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CHANGES IN RESPONSE TIME AND ACCURACY OF LATERALITY RECOGNITION TASKS ACCORDING TO THE AGE IN HEALTHY SUBJECTS: A CROSS-SECTIONAL STUDY

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Abstract

Objectives: The main objective of this study was to evaluate the laterality recognition of the body parts "hands", "neck" and "feet" based on the response time and accuracy of left/right body-part judgments with performance compared across three age groups. The secondary objective was to calculate within age correlations between the time and accuracy variables and a measure of physical activity that provides activity in metabolic equivalents [METs]), and the METs score.

Methods: A total sample of 154 healthy subjects was divided into three age groups: G1 (n = 58), G2 (n = 38), and G3 (n = 58). Response time and accuracy were measured with the application Recognise designed by the NOI Group for "hand", "neck" and "feet" images.

Results: The results showed significant changes between groups in accuracy and response time for all body parts. Post-hoc analysis revealed longest response time and worst accuracy for G3. In the correlation with METs analysis, the strongest correlations were found in G1, where there was a positive moderate association between the METs score and the accuracy for the right-hand images ($r = 0.352$) and right neck images ($r = 0.398$).

Conclusion: Body-part laterality recognition is altered with age. Longer response time and lower accuracy was observed for "hands", "neck" and "feet".

Keywords: Aging, Laterality recognition tasks; Response time; Accuracy; Hand; Neck; Foot

INTRODUCTION

Body part recognition refers to the capacity to analyze and identify a body part when it is presented apart from a global image (Vannuscorps et al., 2012). The capacity to recognize a part of our body as belonging to the right or the left, commonly called left/right judgment or laterality judgment, is a complex cerebral process that has been studied in various ways, and there has been a recent interest in the literature on this subject (Breckenridge et al., 2017) Laterality recognition tasks are properly performed thanks to internal simulation of the movement involving imaginary motion, i.e., the complex cognitive capacity to imagine a motor action without achieving it (Jongsma et al., 2013). Body-part recognition response time (RT) is commonly evaluated, which is defined by the time elapsed between the beginning of the stimulus and the observed response (Parsons, 2001).

The imaginary motion of laterality recognition tasks (implicit motor imagery) involves a complex mental process where the subject must perform a mental rotation of the image and establish a relationship between the trajectory to match the stimulus and response time (Parsons, 1994). This mental rotation model has been supported by neuroimaging studies, and it has been suggested that the cortical activity is proportional to the degree of mental rotation performed (Weiss et al., 2009; Gogos et al., 2010). In addition, chronometric research showed that RT is directly related to the disparity between the real orientation and the new posture orientation, suggesting that neural system to laterality recognition is mental rotation in order to match the new hand picture (Osuagwu and Vuckovic, 2014).

In this regard, proprioception is a sensorial function that converts the stimuli received by an articulation from a tendon, a muscle or the internal ear into nervous impulses in the central nervous system. This feedback adds to the sense of position or movement of a body part. This is a fundamental property for balance, posture control, movement regulation and motor learning (Clark et al., 2015). Proprioception capacities are known to decrease with normal aging, and given this capacity is essential for accuracy in laterality tasks, it is essential to understand how laterality recognition evolve during aging (Ribeiro and Oliveira, 2007). In addition, variations in laterality recognition with mental rotations during normal aging have been investigated. However, the latter has only investigated response time in hand rotation tasks (Saimpont et al., 2009).

On the other hand, previous research has been suggested that motor imagery and laterality task could be related with physical activity levels. Higher levels of physical activity could lead to greater integration of sensorimotor and proprioceptive information, which could lead to better mental representation of movement Goss et al (Goss et al., 1986). In addition, greater familiarity with movement may facilitate imagination and reduce reaction time in mental rotation tasks (Parsons, 1994). In this regard, previous research showed that physical activity enhanced spatial cognitive performance and improves mental rotation task's ability (Jansen et al., 2010).

