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Learning curve and motor retention of a video game in young and older adults

Curva de aprendizaje y retención motriz de un juego de video en adultos jóvenes y adultos mayores

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Abstract. The purpose of the study was to compare the learning curve and motor retention of the Dance Dance Revolution (DDR) video game in healthy adults. Twenty young (M= 23.9 ± 2.8 yr.) and 18 older adults (M= 60.7 ± 5.9 yr.), were randomly assigned to two experimental conditions: a) DDR 7 trials and b) DDR 14 trials. Participants danced the same song six sessions, followed by a detraining period of eight days. Then participants returned to the laboratory and danced again in order to detect a motor retention effect. A three-way ANOVA revealed mean score interactions (sessions x groups x trials; $p = 0.017$). Follow-up analyses revealed differences between young and older participants in both trial sessions ($p < 0.05$). Compared to young adults, older adults showed a learning curve of four sessions when performing 14 trials per session. After eight days of detraining only older participants in the DDR14 condition reduced motor performance. In conclusion, older subjects can learn the DDR game after playing four sessions; however, those dancing the same song 14 times were more likely to reduce their scores after eight days of detraining. Younger participants scored high regardless of the number of trials and sessions with little variability.
Key words. exergames, learning curve, elderly, motor learning, video games

Resumen. El propósito del estudio fue comparar la curva de aprendizaje y la retención motriz del juego de video «Dance Dance Revolution» (DDR) en adultos sanos. Veinte adultos jóvenes (M= 23.9 ± 2.8 años) y 18 adultos mayores (M= 60.7 ± 5.9 años), fueron asignados aleatoriamente a dos condiciones experimentales: a) bailar DDR 7 intentos, y b) bailar DDR 14 intentos. Los participantes bailaron la misma canción seis sesiones, seguidas por un periodo de desentrenamiento de ocho días. Luego los participantes regresaron al laboratorio y bailaron de nuevo para obtener el efecto de retención motriz. La prueba de ANOVA de tres vías reveló interacciones en los puntajes promedio (sesiones x grupos x intentos; $p = 0.017$). Los análisis de seguimiento revelaron diferencias entre los participantes jóvenes y mayores en ambas sesiones de intentos ($p < 0.05$). En comparación con los adultos jóvenes, los adultos mayores mostraron una curva de aprendizaje de cuatro sesiones cuando bailaron 14 veces por sesión. Después de ocho días de desentrenamiento, solamente los adultos mayores del grupo de DDR 14 redujeron el desempeño motriz. En conclusión, los participantes mayores pueden aprender el juego DDR después de jugar cuatro sesiones; sin embargo, quien bailaron la misma canción 14 veces tuvieron más probabilidad de reducir sus puntajes después de ocho días de desentrenamiento. Los participantes más jóvenes obtuvieron puntajes mayores independientemente del número de intentos y sesiones con poca variabilidad.
Palabras claves. «exergames», curva de aprendizaje, adulto mayor, aprendizaje motor, juegos de video

Introduction

A recent report (The Entertainment Software Association, 2013), revealed that the videogame industry produced in 2011, approximately $24.75 billion, and these figures are likely to increase in the years to come. Indeed, videogames are becoming an integral part of our daily lives. Both, children and adults, are widely engaged in videogame playing for several hours during a day (Richards, McGee, Williams, Welch, & Hancox, 2010; Wethington, Sherry, Park, Blanck, & Fulton, 2013).

Scientific studies regarding the acute and chronic effects of playing videogames on different variables have been done before (Moncada-Jiménez & Chacón-Araya, 2012). In general, the findings are contradictory for psychological variables. Some meta-analysis and other reviews suggest a correlation between excess time video gaming on negative social and psychological aspects such as isolation and aggressive behavior (Anderson, 2004; Anderson & Bushman, 2001; Anderson et al., 2010; Cummings & Vandewater, 2007; Richards et al., 2010; Sherry, 2001); while other research suggests a positive association with motor learning, adoption of healthy habits (including increased energy expenditure), motor re-training and resilience (Baranowski et al., 2011; Thompson, Baranowski, & Buday, 2010; White, Schofield, & Kilding, 2011).

