

A Mobile Application Program that Configures Right-Left Hand Recognition According to the Degree of Mental Rotation Difficulty

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Abstract--Right-left discrimination is evaluated with “hand lateralization” and accepted as a criterion of body recognition. In this study, a mobile application assessment method was developed in which the right-left discrimination was categorized within the concept of mental rotation. The objective was to elucidate the variations in users' responses to hand images presented at varying degrees of rotation. Participants' accuracy rates, reaction times, and test completion times were compared across the different difficulty levels in the mobile application. The findings revealed that as the task progressed from easier to more challenging categories, the accuracy rate declined, while both reaction time and test completion time increased. Assessing hand lateralization by presenting a software program where mental rotation tasks are categorized from easy to difficult may guide clinicians to follow the individuals' performance. As a result, clinicians may have a chance to assess their patients' potential on this performance and to integrate them to a particular therapeutic training program.

Keywords--right-left discrimination, laterality judgment, body image, body recognition

I. INTRODUCTION

It is known that the visual, structural, and spatial representations of body regions are linked at the cortical level [1,2]. The assessment of right-left discrimination via laterality paradigms contains information regarding the cortical organization of body representations [1,2]. Among body-related laterality paradigms, “hand lateralization” is commonly preferred and accepted as a criterion of body perception [2].

Researchers may prefer to add various features to a visual stimulus while applying body-related laterality paradigms. One of these parameters is “mental rotation” which is related to visuospatial information of the stimulus [2]. The problem occurs when the laterality paradigms contain different parameters (i.e. body-related stimuli, mental rotation degree of stimuli) at the same experimental design. Studies have reported

that perception of body parts, recognition of body parts as left-right side, and mental rotation of body parts are all determined in separate attentional mechanisms. For instance, hand laterality paradigms provide kinaesthetic and somatosensory information of related body part [3, 4]. Whereas mental rotation contains different stages of neural processes: a) encoding visual information, b) comparing the orientation between the target and the mental template, c) mental rotation of the corresponding body part from the target position, d) response execution [5]. As a result, it would be so difficult to interpret the outcomes of one's performance and evaluate him/her potential from a laterality paradigm containing different cognitive tasks.

When the literature examined, mobile and desktop application of Recognise® used for different body-related laterality paradigms. This software is developed for cognitive-based treatment approach for pathological pain syndromes named as Graded motor imagery [6]. Lateralization stage, which is the first stage of Graded Motor Imagery, cause activation of premotor area, which is the area of representation of the contents of movement planning and movement intention [6]. Lateralization stage lead activation of cortical motor networks without triggering protective response of pain. It is suggested that applications involving lateralization are effective approaches in pathological pain syndromes such as Complex Regional Pain Syndrome Type-1 and phantom pain [6,7]. It has been stated that the lateralization phase has a critical importance in providing cortical reorganization in those groups of patients. Overall, it is proposed that reorganization occurs at the cortical level on the mechanism of sustained attention to pain by practicing body-related laterality paradigms.

According to studies of body-related laterality paradigms, outcome parameters such as accuracy rate and reaction time were taken into consideration [3, 4]. As pointed out above, laterality paradigms are generally practiced by using Recognise® software where the stimuli parameters are not categorized in terms of mental rotation degree. In clinical perspective, patients with pathological pain syndromes suffer from different clinical conditions and their attention may be easily distracted [4,8]. This situation may lead clinicians facing

some problems. For instance, when paradigms are presented with different variables, patients may not focus all the variables at the same time and clinicians may not be sure if the patient understand the concepts of laterality or not. Thus, clinician may not specifically understand where the problem originates from and may failure to interpret their performances correctly. Considering all these explanations, it was thought that categorizing the stimuli according to their mental rotation degrees would solve the potential problems.

In this study, a mobile application assessment method was developed in which the right-left discrimination was categorized within the concept of mental rotation. The objective was to elucidate the variations in users' responses to hand images presented at varying degrees of rotation. We hypothesized that classifying hand images according to their degree of mental rotation would affect their performance. Accordingly, while we expected accuracy response rates to increase and reaction times to decrease for the easy category, we expected the opposite for the difficult category.

II. METHOD

A. Mobile Application Characteristics

A software program designed to categorize the difficulty of right-left hand recognition was developed using the Unity platform for the mobile application. The difficulty levels were defined based on the rotation degrees of hand images and the complexity of hand postures. User performances were recorded separately for the right and left hands, including parameters such as accuracy rates (%), test completion time, and reaction time (ms).

B. Participant Characteristics

The study group consisted of healthy volunteers aged 18-65 years, who scored 21 and above in the Montreal Cognitive Assessment Test [9].

C. Mobile Application Test Procedure

Test parameters, such as the difficulty level of hand visuals, the number of visuals, and the inter-visual transition time, were selected. Once ready, participants were instructed to start the test by pressing the "start test" button. During the test, participants were required to determine whether the hand visual stimuli displayed on the phone screen corresponded to the "right" or "left" hand and to press the "right" or "left" button accordingly. The test categories were administered in a randomized order, with options categorized as easy, medium, or hard. Each set included 30 different hand visuals, shown in various postures and randomly presented as either right or left. The interval between visuals was set to 5 seconds, and participants were instructed to respond as quickly as possible.