More data are necessary on changes in motor imagery and laterality recognition tasks to confirm the preexisting data and to know whether we would obtain the same results in another part of the body (such as the feet). This knowledge is especially important because we know that proprioception decreases with aging and body recognition is related with proprioception, although physical activity could preserve this decrease during aging (Ribeiro and Oliveira, 2007). Additionally, most of the studies have been performed using 2D images of movements (mental rotations), whereas in the present study the laterality recognition tasks are performed using 3D images of movements (postures).

The main objective of this study was to evaluate the laterality recognition of the body parts "hands", "neck" and "feet" based on the response time and the accuracy of left/right body part judgments depending on the age group. The secondary objective of this research was to observe whether there were any relationships between the response time and the accuracy of left/right body part judgments and aging, and the METs score.

METHODS

Study design

A cross-sectional study design with a nonprobabilistic sample was used. The trial was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2008).

Recruitment of participants

A sample of healthy individuals was obtained from La Salle University Center and from the community of Madrid through media and social networks, posters, brochures and emails. Recruitment began in November 2016 and ended in March 2017. The inclusion criteria were healthy individuals with an age range of 18–69 years. The exclusion criteria included the following: (a) any type of diagnosed or potential disease that affects cognition; (b) amputees; (c) musculoskeletal or nervous alterations of the neck or the upper and lower limbs; (d) presence of pain at the time of the study; and (e) underage individuals.

Informed consent was obtained from all participants, who were given an explanation of the study procedures, which were planned to follow the ethical standards of the Helsinki Declaration and which had been approved by the ethics committee of Centro Superior de Estudios Universitarios CSEU La Salle. All the participants were given information about the study and its procedure along with the duration of their participation, after which they provided their consent and completed the epidemiological data questionnaire.

Primary outcomes

Accuracy

The accuracy of the responses (percentage of correct answers) of laterality discrimination, which is the capacity to recognize a body part as being left or right (Spruijt et al., 2015).

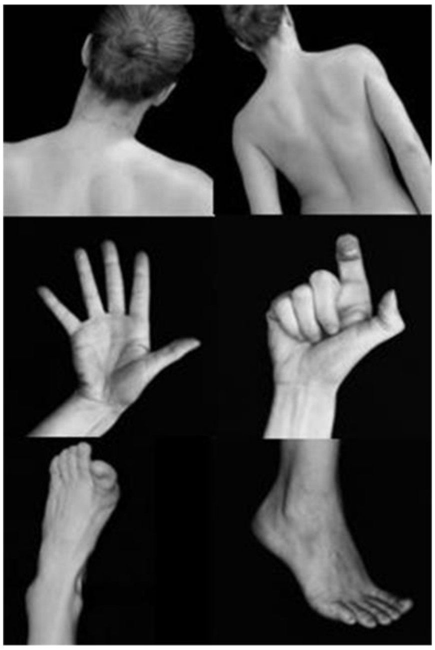
Time to Recognition.

The response time is defined as the time between the beginning of a stimulus (appearance of the image on the screen) and the observed response (choice between right and left). Recognise online is an online app designed to assess the ability to perform laterality judgements. This application displays different right/left images, and it accurately measures the speed and accuracy of making left/right hand discrimination judgements of each image. This app has been developed and released by the NOI Group, and provides the option to vary the number of images and the length of time the user has to view each image (Linder et al., 2016). Recognise online was used to measure both variables. In this study, the "hand," "feet" and "neck" versions were (Fig. 1). The reliability of the Recognise online application was previously established in populations with and without pain (Bray and Moseley, 2011). The intraclass correlation coefficient (ICC) response time for "feet" was ICC = 0.63–0.75 and for "trunk" ICC = 0.51–0.91. For the accuracy of the answers in laterality recognition, ICC = 0.61–0.77 for "feet" and ICC = 0.69–0.71 for "trunk" (Linder et al., 2016).

The internal and external validity were established before the application was online. Trials were conducted using a panel of images tested with the letters "L" for "left" and "R" for "right". The application was tested three times, and the internal validity was 100% (Wallwork et al., 2013).