The commercial process for promoting new video game systems and consoles such as Nintendo Wii (Nintendo of America Inc., Redmond, WA), Play Move (Sony Computer Entertainment America LLC, USA), Kinect (Microsoft Corporation, USA), and others, is very appealing for potential users. Some of these videogames directly promote increased physical activity since most body parts must be used to play. Other potential positive «side-effects» from unknown doses of videogame playing («exergaming») such as improved balance, better rehabilitation, weight loss, and psychological benefits (e.g., increased memory and other perceptual stimuli) are yet to be confirmed (Gatica-Rojas, Elgueta-Cancino, Vidal-Silva, Cantin-López, & Fuentealba-Arcos, 2010; Graves, Ridgers, Williams, Stratton, & Atkinson, 2010; Kliem & Wiemeyer, 2010; Lager & Bremberg, 2005; Middlemas, Basilicato, Prybicien, Savoia, & Biodoglio, 2009).

The Nintendo Wii console and the Dance Dance Revolution (DDR) videogame (Konami Corporation, Japan) are among the most studied exergaming products (Gao & Podlog, 2012; Murphy et al., 2009). This game is a more sophisticated form of an earlier arcade game. The purpose of the game is to use the feet to push arrows drawn in a mat according to a stimuli (i.e., music) shown on a video display, usually a television screen. It is expected that the user move the body according to a specific rhythm or choreography displayed in the video game to score high in the game.

To the best of our knowledge, the manner exergames are learned has not been recently described in the literature. For some authors (Singer & Berrocal, 1986), processes of adaptation to a movement arise depending on the activity and the situation, and when internal control is achieved then external variables no longer distract the performer. It has been proposed that states of motivation, attention, concentration and decision making are improved when a motor skill is mastered (Schmidt & Lee, 2005; Singer & Berrocal, 1986). It follows that a learning curve may allow determining whether or not a skill has been mastered (Song, 2009; Vendituoli, 2008). A learning curve function describes the degree of success attained during a period of instruction (i.e., score over time) (Singer, 1982). When mastery is achieved it is expected a gradual increase in performance (e.g., speed, accuracy) accompanied by a reduction in variability (Adi-Japha, Karni, Parnes, Loewenschuss, & Vakil, 2008).

Learning curves are also used as a feedback tool for performers since motor learning is unique for a particular subject and a particular skill (Magill, 1993; Schmidt & Lee, 2005; Singer, 1982). Skill performance might be impaired or lost due to a lack of practice following training (i.e., detraining) or inappropriate learning and practice, which might be related to motor retention (Magill, 1993; Schmidt, 1975; Singer, 1982). Motor retention has been defined as the ability to maintain high standards of physical performance (e.g., speed, coordination), effectiveness and consistency in a motor task (Bertollo, Berchicci, Carraro, Comani, & Robazza, 2010; Hynes-Dusel, 2002). Performance in a motor task is impaired when practice is discontinued and this

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reduction tends to appear earlier in high demanding tasks as opposed to low demanding tasks (Bertollo et al., 2010).

In spite of a growing body of evidence showing the usefulness of video games for improving health-related variables, there is still scarce information regarding how long does it take for a person to learn how to play a video game; in other words, the motor learning and motor control as it relates to exergaming. Therefore, the purpose of the study was to determine the learning curve of the DDR videogame in a sample of young and older adults, as well as to determine if any retention occurred after a detraining period.

Methodology

Participants

Thirty-eight volunteers were recruited from a university campus and a service program for older adults. Potential participants were naive to the DDR 2 Hottest Party® (Nintendo Wii) videogame or had little or no experience in exergaming.

Measurement instruments

The DDR videogame was played from a Nintendo Wii console and four control mats of the same brand (Nintendo of America, Inc., Redmond, WA) placed in front a 36" television screen (Sony Bravia, Japan). Participants wore a heart rate monitor Polar, model T-61 (Polar Group, Oulu, Finland).

