Granda-Ortells, L.; Alemany-Arrebola, I,; Cortijo-Canto, A.; Mingorance-Estrada, A. y Granda-Vera, J. (202x) Reaction Time as a Biomarker of Aging. A Study with Women over 65 Years. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. X (X) pp. xx. Http://cdeporte.rediris.es/revista/___*

ORIGINAL

REACTION TIME AS A BIOMARKER OF AGING. A STUDY WITH WOMEN OVER 65 YEARS

EL TIEMPO DE REACCIÓN COMO BIOMARCADOR DE ENVEJECIMIENTO. UN ESTUDIO CON MUJERES MAYORES DE 65 AÑOS

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The Authors declares that there is no conflict of interests

Agradecimientos

Nuestro agradecimiento a la profesora de Educación Física y Deportiva del Aula de Mayores por su compromiso en la realización de este estudio. También nuestro agradecimiento a todas las mujeres que colaboraron con su participación en el estudio y lo hicieron posible.

Código Unesco/Unesco code: 6106.11 Psicología Experimental-Reacción / Experimental Psychology-Reaction
Clasificación del Consejo de Europa / Council of Europe classification: 15. Psicología del deporte/ Sport Psychology

Recibido 16 de julio de 2021 **Received** July 16, 2021
Aceptado 30 de enero de 2022 **Accepted** January 30, 2022

ABSTRACT

We investigated the effects of perceptive-motor program in comparison to a program exclusively oriented towards the improvement of strength and aerobic condition in women older than 65 years. A sample of 83 women was distributed in two groups: control and experimental group. Three measures were applied throughout the pretest, retest and post-test phases of the 1 year-period program: Simple Reaction Time (SRT-S1), Selection Reaction Time (SRT-S4) and Movement Detection Time (VTS-MDT-S1).The results reveal significant differences in favor of the experimental group (the one that practiced with the perceptual-motor program) in reaction time and movement time in all the tests performed in the retest and in most of the tests performed in the post-test (SERT-S4, SEMT-S4, MDT-S1 and MMT-S1).

KEY WORDS: aging, physical activity, perceptual-motor program, elderly women.

RESUMEN

Investigamos los efectos del programa perceptivo-motor en comparación con un programa exclusivamente orientado a la mejora de la fuerza y la condición aeróbica en mujeres mayores de 65 años. Una muestra de 83 mujeres se distribuyó en dos grupos: grupo control y grupo experimental. Se aplicaron tres medidas durante las fases de pretest, retest y postest del programa de período de 1 año: tiempo de reacción simple (SRT-S1), tiempo de reacción de selección (SRT-S4) y tiempo de detección de movimiento (MDT-S1) Los resultados revelan diferencias significativas a favor del grupo experimental (el que practicó con el programa perceptivo-motor) en tiempo de reacción y tiempo de movimiento en todas las pruebas realizadas en el retest y en la mayoría de las pruebas realizadas en el postest (SERT-S4, SEMT-S4, MDT-S1 y MMT-S1).

PALABRAS CLAVE: envejecimiento, actividad física, programa perceptivo-motor, mayores.

INTRODUCTION

Aging is associated with a cognitive and sensorimotor functions deterioration. Several studies on physical activity and cognition reveal that practicing physical activity may improve working memory, executive functions and motor ability in elderly; participants face a cognitively challenging environment during exercise, an experience that could stimulate their cognitive skills (Ordnung, Holf, Kaminski, Villringer & Ragert, 2017).

The deterioration of cognitive functions associated to age has been reported, although recent findings suggest that it can be influenced by environmental factors

(Kramer, Bherer, Colcombe, Dong & Greenough, 2004). Regular physical activity is one of the factors comprising an active lifestyle associated with preservation of cognitive function, so it is considered a key activity in anti-aging interventions.

