Research Paper: Relationship Between Laterality and Handedness With the Higher Order Sensory Functions and Manual Dexterity of the Elderly

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ABSTRACT

Objectives: The present study aimed to investigate the possible effects of laterality and handedness on higher-order sensory functions and manual dexterity of the elderly.

Methods: In this non-experimental cross-sectional study, 58 elderly people aged 60-75 years (35 right-handed) were recruited through a convenience sampling method. Laterality of the selected subjects was examined using the Edinburg test, while the higher-order sensory functions were assessed via haptic performance along with weight and texture discrimination tests. Gross and fine manual dexterity functions were assessed with the help of the box-and-block and Purdue pegboard tests, respectively.

Results: Results showed that the main effects of laterality and handedness, as well as the interaction effect of laterality × handedness on the haptic performance of the elderly were not significant. However, the main and interaction effects of laterality and handedness on the texture and weight discrimination of the elderly were significant. On the other hand, the main and interaction effects of laterality and handedness on the gross and fine manual dexterity of the elderly were not found to be significant.

Discussion: Laterality has no effect on the higher-order sensory functions of right- and left-handed elderly people. However, effects of laterality on fine motor dexterity in right-handed individuals were detected.

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1. Introduction

Aging is a natural yet dynamic process that has many systemic effects. Most often, hand performance is impaired with aging, due to which the elderly people lose their independence in performing daily activities. This, in turn, restricts their active participation in social activities [1]. Previous studies have showed that hand functions, such as coordination, dexterity, muscle power and sensory ability, gradually deteriorate with aging [1, 2]. It was thus proposed that detailed analysis of hand sensory-motor assessments can play crucial roles in geriatric rehabilitation and public health preservation.

Conventionally, it is known that manual asymmetry, which is the preferential use of one hand for functional skills caused as a result of variable brain processing pathways of right- and left-handed people, is a key factor that influences sensory-motor functions [3]. Recent studies conducted on the same indicated that dominant hand functions can be quickly and precisely compared with non-dominant hand functions [4]. Interestingly, it has already been shown that the difference in sensory-motor functions between the dominant and non-dominant hand is completely dependent on the task performed as well as the age and laterality of the individual [5, 6]. In a study on young adults, Pauli et al., and Özcan et al., illustrated that pressure pain threshold in right-handed individuals is asymmetric, i.e., the pressure pain threshold in the dominant hand is lower than that in the non-dominant hand. Interestingly, this trait is found to be non-existent in left-handed individuals [5, 6].

However, Hage et al., Van Turnhout et al., and Özcan et al., found no significant differences in the touch pressure threshold between the dominant and non-dominant hand [5, 7, 8]. In a study on right-handed individuals, Teixeira illustrated that repetitive tapping, anticipatory timing and the rate of drawing movement in individuals aged between 18 and 63 years have one asymmetric character, which is that the dominant hand performs these functions better than the non-dominant hand. In addition, it was observed that the sequential finger movements and reaction time of the dominant and non-dominant hand are similar, which indicates that these tasks are symmetric.

On the other hand, maximum grip strength of the dominant and non-dominant hand is an asymmetric character in the young, indicating that the power grip of the dominant hand is stronger than that of the non-dominant hand. However, further studies conducted on older individuals indicated that power grip is not significantly different between the dominant and non-dominant hand of individuals aged 40-63 years [9]. Francis et al., showed that the dominant hand of right-handed young and elderly adults could perform better in the Minnesota rate of manipulation, Purdue pegboard test (PPT), triangle tracing and tapping studies as opposed to the non-dominant hand. Evidently, the difference in performance depended up on the nature of the task. It was also observed that the difference in PPT and triangle tracing task was more significant in the young and the elderly [4]. Buckingham et al., reported that no significant differences in weight perception between the dominant and non-dominant hands of either right- or left-handed young adults exist [10].