Data were collected from the scoring system of the DDR display; however, the original scores were multiplied and transformed into new scores by using the beginner mode of the DDR game. The original scores were multiplied as follows: a) Perfect x 7; b) Great x 6 pts., c) Good x 5 pts., d) Almost x 4 pts., e) Boo x 3 pts., f) OK x 2 pts., and g) NG x 1 pt.

The highest achievable score was 322 pts., defined as the number of correct arrow steps shown for the song (46 arrows) multiplied by the maximal score in the scale (i.e., 7 pts.). The lowest achievable score was 48 pts., as defined by lowest number of arrow steps (16 arrows) multiplied by the score of 3 pts. allowed by the software. Notice that the scores OK and NG are not taken into consideration by the videogame software even when a participant stands still in front of the video display.

Procedures

Younger and older participants were randomly assigned to two groups based on the number of trials to be performed in the DDR. Participants in both age groups were randomly assigned to perform either seven (DDR7) or fourteen (DDR14) trials of the same song during six sessions (days) within a three week period (Bertollo et al., 2010). All participants were required to perform the study in the Human Movement Sciences Research Center under controlled environmental conditions and a predefined distance of the mat from the television screen. Participants read and signed an informed consent to participate in the study in accordance to the standards set forth by the Ethics Scientific Committee of the University of Costa Rica.

Participants were required to visit the laboratory to read and sign an informed consent form. During the same visit, participants were instructed on how to play the videogame by an oral explanation of one of the researchers, who read the same document to all participants to avoid confusion and ensuring for homogenous instructions. Physical exertion was monitored at the end of each trial by placing a heart rate monitor to each participant.

The experimental sessions required participants to dance the same song on each of the six exercise sessions. A pilot study on a different group of people with similar characteristics to the participants of this study revealed that the song *Black or White* (Jackson, 1991) and the *Beginner* level was the easiest combination of a song and a difficulty level for participants to play. Performance scores and heart rate values were recorded at the end of each trial. Once the experimental protocol was finished, a detraining period of eight days was implemented, followed again by a single exercise session. Participants were instructed on not playing any videogames during eight days. Then, participants were appointed to perform one last time the DDR videogame. The score in this last exercise trial was called the «retention» effect.

Statistical analysis

Statistical analysis was performed with the IBM SPSS Statistics for Windows version 20 (IBM Software Group, Chicago, IL, USA). Values are presented as mean and standard deviation (M ± SD). Statistical significance was set *a priori* at $P < 0.05$. Inferential statistics included mixed three-way (groups x experimental treatments x sessions) ANOVA for the score variable and appropriate follow-up analyses. Coefficient of variation ([M/SD] x 100) was also used to describe learning curves (Vincent & Weir, 2012).

Results

Young (n = 20) and older adults (n = 18) participated in the study. Physical characteristics are described in table 1. Mean scores and heart rate response to combined sessions is presented in table 2 for younger and older participants.

Table 1.
Participant's descriptive physical characteristics (n = 38).

	Males (n = 18)		Females (n= 20)	
Variable	**Young (n= 13)**	**Older (n= 5)**	**Young (n= 7)**	**Older (n= 13)**
Age (yrs.)	24.4 ± 2.2	63.0 ± 4.4	22.9 ± 3.8	59.8 ± 6.4
Weight (kg)	67.5 ± 5.6	76.0 ± 7.4	56.7 ± 7.7	65.9 ± 8.6
Height (cm)	174.8 ± 5.8	170.4 ± 2.3	165.1 ± 3.9	159.2 ± 6.9

Table 2.
Mean score and heart rate responses in trial groups.

