The effect of brain lateralization on the memory function

Shahandeh M¹, Alipour A¹

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1. Dept. of Psychology, Payam Nour University, Tehran, Iran

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Abstract

Introduction:
This study aimed to investigate the effect of brain lateralization on the function of memory. In other words, this study was an attempt to find out if brain lateralization is effective on the function of memory.

Materials and Methods:
The study was conducted on 190 university students of Ahwaz Payam Noor University, using random cluster sampling (55 right-handed girls, 40 right-handed boys, 55 left-handed girls and 40 left-handed boys). They completed the Handedness Questionnaire of Chapman (1987), Word-fragment Completion and Yes/No Recognition Test. This study consisted of four sessions. First, the participants completed Handedness Questionnaire of Chapman. Then, they studied 30 frequent words, and completed Word-fragment Completion Test and finally did the Yes/No Recognition Test.

Result:
The results showed that the explicit memory was different between right-handed and left-handed students (P=0.004), but there was no difference between the two groups in implicit memory (P<0.614). Also right-handed girls were significantly different in explicit memory from right-handed boys, left-handed girl and male students.

Conclusion:
There were significant differences between right-handed and left-handed students in explicit memory and this difference was also observed between right-handed girls with right-handed boys and left-handed girls and boys.

Keywords: Functional Laterality, Handedness, Memory

Introduction:
Probably, no theory on organization of human brain has been as fascinating as lateralization for neurologists. This theory that two brain hemispheres have separate functions refers to the fact that two different minds control the behavior (1). Handedness has been defined as a preference of using one hand (2). Psychologists consider handedness as an indirect index of hemispheric dominance or lateralization. In other words, left and right hemispheres dominate in right-dominant and left-dominant people, respectively (3). In most humans, right hand is the dominant hand. Left-
handed people who comprise about 10% of population are in minority in all human populations. Left-handed men are more frequent than women (4). Direction and degree of handedness vary in humans. While many people assume handedness hereditary, others believe that it occurs because left hemisphere is more sensitive to environmental factors than the right one due to its longer growth time (5&6). Brain hemispheres are different in terms of structure and action. Therefore, each has been attributed to special cognitive functions (7). Left hemisphere is more advanced in verbal terms and, for this reason, it controls speaking, reading, writing and calculation. It works analytically and logically and is responsible for controlling movements of the right side of body. On the other hand, right hemisphere plays a special role in the abilities related to music, art, mental imaging, spatial visualization and perception of geometrical designs. It controls left side of the body and processes recognition of visually complex images (8&9). Based on the interaction between function of mental rotation, lateral specialization of function and handedness, theorists mainly believe that right- and left-dominant people are different in cerebral organization; therefore, these two groups are expected to have different mental and cognitive functions (10,11).

Cognitive process of humans, especially memory, has been scientifically studied for almost one century. Memory is classified into two explicit and implicit types. If information is voluntarily and intentionally coded and given to the memory and the person consciously remembers his/her personal experience, the memory will be called explicit. If information is stored and retrieved without any previous intention, the memory will be called implicit (12).

There are two major theories about the difference between explicit and implicit memories. The first theory has been presented by the researchers in the field of mental neuropsychology. According to the theory of this group, people’s performance is different in each of these tests because implicit and explicit memories have two different neural structures in brain (13). The second theory is related to cognitive psychologists. Based on this theory, the information remembered in explicit and implicit memories is processed using different methods. Explicit memory tests utilize conceptual expansion of information and implicit memory tests use information facilitation and transfer processes (14). It has been reported that performance of women in verbal tasks such as remembering and recognizing words and visual recognition memory is better than that of men, but men have better performance in spatial memory tasks than women (15).

Both handedness and memory have special relations with brain actions and functions of its hemispheres. Many studies have confirmed the relationship between handedness and cognitive ability. In order to emphasize the differences between explicit and implicit memories, neural imaging techniques are used. For example, event-related potential shows the difference between temporal spatial components of explicit and implicit memories (16).

Functional magnetic resonance imaging has helped to locate differences of anatomical nerve of explicit and implicit memories. Retrieving explicit memory applies frontal and fornix areas while retrieval of implicit memory uses dorsal cingulate and parietal lobe (17). Many studies have reported involvement of frontal area in explicit retrieval. MRI has shown that volume of hippocampus is the best predictor for all kinds of memory (18).