Although studies have indicated that the functions of the dominant and non-dominant hands change with age [11], the majority of research studies conducted till yet, except for that of Francis et al., have focused on young and adult groups. In addition, the majority of the previous studies conducted on right-handed individuals or else examined the difference in low-order sensory functions between the dominant and non-dominant hands of individuals. No study has ever reported the difference in high-order sensory functions (haptic performance, weight and texture discrimination) between the dominant and non-dominant hands of right- and left-handed elderly individuals.

Studies on the high-order sensory functions of the elderly could help in designing appropriate instruments and technological assistance for this age group [4] which can further improve their quality of life and public health. Moreover, these types of studies are important in the diagnosis, intervention and testing for different hand injuries in elderly individuals with different laterality [5]. Therefore, the present study was designed to compare weight and texture discrimination, haptic performance as well as fine and gross manual dexterity between the dominant and non-dominant hand of right- and left-handed elderly individuals.

2. Methods

Participants

In this non-experimental cross-sectional study, 35 right-handed and 23 left-handed elderly participants were non-randomly selected from Tehran-Iran cultural centers. The inclusion criteria were: complete level of independence in performing daily activities (score of ≥95 on the Barthel Index test) [12]; acceptable level of cognitive function (score of >20 in the Mini-Mental-Status Examination) [13]; normal light touch threshold (≤4.31

mg on the Semmes-Weinstein monofilament test) [14]; normal writing and reading ability; no visual problems that could not be corrected with eye-glasses (based on self-report) and no neurological disorders and diabetes mellitus (based on self-report or physician report).

Participants were excluded if they did not suffice the above-mentioned criteria or were unwilling to participate in the tests. The study was approved by the Ethical Committee of Iran University of Medical Sciences. Prior written consent was signed by all the participants. Information on the age, gender and the dominant and non-dominant hand of the participants were recorded using a demographic questionnaire form, while laterality was assessed with the help of the revised Edinburg Handedness Inventory. High-order sensory functions were assessed by Haptic-Object Recognition Test (HORT) and Hand Active Sensation Test (HAST). In addition, manual dexterity function was evaluated by Box-and-Block Test (BBT) and PPT.

Instruments

Revised edinburg handedness inventory

This questionnaire used in this study was developed by Old field to identify the dominant hand of an individual. Items were scored as follows: 1. Always left-handed (−50); 2. Always right-handed (+50); 3. Sometimes left-handed (−25); 4. Sometimes right-handed (+25); 5. No difference (0) [15]. It was ensured that only always right-handed and/or left-handed individuals participated in this study.

HORT

HORT was used to assess haptic performance. HORT involved the use of non-familiar cubic objects (4.7×2.7×1.5 cm) made of LEGO bricks. Each group had a certain number of rectangular bricks that were placed in various positions on their sides. The HORT has a good accuracy and is conducive to training effects in healthy elderly (SEM=1.3 to 1.8) [16, 17].

HAST

Weight and texture discrimination was evaluated with HAST, a standardized protocol developed by Williams et al., The materials used in this test consisted of 9 cylindrical objects in 3 binary sets, in which every pair was similar in texture and weight. Throughout the test, cylinders were lifted from the target place on the table, which was set at a constant height for all participants. In all the 18 trials, the participants manually explored the objects using only one hand. The participants then matched the pairs twice based on the weight and texture of the objects without any visual assistance and without describing the manner of matching. The total number of correct matches (0-18) and number of correct matches for each item based on weight and texture (0-9) for the dominant and non-dominant hands were recorded and considered as a test score. The HAST is a valuable, quantitative clinical measure that has a strong and acceptable reliability (ICC=0.77) and validity (r=-0.67) for measuring haptic perception [18].

BBT

Gross manual dexterity was assessed using BBT. The participants were asked to transfer wooden blocks from one compartment to another as quickly as possible but using only one hand. The score was based on the number of blocks transferred in one minute. This test has high reliability (ICC=0.89 to 0.97) and good validity (r=0.80 to 0.82) [19].