The results agree with studies carried out with elderly people that found that the maintenance of a good aerobic condition is associated with good cognitive performances in tasks that measure attention and executive functions (Colcombe & Kramer, 2003). These results support that physical activity can improve controlling aspects of cognition (Hall, Smith & Keele, 2001). This is consistent with the results obtained after analyzing interventions with people older than 60 years in the last decade (Etnier et al., 2006) and with the review carried out by Martinez, Santaella and Rodríguez-Garcia (2021), who synthesize the health benefit of physical exercise as it improves the quality of sleep, decreases anxiety, stress, depression and insomnia and reinforces intellectual activity due to good brain oxygenation.

Moreover, comparative studies reveal that combining motor and cognitive demands during exercise may have a better impact on the cognition than training these skills separately (Fabre et al., 2002).

On the other hand, Pedersen, Surburg & Brechue (2005) measure cognitive function through reaction time, which gradually worsens as people get older. Subirana, Bruna, Virgili, Signo and Palma (2014) point out that cognitive performance in normal population is influenced by numerous factors, including age; the older the participants are, the lower their speed of cognitive processing is. Thus, a slower and more variable reaction time (RT) is often associated with a higher risk of death (Roberts, Der, Deary, & Batty, 2009; Shipley, Der, Taylor & Deary, 2008). Moreover, it gets worse with age (Granda, Barbero & Cortijo, 2015), and its deterioration is related with the difficulty of the task that subjects face (Salvia, Pettit, Champely, Chomette, Di Rienzo & Collet, 2016). In this regard, studies indicate that physical activity (PA) seems to be a good alternative to improve RT values (American College Sport Medicine, 2009).

It is also outstanding that numerous studies indicate that physical activity is a remarkable alternative to reduce or slow down this cognitively deterioration for old people (Van Uffelen,, Chinapaw, Hopman-Rock, & Van Mechelen, 2008). Despite these findings, Levin, Netz and Ziv (2017) conclude after reviewing studies regarding the effects of physical activity on cognitive and motor functions that "improvements in motor and cognitive functions were found primarily in interventions that adopt physical-cognitive training or combination training. While this finding advocates the use of multimodal exercise, training paradigms or interventions to improve cognitive-motor skills in older adults, considerable inconsistency between training protocols and final measures complicates the generalization of this finding" (pp. 1).

The physical activity can reduce reaction time in old adults (Hunter, Thompson, and Adams, 2001). Similarly, studies indicate that aerobic activity improves RT

(Barella, Etnier & Chang, 2010), although not all studies agree with these results. A large group of investigations have not found a significant correlation between aerobic capacity and RT (Angevaren, Aufdemkampe, Verhaar, Aleman & Vanhees, 2008; Gálvez, Caracuel & Jaenes, 2011).

Therefore, aging is generally accompanied by an increase in the values of the simple reaction time (SRT) and, particularly, in the selection or discriminative reaction time (SERT), in which the central nervous system must inhibit incorrect responses while activating the correct response related to the stimulus presented (Yordanova et al., 2004). Likewise, it has been proven that the decrease in SRT begins at earlier ages than the deficits in the SRT performance (Der & Deary, 2006).

These results suggest that the decrease in RT values could depend on cognitive-motor factors such as perception, attention and motor memory. Therefore, the physical activity program should stimulate these cognitive processes as a key aspect of the program (Willis et al., 2006).

Regarding the cognitive dimension, numerous studies have found that the combination of physical and cognitive activity produces more positive effects on cognitive function (Fabre, Chamarí, Mucci, MasseBiron & Prefaut, 2002) in old adults than practicing just one activity. Gálvez et al. (2011) and Marmeleira, Soares, Tlemcani & Godinho (2011) carried out an aerobic physical exercise program with healthy old adults in which cognitive tasks were incorporated, finding significant improvements in their SRT at the end of the intervention program.

From these studies, the present research focuses on knowing the effects on a group of women over 65 of a physical activity program aimed at improving their aerobic capacity and their cognitive processes (reaction time to make the right decision), whose results are compared to the results obtained by another group of women of the same age who only participate in a physical activity program aimed at improving aerobic capacity.