Tarc Brown, Yi, Lebre and Chan (17) studied the effect of lateralization and procedural response on emotional recognition. Their results supported the memory model that audio nonverbal materials are coded and retrieved in right hemisphere of the brain. Bjornis, Engberg, Rosette and Bac (19) studied the effect of gender and lateralization on changes of verbal and nonverbal memory. They found that men whose left frontal lobe was incised
showed reduction of long-term verbal memory after surgery while there was no difference in other groups between memory scores before and after surgery. Injury or unilateral electrical stimulation of left or right hippocampus disrupts yes/no recognition memory test (18). Koppelman et al. compared recalling and recognition in patients who had cerebral injury in hippocampus, parietal lobe or frontal lobe and found that hippocampus injury had a significantly positive relationship with recalling and recognition memory; thus, they opposed the theory that cerebral injury could only affect recall memory (20). Alipour and Baghban Porshokoohi found that the effect of family handedness was significant on mental rotation ability. Gender also showed a significant effect on mental rotation ability (21). Function of explicit and implicit memories is affected by gender differences and information type. This interaction is due to processing factors, not the point that these two memories have different systems or structures (12).

By observing behavioral, cognitive and neurological differences, it is generally asked if there is any difference between implicit and explicit memories of right- and left-dominant people given the mentioned cases. In other words, is cerebral lateralization effective on function of explicit and implicit memories? Is this difference equal among women and men?

**Materials and Methods:**

This quasi-experimental study enrolled students of Payam-e-Noor University composed. Sampling was done using multistage cluster sampling method such that the samples were selected from among the educational departments which were considered clusters. Then, the admitted students of one semester were selected in each cluster and the sample people were randomly determined from among the names of these students. Half of the total size of the selected sample (190 people) was right-dominant (55 girls and 40 boys) and another half was left-dominant (55 girls and 40 boys). The students with the same major were matched based on age, gender and handedness. Inclusion criterion of the study was age of between 21 and 23 years old. Ambidextrous students, based on handedness test, or those not in the mentioned age range were excluded from the study.

The test was performed in four stages. In the first stage, the participants were asked to answer questions of Chapman Handedness Test. In the second stage (learning stage), 30 words were represented to the students from among high frequency words (12). In the third stage, word root completion test was performed for measuring their explicit memory. This test was such that three-letter root of the words with three-letter root of the words which were not observed by the participant in the learning stage were presented and they were asked to complete the words with the first suitable word which came to their minds. In the fourth stage, yes/no recognition test was performed for measuring explicit memory. In this test, each participant was supposed to determine if the words given in the list had been seen in the learning stage or not.

For the present research, three tests were used which included Chapman Handedness Test containing 13 simple and short items, already validated in Iran by Alipour. In this test, people are asked to determine the hand they use to perform activities such as writing, drawing, throwing, hammering, brushing, cleaning, lighting a match (holding a matchstick), shaking an ink glass, using a spoon, a pair of scissors, a knife and a screwdriver and capping and uncapping a bottle (3). Chapman and Chapman reported this questionnaire's internal consistency, retest reliability and correlation with handedness behavioral evaluation as 0.96, 0.97 and 0.83, respectively (3). Alipour validated the test in a sample of junior high school students in Tehran as 0.94 using Cronbach's alpha and 0.94 using split-half
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The relationship of handedness and gender was not significant at \( p<0.582 \) (3). In a sample of elementary school students, absence of interaction between gender and handedness (\( p<0.487 \)) was confirmed (28). Word root completion test was applied for measuring implicit memory (12). In this test, the participants were asked to complete roots of words with the first suitable word which came to their minds. Yes/no recognition test was used for measuring explicit memory. In this test, the participant was supposed to determine whether s/he had seen the given words before or not (22).

The obtained data were analyzed in SPSS statistical software (version 17) using MANOVA and Tukey’s post-hoc test.