PPT

Fine manual dexterity was assessed by using PPT. The participants were asked to pick up pins using one hand and place them in the holes of the pegboard. Fine manual dexterity was scored based on the number of pins placed in the holes within 30 seconds. PPT has good test-retest reliability (ICC=0.66 to 0.00, dependency on the subtest) for measuring manual dexterity [20].

Procedures

The participants completed the demographic questionnaire prior to sensory-motor function assessment. All assessments were administered in one day by a trained examiner. The testing procedure was explained to all participants. The tests were implemented after the participants provided assurance that they correctly understood the procedures. The participants were allowed to take rest between each assessment to prevent fatigue. Participants were blindfolded in sensory tests that required visual deprivation. Tests were administered in a random order to each participant.

Statistical analysis

Shapiro-Wilks test was used to assess if the data were normally distributed. Considering that initial analysis showed that the main effect of gender was not significant, the collected data from male and female participants were combined and used together. Two-way analysis of variance was used to examine the effect of laterality and

handedness on high-order sensory functions as well as fine and gross manual dexterity. The Bonferroni adjustment method was used for multiple comparisons (alpha level was set at 0.05).

3. Results

Participant characteristics

35 right-handed elderly individuals (14 males, 21 females, mean±SD:67.88±4.98 years) and 23 left-handed elderly individuals (11 males, 12 females, mean±SD:68.47±4.41 years) participated in this study. There was no significant statistical difference (t=−0.67, P=0.5) in the age of the right- and left-handed groups. The results of the Shapiro-Wilks test showed that sensory-motor functions using the dominant or non-dominant hand were normally distributed in right- and left-handed elderly individuals for all assessments. The results for sensory and motor function will be presented in two separate sections.

Effect of laterality and handedness on the higher-order sensory functions of the elderly

Data analysis revealed that the main effects of laterality and handedness as well as the interaction effects of laterality × handedness on haptic performance were not significant (P>0.05) (Table 1). Moreover, multiple comparisons indicated that haptic performance was not significantly different between the dominant and non-dominant hand of right- and left-handed elderly individuals

Table 1. Summary of two way analysis of variance (main and interaction effects of laterality and handedness) on sensory-motor function of the elderly participants (*P≤0.05)

	Variable		Mean of Square	df	F	P	Effect Size
Main effect	Laterality	HORT	4.143	1	2.786	0.097	0.024
		HAST	6.717	1	4.679	0.032*	0.040
		HAST-weight	1.989	1	4.258	0.041*	0.037
		HAST-texture	1.22	1	2.983	0.087	0.026
		BBT	5.959	1	0.194	0.660	0.001
		PPT	0.472	1	0.594	0.594	0.002
	Handedness	HORT	0.115	1	0.077	0.780	6.950
		HAST	0.546	1	0.381	0.538	0.003
		HAST-texture	0.056	1	0.135	0.714	0.001
		HAST-weight	0.533	1	1.140	0.288	0.010
		BBT	2.406	1	0.078	0.780	6.990
		PPT	2.426	1	1.462	0.229	0.012
Interaction effect	Laterality× handedness	HORT	0.012	1	0.008	0.927	7.433
		HAST	7.271	1	5.065	0.026*	0.043
		HAST-weight	1.774	1	3.797	0.05*	0.033
		HAST-texture	1.297	1	3.163	0.078	0.027
		BBT	32.199	1	1.048	0.308	0.009
		PPT	22.702	1	13.688	0.000*	0.109

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Abbreviations: HORT: Haptic Object Recognition Test; HAST: Hand Active Sensation Test; BBT: Box Block Test; PPT: Purdue Pegboard Test