"Left" and "right" were included as a factor in the analysis because the study conducted by Saimpont et al. (Saimpont et al., 2009) performed a similar separation in their research based on the hands. In the present study it was carried out in a similar way but

Figure 1. Part of the images (Recognise online, NOI group) used in the intervention.



also to analyze other parts of the human body both single (neck) and doubles (feet).

Secondary outcome

Level of physical activity

The physical activity level was classified using the International Physical Activity Questionnaires (IPAQ), which classifies participants by translating the data obtained regarding physical activity (in metabolic equivalents [METs]) conducted during the past week. Based on this estimate of consumed METs, the IPAQ divides the participants into three physical activity levels: low, moderate and high. This questionnaire has shown acceptable validity for measuring total physical activity. The questionnaire's psychometric properties have therefore been accepted for use in studies that measure physical activity (Roman-Viñas et al., 2010).

Procedure

An information sheet with an explanation of the procedure and an informed consent form were given to all the participants. Once the individual had read the information from the study, they were allowed to ask any questions about its nature. Those who agreed to participate proceeded to complete the sociodemographic questionnaire, which collected data on gender, date of birth, living arrangements and educational level. Once completed, the test was performed with the application Recognise Online with three body parts: "hands," "neck" and "feet," always in that order. The test consists of recognizing a sequence of body parts that appear on the screen as being right or left, in the minimum amount of time and with no mistakes. All the participants performed the tests while seated on a chair, with their arms free and their feet parallel. The "basic" level of the application was used the first time, to perform a run-through of the application, which is composed of 10 images with 10 seconds allowed for each (this pretest was performed at the beginning of each body part to be sure that the participant has understood the task correctly). Then the test was performed using the "vanilla" level, which consists of 20 images per category, with 4 seconds allowed per image.

Statistical analysis

The statistical treatment of the data was performed using IBM SPSS Statistics 22 informatics software. A 95% confidence interval was established, considering all values for which $p < .05$ statistically significant.

A normal distribution of the variables was assumed based on the central limit theorem, because the three group samples were large (>30 participants per sample); thus, a statistical analysis using parametric data could be performed. A 2-way repeated measures analysis of variance (ANOVA) was conducted to study the effect of the between-participant "age group" factor in each of the three age categories (young, adults and elder) and the within-participant "body size" factor, also in each of the three categories of all the dependent variables. A post hoc analysis with Bonferroni correction was performed in the case of significant ANOVA findings for multiple comparisons between variables. Effect sizes (d) were calculated according to Cohen's method, in which the magnitude of the effect was classified as small (0.20–0.49), moderate (0.50–0.79) or large (0.8). The α level was set at 0.05 for all tests.

The association within groups between response time and accuracy of left/right body part judgment and aging, and the METs score was examined using Pearson's correlation coefficient. A Pearson's correlation coefficient greater than 0.60 is considered to have a strong association; a correlation between 0.30 and 0.60 indicates a moderate association; and a correlation less than 0.30 indicates a poor association (Hinkle et al., 1990).

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RESULTS

A total of 154 healthy individuals were included in the present study and were assigned to three non-balanced groups consisting of the following: group 1 (young), 58 participants; group 2 (adult), 38 participants; and group 3 (elder), 58 participants (Table 1). No adverse events or dropouts were reported in any of the groups.

Hand images: accuracy

The ANOVA revealed differences between group age, when elder participants were compared with adults and young (F=8.53; p=.001, p=.002 respectively, η=.101), but no intragroup differences were found for body size on any age group (F=.612; p=.435) (Fig. 2).

The post hoc analysis revealed between group significant differences for the interaction age group*body size (F=3.54; p=.031), showing significant changes among young participants (F=4.20, p=.042, η=.027), but not for adults and elder (p>.05). The body side*age group also showed significant differences, being for the right-side significant values of elder participants when compared with adults and young (F=11.24; p<.001, η=.13). For the left side, only changes were found when comparing elder with adults (F=3.77; p=.035, η=.048).