**Results:**

Descriptive summary of the collected data is given in Table 1. Mean (standard deviation) of the explicit memory scores was 11.145 (2.69) in right-dominant female participants, 9.325 (3.31) in right-dominant male participants, 8.945 (3.06) in left-dominant female participants and 9.00 (2.66) in left-dominant male participants. Also, mean (standard deviation) of the implicit memory scores was 12.40 (2.02) in right-dominant female participants, 11.67 (2.08) in right-dominant male participants, 12.200 (2.77) in left-dominant female participants and 11.65 (2.48) in left-dominant male participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistical indices</th>
<th>Number</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explicit memory</td>
<td>Right-dominant girl</td>
<td>55</td>
<td>2</td>
<td>15</td>
<td>11.145</td>
<td>2.69</td>
</tr>
<tr>
<td></td>
<td>Right-dominant boy</td>
<td>40</td>
<td>4</td>
<td>15</td>
<td>9.325</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td>Left-dominant girl</td>
<td>55</td>
<td>0</td>
<td>16</td>
<td>8.945</td>
<td>3.06</td>
</tr>
<tr>
<td></td>
<td>Left-dominant boy</td>
<td>40</td>
<td>3</td>
<td>15</td>
<td>9.000</td>
<td>2.66</td>
</tr>
<tr>
<td>Implicit memory</td>
<td>Right-dominant girl</td>
<td>55</td>
<td>8</td>
<td>15</td>
<td>12.400</td>
<td>2.02</td>
</tr>
<tr>
<td></td>
<td>Right-dominant boy</td>
<td>40</td>
<td>6</td>
<td>15</td>
<td>11.675</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td>Left-dominant girl</td>
<td>55</td>
<td>0</td>
<td>15</td>
<td>12.200</td>
<td>2.77</td>
</tr>
<tr>
<td></td>
<td>Left-dominant boy</td>
<td>40</td>
<td>4</td>
<td>15</td>
<td>11.65</td>
<td>2.48</td>
</tr>
</tbody>
</table>

In order to compare the effect of handedness on scores of explicit and implicit memory, MANOVA was run between scores of explicit and implicit memories in right- and left-dominant participants. Results of analysis of variance of mean difference of explicit memory scores in the groups showed that F value obtained for effect of handedness for explicit memory was 8.433 with 1 degree of freedom and 186 at significance level of \( p=0.004 \). As a result, explicit memory rate of the right-dominant people was different from that of left-dominant ones (Table 2).
Table 2: Results of analysis of variance in studying the effect of handedness in female and male participants on mean scores of explicit and implicit memory

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
<th>Sum of squares</th>
<th>Degree of freedom</th>
<th>Mean squares</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction</td>
<td>Implicit</td>
<td>26125.359</td>
<td>1</td>
<td>26125.359</td>
<td>4700.528</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>16878.160</td>
<td>1</td>
<td>16878.160</td>
<td>1956.637</td>
<td>0.000</td>
</tr>
<tr>
<td>Handedness</td>
<td>Implicit</td>
<td>1.415</td>
<td>1</td>
<td>1.415</td>
<td>0.255</td>
<td>0.614</td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>72.743</td>
<td>1</td>
<td>72.743</td>
<td>8.433</td>
<td>0.004</td>
</tr>
<tr>
<td>Gender</td>
<td>Implicit</td>
<td>32.716</td>
<td>1</td>
<td>32.716</td>
<td>5.886</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>35.774</td>
<td>1</td>
<td>35.774</td>
<td>4.147</td>
<td>0.043</td>
</tr>
<tr>
<td>Handedness × gender</td>
<td>Implicit</td>
<td>0.667</td>
<td>1</td>
<td>0.667</td>
<td>0.120</td>
<td>0.729</td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>40.081</td>
<td>1</td>
<td>40.081</td>
<td>4.646</td>
<td>0.032</td>
</tr>
<tr>
<td>Error</td>
<td>Implicit</td>
<td>1033.781</td>
<td>186</td>
<td>5.558</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>1604.456</td>
<td>186</td>
<td>8.626</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Implicit</td>
<td>28572.00</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>19556.00</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F-value obtained from handedness variable for explicit memory was 0.255 with 1 degree of freedom and 186 at significance level of p<0.614; therefore, it cannot be concluded from the available data that implicit memory rate of right-dominant people was different from that of left-dominant ones.

The obtained F-value was F=4.646 for effect of handedness variable for explicit memory with gender at significance level of p=0.032. Therefore, it can be concluded that explicit memory rate was different between the right- and left-dominant people. However, no difference was found between female and male right- and left-dominant people in implicit memory (p<0.729 and F=0.120). Therefore, in order to specify the groups which were different from each other, Tukey's post-hoc test was used. There was difference in explicit memory between right-dominant girls and...
right-dominant boys and left-dominant girls and boys; but, there was no significant difference between left handed people. Comparison of means showed that explicit memory of right-dominant girls was higher than that of other groups (Figure 1).

Discussion:
The most important result of the present research was that explicit memory of right-dominant people was different from that of left-dominant ones and this difference was between right-dominant girls and right-dominant boys and left-dominant girls and boys. Also, right-dominant girls had more explicit memory.