	DDR7		DDR14	
Groups	**Young (n= 11)**	**Older (n= 9)**	**Young (n= 9)**	**Older (n= 9)**
Score DDR (pts.)	299.5 ± 12.2	212.1 ± 31.9	302.4 ± 11.5	233.6 ± 43.4
Resting HR (beats/min)*	83.8 ± 6.3	81.9 ± 6.6	88.4 ± 10.5	80.4 ± 12.7
Session HR (beats/min)**	102.8 ± 11.2	107.7 ± 14.5	109.6 ± 19.4	109.8 ± 23.1

Note: DDR = Dance Dance Revolution; DDR7 = Dance Dance Revolution 7 trials; DDR14 = Dance Dance Revolution 14 trials; HR = Heart rate
* Resting heart rate before session start (pre).
** Mean session's heart rate (post)

Three-way ANOVA showed triple ($p = 0.017$) and double significant interactions (groups x sessions) ($p = 0.001$), and significant main effects for sessions ($p = 0.001$) and groups ($p = 0.001$) in DDR scores. Two-way ANOVA comparing the two age groups and the two trial regimens (i.e., DDR7 vs. DDR14) revealed significant interaction ($p < 0.05$), and main effects for trials ($p < 0.05$), and sessions ($p < 0.05$) in DDR scores. One-way ANOVA revealed significant differences in the within-session DDR mean scores in the experimental group DDR7 ($p < 0.05$). Tukey's HSD post hoc analysis indicated that significant mean differences were obtained in session 6 vs. sessions 1, 2, 3; session 5 vs. sessions 1 and 2; and between session 1 vs. sessions 3, 4 and 7. One-way ANOVA also revealed significant differences in the within-session DDR mean scores in the experimental group DDR14 ($p < 0.05$). Tukey's HSD post hoc analysis indicated that significant mean differences were obtained in sessions 4, 5, 6 vs. sessions 1, 2, 7; sessions 3, 7, 2 vs. session 1; and between session 2 to 6 in both groups.

Among younger participants performing in the DDR7 and DDR14 groups, only the main effect session was statistically significant ($p < 0.05$) for the DDR scores. One-way ANOVA failed to reveal significant mean differences in DDR scores in the within-sessions factor.

Two-way ANOVA revealed a significant interaction ($p < 0.05$) and main effect group (p d» 0.05) and sessions ($p < 0.05$) in DDR scores among younger and older participants performing DDR7. One-way ANOVA revealed significant mean differences among all sessions in both age groups ($p < 0.05$).

Two-way ANOVA revealed a significant interaction ($p < 0.05$) and main effect group ($p < 0.05$) and sessions ($p < 0.05$) in DDR scores among younger and older participants performing in the DDR14 groups. One-way ANOVA revealed significant mean differences among all sessions in both age groups ($p < 0.05$).

Younger and older males significantly ($p < 0.05$) increased heart rates from rest following exercise by 9.4% and 19.9%, respectively. Younger and older females significantly ($p < 0.05$) increased heart rates from rest following exercise by 11.7% and 16.4%, respectively.

Discussion

The processes of movement adaptation are directly related to the activity and the situation (Singer & Berrocal, 1986). In other words, random elements (i.e., external variables) are reduced as more self-control is achieved following practice; therefore, a more stable and consistent motor performance. In this study, performance patterns in younger participants did not change significantly in the DDR videogame. Older participants performing DDR7 and DDR14 per session increased significantly their scores in the DDR videogame. Furthermore, older participants in the DDR14 group improved their performance after five sessions and had a low retention following the detraining period. This means participants were unable to maintain their previous improved performance. However, this response was not found in the group performing DDR7, which were able to maintain their performance following eight days of detraining. Motor performance is expected to decrease following a detraining period especially for difficult tasks requiring complex and coordinated movements and high memory processes (Bertollo et al., 2010; Hynes-Dusel, 2002); therefore, further research is guaranteed in older exergamers.