METHODS

Design

We employed a quantitative methodology from an empirical-analytical approach using quasi-experimental non-equivalent groups (Ato, López, & Benavente, 2013).

Participants

The participants were women older than 65 (65-80 years) who attended the Senior Citizens' Classroom and voluntary accepted to participate. Two criteria were required to be included in the study: a) living normal lives within the community and they are autonomous and independent and b) not suffering from serious cardiovascular, muscular or bone diseases. Moreover, all of them have a normal or corrected vision. All participants signed an informed consent to voluntarily participate in the study, in accordance with the ethical standards established in the Declaration of Helsinki of 1961 (and modified in Edinburgh in 2000) and approved by the Ethics Committee for Human Research of the University of Granada. The sample was divided in two groups: control group and experimental group (see Table 1).

Table 1. Sample distribution: experimental and control group

	Grupo Control	Grupo Experimental
N	42	41
M (edad)	69.8	69.4

Variables

Independent variables: Intervention program

Dependent variables: SRTS1, MTS1, SERTS4, SEMTS4, MDTS1, MCRTS1 and MMTS1.

Instrument

They were used three different tests obtained from the Vienna System Test (VTS) (Schuhfried GmbH, Moedling, Austria). The system consisted of a desktop computer with a set of peripherals from the VTS system.

The participants sat approximately 50 cm from the computer screen, which was placed about 15 cm in front of the response panel and at participants' head level. They were asked to use the index finger of the hand they choose to respond to the stimuli. The other hand should be placed next to the response panel. Prior to the test, participants received instructions and were given time to practice until they performed 5 correctly executed repetitions.

The following measures were carried out:

SIMPLE REACTION TIME S1 (SRTS1) (milliseconds). This test used a yellow light as a visual stimulus that appears on the screen at random intervals. The participant had to react as quickly as possible by pressing a square black button on the panel. While there was no stimulus, the participant's finger remained on the sensor button. Reaction time (SRTS!) and movement time (MTS!) were measured.

DISCRIMINATIVE REACTION TIME S4 (SERTS4) (milliseconds). This test measures the selection reaction time and consisted of a yellow and a red light that could be displayed on the screen individually or together, plus a sound that appeared randomly. The participant had to press the black square button as fast as possible only when both stimuli appeared simultaneously. If there was no stimulus, or the stimulus was only one of the two circles or the sound, the participant's finger should remain on the sensor. Reaction time (SERTS4) and movement time (MTS4) were measured.

MOVEMEN DETECTION TIME S1 (MDTS1) (milliseconds). This test consisted of a stimulus moving from the center of the screen to any of the four screen corners. The participant had to react as quickly as possible by pressing the square black button on the panel when the stimulus began to move.

The parameters measured in the first two tests were:

1) RT: the time lapse between the appearance of the stimulus on the screen and the moment the participant stopped pressing the sensor with the finger; 2) MT: the time lapse between moving the finger away from the sensor and the pressing of the black button.

In the third test, movement detection time (MDT), cognitive reaction time (MCRT) and movement time (MMT) were measured.

Programs

During the 12-weeks physical activity programs, the participants attended to 4 sessions per week lasting about 60 minutes; they were conducted according to the ACSM (2009) recommendations. The difficulty of the tasks increased depending on the participants' progress. All groups were supervised by a Sports Science and Physical Activity teacher. To quantify the exercise intensity during the sessions -that was supposed to be moderate-, the criteria established by van Uffelen, Chinapaw, HopmanRock and van Mechelen (2008) were applied: that participants should be able to speak and show symptoms of having participated in physical activity, such as high breathing rate, flushing and sweating.

Both experimental and control group were randomly formed. In the case of the control group, the sessions started with a 5 minutes warm-up period that included stretching and gentle movements. This phase was followed by 15 minutes of strengthening activities that involved the main muscle groups, using body weight as resistance or light weights and elastic extensors. The participants then moved on to aerobic exercises (dance and circuits) and a 10 minutes final relaxation routine.