Hand images: response time

The ANOVA did not reveal significant differences, not between group (F=1.179; p>.05), neither intragroup (F=3.57; p=.061).

The post hoc analysis revealed between group significant differences for the interaction age group*body side, but only for young participants (F=8.072; p=.005, η=.051), not being significant for adults (F=1.635; p=.203) and neither for elder participants (F=.761; p=.384). For the interaction body side*age group, significant changes were only shown for the left side in the comparison between elder and young participants (F=4.052; p=.026, η=.051). No significant changes were shown for the right side in any age group (F=.484 and p>.05).

Neck images accuracy

The ANOVA revealed between groups significant changes in accuracy between elder and young participants (F=4.06: p=.023, η=.051). No intragroup differences were found for body side variable (F=.84; p=.434).

The post hoc analysis revealed significant differences on body side*age group interaction, but only between elder and young participants (F=4.83; p=.010, η=.060). In addition, no differences were found for the age group*body side interaction (p>.05 in all cases).

Neck images: response time

The ANOVA revealed between groups significant changes between elder and young participants and

Table 1. Descriptive statistics of socio-demographic data.

Measure	G1 (n = 58)	G2 (n = 38)	G3 (n = 58)
Age-range (years)	20-35	36-49	50-69
Age (years)	27,38 ± 4,6	42,58 ± 3,99	59,08 ± 6,27
Gender of men	29 (50)	20 (52.6)	44.8 (44.8)
IPAQ (METs)	1559 ± 915	1549 ± 932	1622 ± 911
Right handed	51 (88)	30 (79)	56 (96.5)
Superior Education Level	44 (67)	19 (42)	31 (44)

between elder an adult participant (F=13.064; η=.148; p<.001; p=.014 respectively). No intragroup differences were observed (F=2.387; p=.124) (Fig. 3).

The post hoc analysis revealed significant differences on age group*body side interaction, but only in elder participants group (F=7.685; p=.006; η=.048). No differences were found on young (F=.004; p=.949) or adult participant groups (F=.003; p=.958). For the interaction body side*age group on the right side, differences were found between elder and young participants and between elder and adult participants (F=11.700; η=.134 p<.001; p=.008 respectively). On the left side, differences were only found between elder and young participants (F=4.163; η=.052 p=.013).

Foot images: accuracy

The ANOVA revealed between groups significant changes in accuracy between elder and young participants and also between elder and adult participants (F=8.99; η=.106; p<.01; p=.02 respectively). No intragroup differences were found in any age group (F=1.16; p=.282).

The post hoc analysis revealed significant differences for the age group*body side comparison, but only on elder participants group (F=5.47; η=.035; p=.021). For the body side*age group interaction, differences were also found. On the right-side differences were found between elder and young participants, and between elder and adult participants (F=9.90; η=.116; p<.001; p=.0012 respectively). On the left side, differences were found only between elder and young participants (F=7.05; η=.085; p=.001).

Foot images: response time

The ANOVA revealed between groups significant changes between elder and young participants and between elder and adult participants (F=14.270; η=.16; p<.001; p<.001 respectively). No intra-group differences were observed (F=.073; p=.787).

The post hoc analysis did not show significant differences in the age group*body side interaction (p>.05 in all cases). For the body side*age group interaction on the right side, differences were observed between elder and young participants and between elder and adult participants (F=11.736; η=.135;