There are two explanations for the obtained results. The first one is related to the structure of brain and changes made at time of recognition and recall, as mentioned in the review of literature. According to the laterality theory, the left side system of memory which is involved in verbal subjects and right side system gets involved in nonverbal subjects, is also related to medial temporal lobe (23). That is, although hippocampus complexes of left and right sides are anatomically almost similar, they have major differences in their functional roles, which conforms to brain's functional arrangement by nature. For this reason, more people have specialized in linguistic abilities in the left hemisphere and in spatial and nonlinguistic abilities in their right hemisphere. On the other hand, the performed studies on patients with unilateral injury of left hippocampus complexes have shown disorders in verbal learning subjects (24).

There is evidence in research on cerebral imaging studies that activities of medial temporal lobe have been lateralized for verbal subjects in the left hemisphere while they have been lateralized on both sides for nonverbal subjects (25). Considering that left hemisphere is dominant in right-dominant people, therefore, the available difference can be explained based on verbal subjects in order to measure explicit memory.

Results of the present research were in line with those of the following studies: Farhangi believed that performance of women was higher than that of total mean performance of men in retrieving explicit memory. Tulving et al. found that left prefrontal cortex structures were specialized in retrieving general knowledge (semantic knowledge) and coding new aspects of input data to the explicit memory and right prefrontal cortex was specialized in retrieving episodic memory, especially retrieving the efforts which were episodically made. Structures of prefrontal cortex in the right lateral posterior areas (Brodmann’s 10 and 74 areas) which are related to retrieval in functional imaging studies are completely related with the right temporal anterior structures whose role has been emphasized in studies on cerebral lesions (14&22).

In order to explain the absence of difference in implicit memory due to the effect of lateralization, the evidence presented by Schachter and Wagner (26) can be referred to. In other words, posterior area of medial temporal lobe is more involved in memory coding processes and anterior area is more involved in information retrieval processes of memory. Therefore, it can be said that both hemispheres are equally involved (26). Hippocampus complexes also have a very important role in learning visual information which is retrieved by declarative nature or explicit memory from mind. Nevertheless, hippocampus system does not have an important role in learning the knowledge called non-declarative knowledge or implicit memory, which indicates changes in performance due to experience and is not consciously retrieved. Therefore, acquisition of motor skills, habits and special types of conditioned responses and effects of perceptual preparation are mostly independent from function of hippocampus and, even when medial temporal lobe is severely injured, they can have normative function (27). Bald et al. mentioned that patients suffering from
prefrontal cortex lesions showed considerable problems in performing their tasks relating to free retrieval of the word list. The tasks which had the lowest demand in retrieval such as word completion test with first few letters and category sample preparation test had no necessary diagnostic sensitivity to the lesions of frontal area. Therefore, no difference was found between right- and left-dominant people (28).

The second explanation is related to the cognitive approach which experimentally evaluates semantic coding by comparing memory of the patients in the related and unrelated lists. In normal participants, performance of retrieving the related lists is high because semantic associations in list facilitates organization during learning period and this organization in the test could act as a retrieval cue. Several studies have shown that free retrieval problems in patients with anterior lobe problems are due to their inability in using hidden semantic organization in retrieving listed materials (29). Research findings indicate that, when the participants perform the tasks which improve information coding in memory, the left frontal area, especially anterior part of lower prefrontal gyrus, is active. When the goal is to code semantic words, activity scope of the left frontal area is more than that of non-semantic words (28).

Tasks of implicit memory are different in terms of their infrastructural strategic memory demand. In other words, this strategic memory determines how much information is retrieved, evaluated, manipulated and changed. Therefore, function of frontal lobe in implicit memory may be due to its function in problem solving and reasoning used in different tasks of declarative memory. The reason is that the difficult tasks which require using active memory’s ability usually increase activity of frontal area in both cerebral hemispheres (29). The result is that lateralization is not involved in implicit memory and there is no difference between right- and left-dominant people.

**Conclusion:** Considering the structural and functional differences between right- and left-dominant people and difference between ability of explicit memory in these two experimental groups, it can be emphasized that right-dominant people use verbal and linguistic concepts and semantic associations for storing and cues for retrieving the memorized things from memory. Left-dominant people take the most advantage of spatial and nonverbal abilities. The absence of difference in implicit memory indicates equality of memory coding and retrieving processes in non-declarative categories in which both groups are equal.

It is suggested more studies be conducted on memory stages such as coding, storing and retrieving subjects in other types of memory and skills on right- and left-dominant people. Also, more investigation should be done to see the presence of difference between memory performance of people who are either right- or left handed and those who are ambidextrous in case of cerebral injury frontal or temporal areas.

**References:**