Regarding the experimental group, the purpose of this program was to improve perceptive-cognitive processes, such as stimulus processing, decision making and movement programming (Schmidt & Lee, 2011). These sessions were designed identical to the sessions completed by the control group, incorporating some cognitive challenges, including an audio or visual signal that required the participants' motor response while they were walking or carrying out different tasks with several materials at the same time, or they were asked to remember movement sequences. It was essential that participants react with different motor responses as soon as possible. The tasks gradually became more difficult in terms of the number of stimuli and the associated motor skills; the objective was to create a permanent cognitively challenging environment.

Procedure

RT and movement time (MMT) were measured before to start with the interveniton program (PRETEST), during the impartition of the program In half the time of duration (RETEST) and after finishing said program (POSTEST).

Oonce the pretest was performed, the program was developed for 12 weeks. At the end of these 12 weeks, the retest was performed.

Then the following 12 weeks were developed and the end of these weeks, the postest was carried out.

Statistical analysis

After collecting the data, statistical descriptive and multivariate analysis were carried out as well as the Kolmogorov Smirnov's test for the normality of the sample distribution. Differences in pretest-retest-postest evolution for each group and variable were examined using the Student's paired-samples t-test. The data were analyzed using SPSS V24.0 for Mac.

Results

Data were collected on 3 phases: pretest, retest and post-test. The values of the mean and standard deviation of the different investigation phases are presented in table 2.

Table 2. . Descriptive statistics for the control and experimental groups in each phase (msg.)

	PRETEST				RETEST				POST-TEST			
	Media GC	SD GC	Media GE	SD GE	Media GC	SD GC	Media GE	SD GE	Media GC	SD GE	Media GC	SD GE
STRS1	309.45	42.89	315.70	39.11	301.47	41.67	295	35.66	299.56	45.78	267.40	33.93
TMS1	300.45	40.67	301.74	42.11	290.56	39.23	279.33	36.33	285.32	35.67	241.26	30.06
SETRS4	498.56	68.45	486.29	70.44	487.46	61.68	434.47	68.23	482.67	67.45	431.80	70.80
TMS4	305.67	38.89	301.14	39.37	294.59	38.49	261.71	71.04	292.34	36.89	255.73	33.13
MTD	611.89	90.34	609.07	86.78	598.36	83.67	526.66	78.34	592.96	65.32	519.73	67.89
MCTR	356.78	36.23	359.37	34.56	351.78	43.29	319.38	41.78	351.37	41.23	306.73	39.45
MMT	246.58	28.49	244.48	27.89	241.56	31.69	207.42	28.39	240.12	32.78	204.93	31.56

Firstly, it was verified that there were no significant differences between the two samples before starting the intervention program (pretest phase). Subsequently, Student's for independent samples confirmed the existence of significant differences between the two study groups in each of the investigation phases.

Table 3 shows the results of the first phase of the intervention. The data indicate that there are significant differences in the movement time of the S1 test, in reaction time and movement time in the S4 test and in the three measures of the MDT S1 test, being the effect size medium in all cases.

Table 3. . Comparison of Retest results (msg.)

Test	Media Retest GC	Media REtest GE	T	P	d_{COHEN}	Effect-size *R*
STRS1	301.47	295	1,765	n.s.	.11	.09
TMS1	290.56	279.33	2.987	.034	.47	.34
SETRS4	487.46	434.47	2.985	.027	.39	.28
TMS4	294.59	261.71	2.178	.044	.45	.32
MTD	598.36	526.66	2.45	.028	.49	.41
MCTR	351.78	319.38	2.234	.034	.46	.38
MMT	241.56	207.42	2.065	.046	.40	.39

Table 4 presents the results of the comparison of the data collected in the second phase of the investigation. The data indicate that there are significant differences in reaction time and movement time in the S4 test, and in detection time and movement time in the MDT S1 test, with the effect size being medium.

Table 4. Comparrison Postest results (msg.)