Figure 2. Within- and between-group differences in accuracy

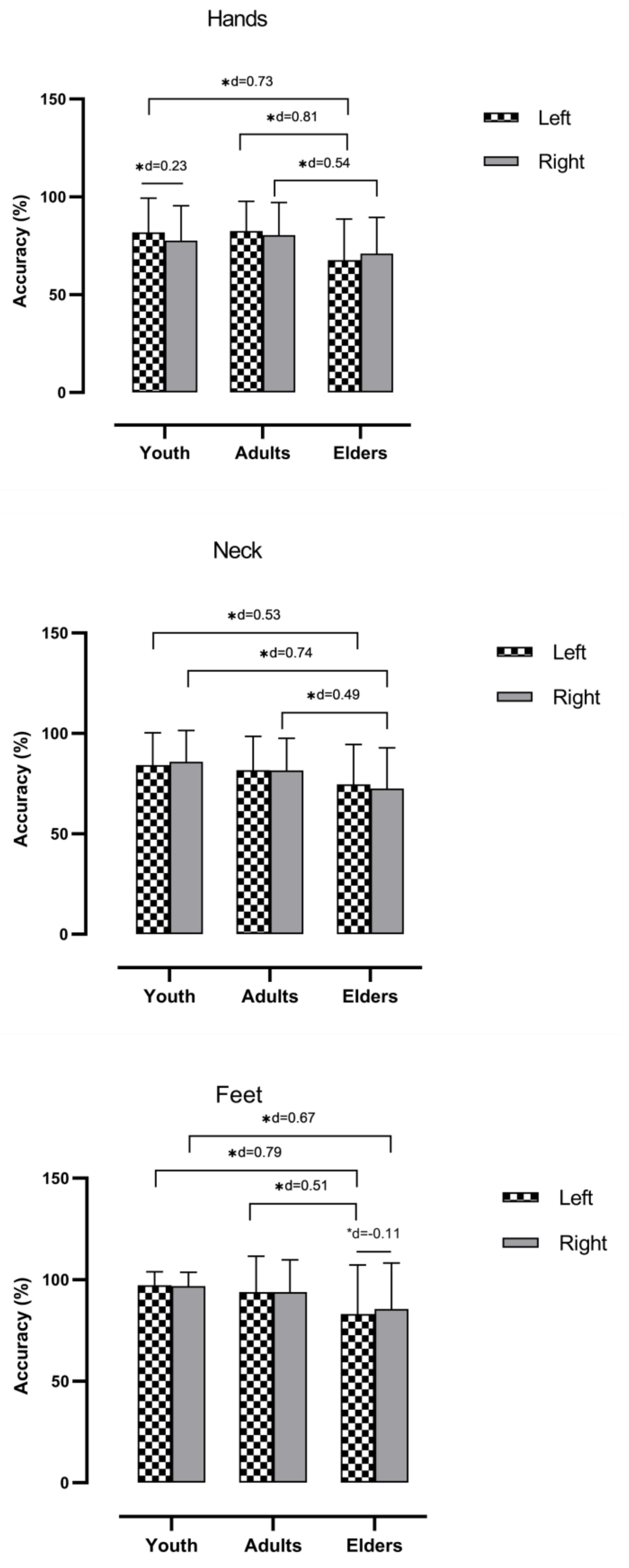
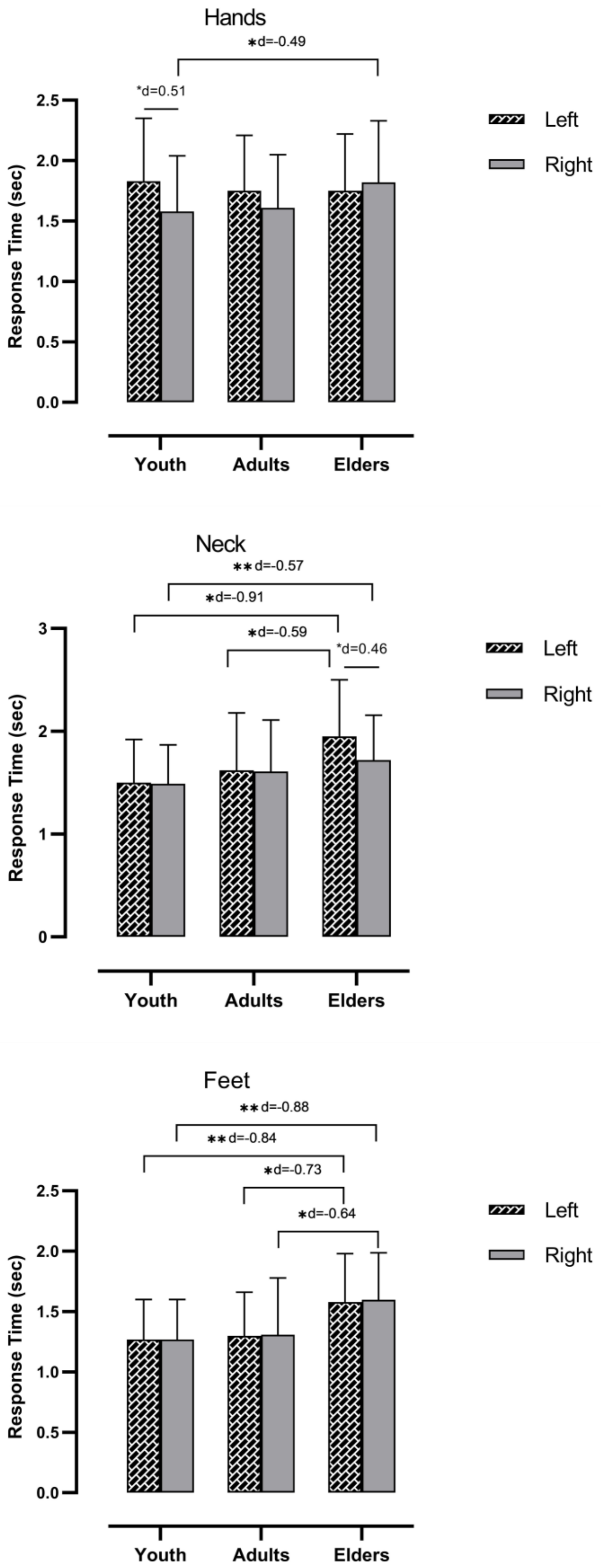