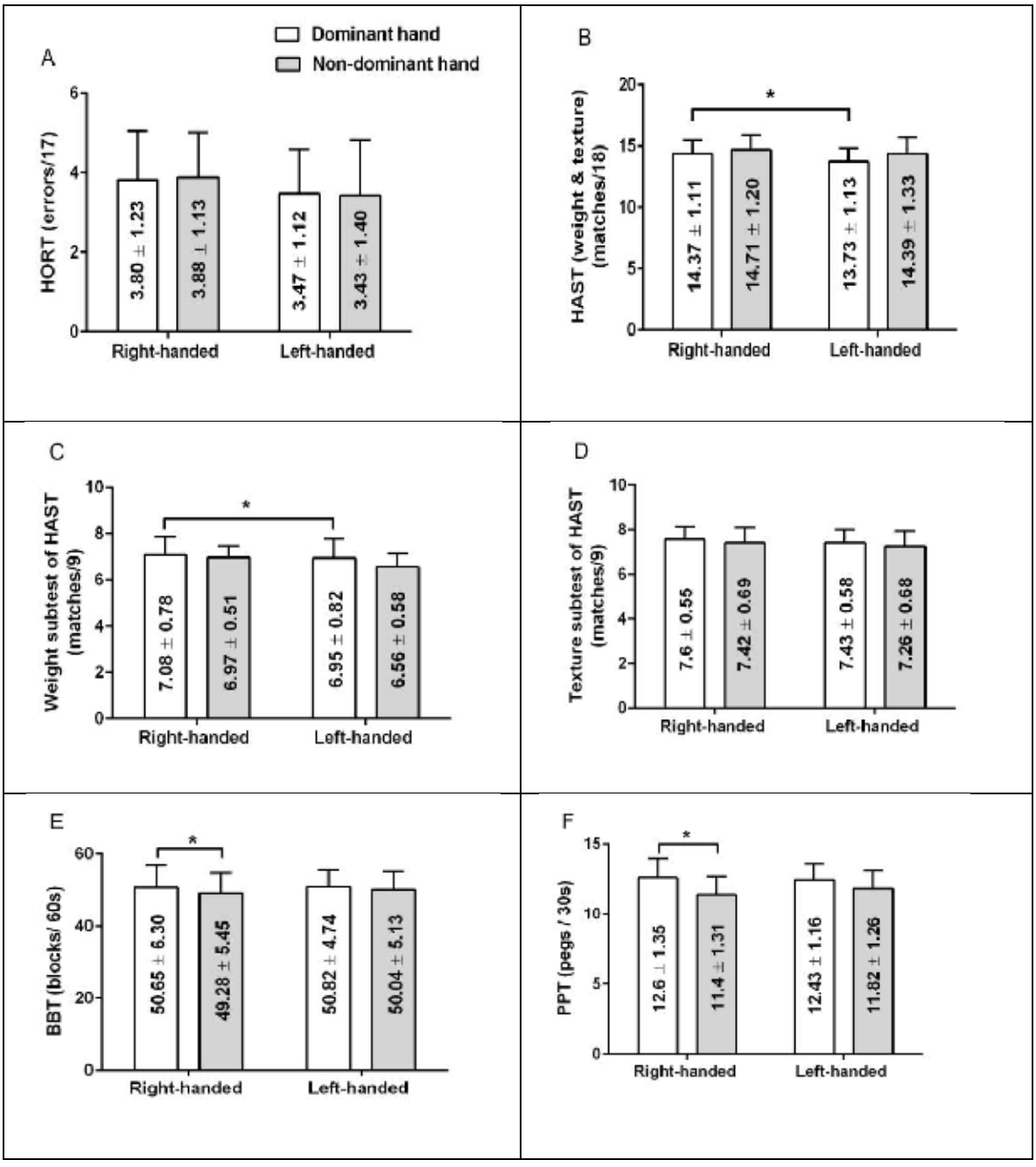

Figure 1. The results of multiple comparisons for interaction between laterality and handedness in sensory-motor functions of the elderly participants (*P≤0.05)

Abbreviations: HORT: Haptic Object Recognition Test; HAST: Hand Active Sensation Test; BBT: Box Block Test; PPT: Purdue Pegboard Test

(Figure 1A). The results demonstrated that the main effect of laterality (F=4.68, P=0.03) and the interaction effect of laterality × handedness (F=5.07, P=0.03) on object weight and texture discrimination were significant among elderly individuals. The main effect of handedness, however, was not found to be significant (Table 1).