Test	Media Post-test GC	Media Post-test GE	T	P	d_{COHEN}	Effect-size *R*
STRS1	299.56	267.40	1.687	n.s.	.12	.10
TMS1	285.32	241.26	2.589	.042	.14	.13
SETRS4	482.67	431.80	2.345	.039	.46	.33
TMS4	292.34	255.73	2.082	.045	.45	.28
MTD	592.96	519.73	2.033	.049	.41	.29
MCTR	351.37	306.73	2.584	.037	.39	.12
MMT	240.12	204.93	2.145	.046	.42	.32

Subsequently, the three data collections of each sample were compared. No significant differences were found in the control group for any of the intrasubject comparisons. Moreover, no significant differences were found in the experimental group between the retest and post-test phases in any of the two measures (see Tables 5 and 6).

Table 5. Results of the experimental group in the pretest- retest

	Student´s t	Sig.
MTS1PRE-MTS1RETEST	2.481	.022*
MTS4PRE-MTS4RETEST	2.053	.049*
MTDPRE-MTDRETEST	2.420	.025*
MMTPRE-MMTRETEST	2.341	.030*

p < .05

Table 6. Results of the experimental group in the pretest and post-test

	Student´s t	Sig.
MTS1PRE-MTS1POSTEST	3.097	.008**
SETRS4PRE-SETRS4POSTEST	2.331	.035*
MTS4PRE-MTS4POSTEST	2.145	.048*
MTDPRE-MTDPOSTEST	2,678	.028*
MMTPRE-MMTRETEST	2.186	.046*

p < .05 p < .01 **

Assuming the normality for the ages of the sample within the MDT test (obtaining three values from the MDT, MCRT and MMT tests), the values obtained by the experimental group present significant differences between the pretest, and the retest and post-test results, not finding significant differences between the retest and the post-test results (see table 7).

Table 7. Comparison of normal values of the experimental group in the three phases

	Student´s t	Sig.
PRETESTMDT - RETEST1MDT	-2.987	0.01*
PRETESTMDT – POSTESTMDT	-2.933	0.013*
PRETESTMCRT - RETEST1MCRT	-3.046	0.009**
PRETESTMCRT – POSTESTMCRT	-3.828	0.002**
PRETESTMMT - RETEST1MMT	-2.260	0.04*
PRETESTMMT – POSTESTMMT	-2.881	0.014*

*$p < .05$ $p < .01$ ***

Discussion

The objective of this study was to analyze the effects of different physical acitvity programs on reaction time (RT) and movement time (MT) in three tests (simple reaction time test, selection or discrimination reaction time test and movement detection test) as a measure of the effects on the cognitive processes involved in making the most appropriate decisions.

The results reveal intragroup differences in all the parameters, although only differences significant were found between both groups only in the retest in the movement time of the S1 test (TMS!), reaction time (SETRS4) and movement time (TMS4) in the S4 test and in the three measures in the MDT S1 test. These results are similar to those found by León et al., (2011).

In the experimental group significant differences between the pretest-retest and post-test phases were found in some of the variables, findings that agree with the reviewed literature. Significant differences were not found in the simple reaction time results in retest or post- test phases in SRTS1. Significant differences were found in MTS1, SERTS4, MTS4 test and in the three registers of the MDTS1 test.

The absence of significant differences in the SRTS1 test might be because actions based on movement repetition require a minimum decision process (Spirduso et al., 2005). Besides, the degree of complexity and the analysis process required in this type of tests (simple reaction time) does not involve a difficulty that may cause differences in reaction time between the two groups. On the contrary, SERT variable begins to deteriorate earlier than SRT (Yordanova et al., 2004), which involves more complex decision-making processes. This is the case of MDTS1 test, which entails more complex processing as it involves movement detection.