Figure 3. Within- and between-group differences in response time



p>.001; p=.001 respectively). On the left side, differences were also observed between elder and young participants, and between elder and adult participants (F=11.316; η=.130 p>.001; p=.002 respectively).

Correlation analysis

In the correlation analysis, regarding the METs score and accuracy, the strongest correlations were found in G1, in which there appears to have been a positive moderate association between the METs score and the accuracy for the right-hand images (p = .038, r = 0.352) and right neck images (p = .031, r = 0.398). In relation to the METs score and response time, the strongest correlation was again found in G1, in which a moderate negative association was shown between the response time for the left neck images and the METs score (p = .033, r = -0.344). Regarding aging, no associations were found between response time, accuracy and age.

DISCUSSION

The main aim of the present study was to investigate whether there was an influence of normal aging on body laterality judgment tasks in which participants were required to discriminate between left and right hands, feet and neck images, presented in various positions. Our results showed the longest response time for all body parts occurred in elderly individuals (G3), as well as this group having the poorest accuracy.

These results suggest that aging indeed affects capacity and corroborates the findings of Saimpont et al. (Saimpont et al., 2009), who showed that elderly individuals were less accurate and slower than their younger counterparts in their left-right hand judgments. Previous findings have revealed that normal aging influences the ability to recognize visual-mental images. Numerous studies have shown that elderly people perform more poorly than younger ones in terms of response time and accuracy in mental tasks identifying objects presented in various orientations (Hertzog et al., 1993; Dror and Kosslyn, 1994). In regard to cognitive psychology, it appears that the recognition of one's own body is not processed the same way as other objects; the observer imagines moving his own hand from its orientation during the task into the orientation of the stimuli of comparison. Individuals are typically unaware of imagining movement (implicit motor imagery). The imagined movement involves activation of the frontal lobe of the contralateral hemisphere of the brain (Parsons, 2001); the premotor area of the brain is activated in implicit motor imagery (left/right judgments), whereas the primary motor cortex is activated during explicit motor imagery tasks (Moseley et al., 2012). It is possible that the increase in age leads to a decline in cognitive processes related to laterality tasks, such as working memory, and specifically to its visuospatial component (Malouin et al., 2004). Age-related deficits in visuospatial working memory and reduced speed of information processing have been repeatedly demonstrated, agreeing with the results obtained in the present study (Jenkins et al., 2000).