As observed in Figure 1B, weight and texture discrimination performances between the dominant and non-dominant hand in right- and left-handed elderly individuals were not significantly different. In addition, weight and texture discrimination using the non-dominant hand was not significantly different between right- and left-handed elderly people. However, the ability to discrimi-

nate between weight and texture using the dominant hand was significantly higher in the right-handed group than in the left-handed group.

Effect of laterality and handedness on the fine and gross manual dexterity functions of the elderly

The main effects of laterality and handedness and the interaction effect of laterality × handedness on the gross manual dexterity function of the elderly were not found to be significantly different (Table 1). Multiple comparison results for the gross manual dexterity function of the participants illustrated that there exists no significant difference in the function of the dominant and non-dominant hand of left-handed individuals. However, in right-handed individuals, the dexterity function of the dominant hand was significantly higher than that of the non-dominant hand. Based on these results, it was concluded that the gross manual dexterity function of the dominant and non-dominant hand is not significantly different between the right and left-handed groups (Figure 1E).

In contrast to the significant effects of the interaction of laterality×handedness on the fine manual dexterity function of the elderly, the main effect of laterality and handedness on the same function was not significant (Table 1). The results of multiple comparisons showed no significant difference in the fine manual dexterity function of the dominant and non-dominant hand of left-handed participants. Conversely, the dexterity function of the dominant hand of right-handed participants was significantly higher than that of the non-dominant hand. In addition, there was no significant difference in the function of the dominant and non-dominant hands of the right- and left-handed participants (Figure 1F).

4. Discussion

The results of the study indicated that the HORT and HAST did not present significant differences between the higher-order sensory functions of the dominant and non-dominant hand in both right and left-handed subjects. Unlike the results obtained in the left-handed elderly group, the gross and fine manual dexterity values of the dominant hand of right-handed elderly individuals were better than those of the non-dominant hand of the same group.

Higher-order sensory functions

The results of HORT and HAST did not show significant differences between the higher-order sensory functions of the dominant and non-dominant hand of right- and left-handed elderly individuals. The results of studies conducted by Ozcan et al., [5], Hage et al., [7] and Van Turnhour et al., [8] illustrated that the pressure sense thresholds of the dominant and non-dominant hand of right- and left-handed individuals in different age groups are not significantly different. The probable reasons for these findings are: 1. HORT requires an exploratory procedure to discriminate between different objects [21].Furthermore, it is based on the aspects of object arrangement, size, shape and orientation [22], which makes it a complicated task that requires more attention [23]. Based on the HAROLD model, asymmetry in complex tasks decreases as age increases, thereby providing results that show lack of significant differences in the functions of the dominant and non-dominant hand of right- and left-handed groups. 2. HAST and HORT tests' perception are based on kinaesthetic or cutaneous afferent systems [24].

Studies have shown that cutaneous sensation changes in the dominant and non-dominant hands of the elderly and in different areas of the hand through a complicated pattern; thus, limited changes are observed in some areas (such as the tip of the index finger) and extensive changes occur in other areas (such as the hypothenar area) [2]. The lack of significant differences in the functions of the dominant and non-dominant hand can thus be attributed to the fact that both HORT and HAST involve object manipulation and thus necessitate application of all hand areas. 3. HORT and HAST lack speed-based properties, and it has already been established in some of the most recent studies that speed-based tasks exhibit more asymmetry than attention-based tasks [4, 25, 26].