The evidence suggests that simple reaction time in a test designed just for detecting the appearance of a fixed stimulus is an insufficient variable to stablish significant differences between subjects who practice aerobic physical activity and subjects who practice aerobic physical activity plus a perceptual-cognitive intervention program. Therefore, the use of this variable with physically active people as an aging indicator does not appear to have a high predictive value. This is also supported by the intrasubject evidence, where no significant differences in this variable were found in either of the two study groups. Significant differences were only found in the experimental group (the control group did not obtain any significant improvement between each of the phases) from pre-test to retest and post-test but not from retest to post-test.

As for the movement time, differences were found between both groups in the values of the three tests carried out in the retest and post-test phases. These results indicate an improvement in the movement time of the subjects in the experimental group, perhaps due to an improvement in the higher centers responsible for elaborating the response and transferring the neuronal order, which results in a more efficient motor time response.

CONCLUSIONS

This study argues that a work program combining physical and cognitive activity is the most likely to prevent an increase in reaction time in older people, as Willis et al. (2006), Galvez et al., (2011) and Marmeleira et al., (2011) suggest, which would translate into less deterioration of aging.

It is also relevant the significant improvement that the experimental group experienced in the parameters of normality -considering the age of the participants-, in comparison to the control group, which did not improve at all. This also indicates a better level of performance because of the participation in this combined program of physical activity and cognitive variables as opposed to a program exclusively oriented to the improvement of physical condition in tests that require more complex situation processing (detection of a moving object versus the appearance of a static object on the screen) (see Figure 1).

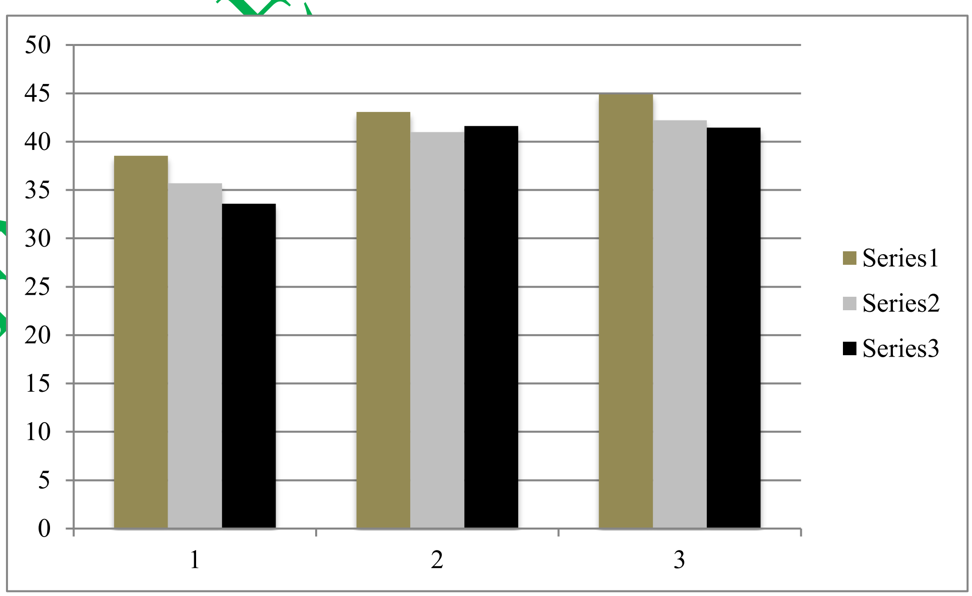

Figure 1. Values for each phase of the normal values in the MDT S1 Test in the experimental group

This study acknowledges some limitations that should be considered in future research. First, we were unable to assess physical level. Therefore, on the one hand, it was not possible to stablish whether the "cognitive improvements obtained were due to the characteristics of the program or to the improvement in physical condition”. On the other hand, although a combination of physical exercise and cognitive effort leads to significant improvements in MT values, the program does not guarantee an effect on other variables apart from physical fitness due to the limited number of stimuli. Therefore, we recommend that physical exercise should be combined with complex tasks in training routines, since this combination is essential in programs in which healthy older adults aim at maintaining and improving their cognitive function.

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