This pilot study recruited only a few participants, so further validation with a larger sample size is necessary. Nevertheless, several studies conducted with fNIRS have reported similar sample sizes. The present study focused the analyses only on oxy-Hb measurements and does not report any deoxy-Hb-related effects. The reasons for this are associated with the higher signal-to-noise ratios of oxy-Hb *versus* deoxyHb, and reduced inter-subject variability (Wilson *et al.*, 2014). Furthermore, Jantzen, Steinberg and Kelso (2009) have reported that when movement frequency increases, SMA activity can also increase. So as frequency could modulate SMA activation, movement frequency while performing the task could also be manipulated. Moreover, it would be interesting to study the effects of such interventions according to gender as a future research line. Future studies could include different gamification elements, for example, another exergame or distinct PE contents, to apply and compare them. The association between neurofunctional effects and other psychological variables, such as motivation, satisfaction and physical self-concept, could also be studied.

A major change in SMA activation due to the exergaming intervention could be associated with students' efficient preparatory motor activity capacity to perform a dance properly in the classroom as an academic task

To conclude, our study reports neurofunctional evidence for the effects of exergames on motor coordination. These results represent an opportunity to establish a neuroeducational approach to determine the impact of an innovative intervention at school.

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