The present study revealed that the dominant hand of right-handed individuals performed better in the weighing item of HAST as compared with the dominant hand of left-handed individuals (Figure 1C). The functions of right- and left-handed individuals were not significantly different in the texture item of HAST (Figure 1D). Object weight memory is formed by handling objects during daily activities [27]. Right-handed people use their dominant hand in handling objects, whereas left-handed use both hands [28]. Therefore, right-handed individuals use their dominant hand more often for weight recognition.

However, expertise in any mastered function may have been gradually lost in elderly individuals [11], thus accounting for the higher ability for right-handed individuals to recognize weight using their dominant hand as compared with left-handed individuals. Furthermore, unlike tactile sensation (more use in texture discrimination) kinaesthetic sensation (more used in weight discrimination) is lost with aging [29], therefore causing

significant differences in weight discrimination using the dominant hand of right- and left-handed individuals. This result is contrary to that for the texture item, which exhibited no difference.

Fine and gross manual dexterity

The gross and fine manual dexterity of the dominant hands of right-handed elderly individuals, particularly the fine dexterity of the dominant hand, were found to be better than those of the non-dominant hand of the same group. However, such differences were not observed in left-handed elderly individuals. These findings are compatible with that obtained from the studies conducted by Ozcan et al., which indicated that the dexterity of the dominant hand of right-handed young adults is significantly better than that of the non-dominant hand of the same group. Interestingly, these results were not observed in left-handed individuals [5].

One reason for such results may be the use of hands in daily activities. Furthermore, all instruments and utensils for daily living are designed for right-handed individuals, which means that left-handed individuals also use these right-handed designed tools in the majority of their daily living activities. This means that they use their non-dominant hand more frequently which in turn decreases asymmetry [28]. Other research findings have shown that asymmetry may also be decreased with exercise [4, 30].

The present study also showed that the difference of fine manual dexterity function between dominant and non-dominant hand was greater than the difference of gross dexterity function between the two hands of right-handed individuals. Studies have reported that asymmetry in motor functions is task-dependent. Francis et al., have suggested that with increasing age the ability to perform difficult tasks using the non-dominant hand deteriorates more as compared with that of the dominant hand [4]. The difference in fine motor function between the dominant and non-dominant hand of right-handed elderly individuals results from the complexity and difficulty of the fine motor functions as compared with gross motor function [2, 4].

Another probable reason for the decreased asymmetry in gross motor functions is the direct and short pathway for the BBT task as compared with that for the PPT task. This means that the elderly could perform the BBT task using either their dominant or non-dominant hand. On the contrary, the PPT task involves a more complicated pathway. The results obtained in the present study were thus expected, especially if the individuals find that using their dominant hand to perform tasks is more convenient. According to the HAROLD theory, the asymmetry percentage for tasks that proceed through a direct pathway is lower in adults [31].

This study also showed that there are no significant differences in the motor functions of the dominant and non-dominant hands of right- and left-handed elderly individuals. Earlier studies have also illustrated that using one hand more frequently improves function and delays the functional destruction of the same hand [4, 28, 30]. Therefore, the dominant hand of right-handed individuals functions better as compared with the dominant hand of left-handed individuals. The results of the present study, however, showed no difference in the functions of the dominant hands of right- and left-handed individuals. This deviation is likely to result from type II error in data analysis caused because of the low sample size of this study [28]. Further research should be conducted with a larger sample size and calibrated with precise assessment tools. This study was limited by its low sample size and lack of young adult group for comparison. Therefore, future studies should address these limitations.

5. Conclusion

In conclusion, laterality has no effect on the high-order sensory functions (weight and texture discrimination and haptic performance) of right- and left-handed elderly individuals. The effect of laterality on motor functions in right-handed elderly individuals is dependent on the kind of task. Thus, in the elderly, the effect of laterality on fine dexterity motor function is more significant than that on gross dexterity motor function. Nevertheless, laterality does not affect the fine and gross motor function of left-handed elderly individuals.

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Conflict of Interest

The authors declare no conflicts of interest.

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