Motivation, attention, concentration and decision-making processes are enhanced when a motor task is mastered after three stages of skill acquisition are achieved (Fitts & Posner, 1967; Ruskin, Proctor, Neeves, & Fitzgibbon, 2007; Schmidt & Lee, 2005; Singer & Berrocal, 1986). The first stage is cognitive and the performer tries to understand the nature of the motor task. Errors often occur as a result of the novel task (Fitts & Posner, 1967). Older adults in this study indicated that during the first session it was hard to understand the nature of the videogame. The mean scores achieved by these subjects in session one support the later statement. The second stage is associative in nature, and the performer already understands what is needed to do to achieve a superior performance; therefore, the person tries to determine the most effective movements to achieve the task at hand and repeat them to enhance synchronization (Fitts & Posner, 1967). In this stage, less frequent errors appear than in the cognitive stage. Stage two of skill acquisition in older participants in this study was observed in sessions 2, 3 and 4, where scores were dramatically improved. However, improved scores tended to *plateau* in sessions 5 and 6, which may reflect the autonomous stage of skill acquisition (Fitts & Posner, 1967). In this stage, older participants automatically and fluently executed the movement, allowing them to achieve higher scores in the DDR videogame. Fitts and Posner's three-stage theory of skill acquisition was not found in the younger group of participants of this study under the proposed practice regimens (DDR7 vs. DDR14) and sessions

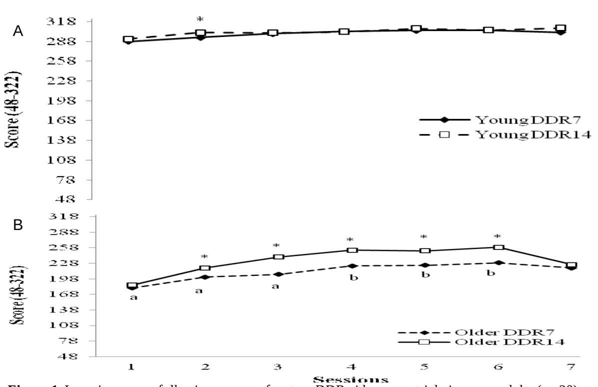

Figure 1. Learning curves following seven or fourteen DDR video game trials in young adults (n=20) (panel A) and older adults (n = 18) (panel B). Significant differences were observed between young and older participants ($p < 0.05$). Asterisk represents significant differences between trials ($p < 0.05$). Different letters represent significant differences between sessions ($p < 0.05$).

(Figure 1). A reasonable explanation to this finding could have been that the beginner level and song chosen did not represent a challenge to participants in this age group. In fact, this is a limitation of the present study. Younger participants did not achieve the highest possible score (322 pts.); yet, scores were consistently high in participants in both practice regimes, with less than 8% variation between sessions (Figure 2). A plausible explanation of this finding could have been that the processes mentioned earlier by others (Schmidt & Lee, 2005; Singer & Berrocal, 1986) happened so fast that were likely undetected.

Learning curves shown in figure 1 allow for comparison of the practice effect on score precision of a videogame and the mastery time for the motor skill to occur, especially in older adults (Magill, 1993; Schmidt & Lee, 2005; Singer, 1982; Song, 2009; Vendituoli, 2008). It also provides a starting point for further research in younger participants.

In conclusion, no significant differences in scores were observed in younger participants within trials or between sessions. Older adults improved their performance in the DDR videogame either practicing DDR7 or DDR14 from session one to session four, moment when scores became stable (i.e., learning curve). Older adults performing DDR14 achieved significantly higher scores than their counterparts on the DDR7 group; however, only the adults on the DDR14 group reduced their performance scores following eight days of detraining.

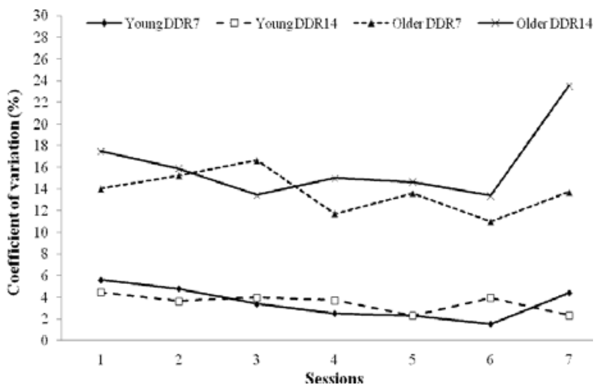

Figure 2. Coefficient of variation in DDR scores in young and older adults following seven (DDR7) or fourteen (DDR14) game trials (n=38).

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