In addition, Wallwork et al. (Wallwork et al., 2013), found slower response time and lower accuracy in a neck laterality task for elderly individuals. A possible reason for these findings could be that response time for laterality tasks involving images of body parts has a strong correlation with the time lapse required to execute the movement necessary to place our corresponding body part in the same position as the one in the image. The response time will be in proportion to the time needed to rotate (or imagine the rotation) the hand for its posture to match the one in the image (Decety, 1996). Furthermore, hand laterality judgment is faster and more accurate when dealing with one's own hand than with another person's hand, and this capacity is called self-advantage (Brady et al., 2011).

A recent study has confirmed that self-advantage is enhanced when the superior limb of the individual is positioned in a comfortable posture, arms flexed in front of them (Conson et al., 2015). This phenomenon appears to be related to the activation of sensorimotor mechanisms that are not activated when seeing a picture of a body part that is from a different person. Moreover, Shenton et al (Shenton et al., 2004). showed evidence of proprioceptive dominance in hand laterality judgments. In this study, participants were required to judge whether a pictured stimulus was a right or left hand, in three conditions: with a picture of a real hand, a fake hand or without an image, focusing attention on proprioceptive information. Proprioceptive input had a significant influence on the mental rotation task, whereas the visually perceived posture of the hand did not. Proprioceptive inflow could represent the dominant sensory input to the online representation of the body in space and highlights the importance of proprioceptive information in these tasks. In this regard, numerous studies have shown declines in planning, proprioceptive information input and execution of movement in the elderly, and this effect increases with task complexity (Goble et al., 2009; Lee et al., 2013). Our hypothesis is that the decline due to aging could affect laterality tasks; one of the causes of the results obtained in the group of elderly participants.

Another relevant result from our study is the difference shown in response time in right hand images between G1 compared with G3, but not in left hand images. Previous research comparing differences in reaction times between left-handed and right-handed participants during a mental rotation task using hand pictures showed that the right-handed recognized a right hand faster than a left hand (Takeda et al., 2010). For this reason, our results could be due to the fact that most of the participants in our study were right-handed.

The secondary objective of this research was to observe whether there were any relationships between the left/right judgments and the METs score. Our results showed a positive moderate association in G1 between the METs score and the accuracy of right-hand images and right neck images and a moderate negative association between the response time for left neck images and the METs score. Previous research by Feng et al. (Feng et al., 2017) showed that adolescent elite athletes had a faster response time in mental rotation tasks compared with adolescent nonathletes, agreeing with our results. Similar results were obtained comparing soccer players, gymnasts and nonathletes, showing poorer results in mental rotation tasks in nonathletes (Jansen and Lehmann, 2013). Moreau (Moreau, 2015) argue that more experience with spatial activities could be transferred to higher cognitive abilities, such as mental rotation, and consequently, with laterality tasks. For this reason, it is possible that a higher METs score is correlated with shorter response time and better accuracy in motor laterality tasks, but more studies are needed to be able to respond to these findings.

In conclusion, laterality recognition tasks are altered in elderly people. Longer response time and lower accuracy have been found for "hands", "neck" and "feet". Declines in visuospatial working memory and proprioceptive input could be related to these findings and could have implications in the design of rehabilitation protocols.

Limitations

This study presents several limitations that must be considered. The results obtained in the present study should be interpreted with caution, due to the fact that this is a cross-sectional study instead of a longitudinal study, which makes it impossible to establish a cause–effect relationship. In addition, the first test was always "hands," which could have been more difficult for the participants to perform. This complicates the analysis of the differences between "hands", "neck" and "feet" Finally, the majority of our participants were right-handed. It would be interesting to analyze the results with groups separated by handedness.

FRASES DESTACADAS

- A positive association was found between laterality judgement and level of physical activity.
- There are differences in laterality judgement discrimination according to age.

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