D. Ethics Statement

Ethical approval for the study has been taken from the Istanbul Medipol University Non-Interventional Clinical Trials Ethics Committee (Approval no: E-10840098-772.02-6760)

and a written informed consent was obtained from the subjects according to the Declaration of Helsinki.

E. Statistical Analysis

Statistical analysis was conducted using the Jamovi (2.3.28.0) software. Analyses were performed with a significance level set at $p < 0.05$. Variables measured numerically were described using the arithmetic mean and standard deviation (mean \pm SD). The normality of the data was assessed using the Shapiro-Wilk test. For comparisons between two groups, either the t-test or the Wilcoxon test was used. "Repeated Measures ANOVA" test was performed to compare variables across three independent groups. Post-hoc comparisons were adjusted using the Bonferroni Correction.

III. RESULTS

The characteristics of the participants included in the study are shown in Table 1.

Demographic Information (n=146)	Values	Statistical Values
Gender (%) (Female; male)	50,68; 49,32	$\chi^2=0.0274$; $p=0.869$
Hand Preference (%) (Right; Left)	89,73; 10,27	$\chi^2=92.2$; $p<0.001$
Education (%)		
Highschool	10.96	
University	82.19	$\chi^2=157$; $p<0.001$
Master Degree	6.85	
Age (years) Mean \pm SD	25.8 \pm 7.45	

SS: Standart Deviation, n: Number Of Participants

Table1. Characteristics of the Participants

Performance outcomes regarding accuracy rates, reaction times, and test completion times were compared according to the difficulty levels in the mobile application (Table 2).

Performance Measures	Side	Category	Mean	SD	SE	F (df)	p
Accuracy rates (%)	Left	Easy	88.52	12.7	1.05		
		Medium	85.54	14.7	1.22	23.9 (2-279)	$p<0.001$
		Hard	72.82	21.6	1.79		
	Right	Easy	90.16	13.4	1.11		
		Medium	86.27	13.5	1.12	42.4 (2-284)	$p<0.001$
		Hard	72.52	19.0	1.57		
Reaction Time (ms)	Left	Easy	1828.83	525	43.5		
		Medium	1957.79	550	48.0	9.25 (2-284)	$p<0.001$
		Hard	2492.21	1861	151.0		
	Right	Easy	1745.06	534	44.2		
		Medium	1852.99	532	44.1	25.3 (2-288)	$p<0.001$
		Hard	2259.01	532	42.9		
Test completion time (s)	Easy	98.28	13.5	1.31			
	Medium	62.98	16.3	1.36	36.6 (2-288)	$p<0.001$	
	Hard	76.74	19.3	1.60			

SD: Standart Deviation, SE: Standart Error

Table 2. Descriptive information and group comparisons of performance measurements

3 (Level: Easy, Medium, Hard) x 2 (Side: Right, Left) ANOVA design was used to analyse the accuracy rates for the right and left sides according to difficulty levels. The analysis revealed a significant difference only between the difficulty levels ($F_{(df=2-290)}=103,232$; $p<0,001$; $\eta^2=0.165$). In the post-hoc comparisons of the difficulty levels, statistically significant differences were found between easy-medium, easy-hard, and medium-hard ($p<0.001$ for all) (Figure 1).

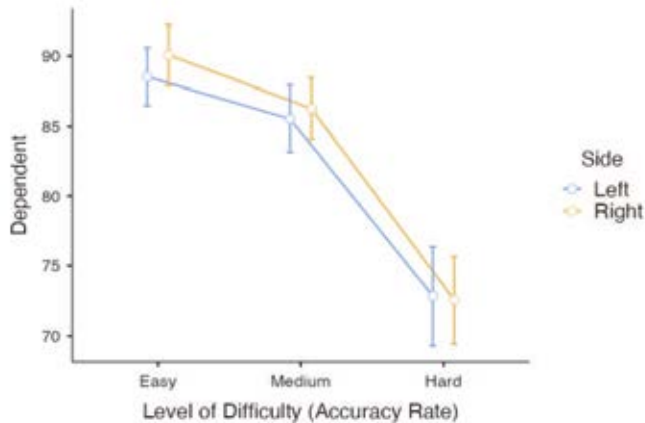


Fig. 1. Accuracy rates according to level of difficulty

3 (Level: Easy, Medium, Hard) x 2 (Side: Right, Left) ANOVA design was used to analyse the reaction times for the right and left sides according to difficulty levels. The analysis revealed significant differences based on difficulty levels ($F_{(df=1,16-168,61)}=43,857$; $p<0,001$ $\eta^2=0.071$); and between the sides ($F_{(df=1-145)}=6,531$; $p=0,012$ $\eta^2=0.005$). Post-hoc comparisons of the difficulty levels showed statistically significant differences between easy-medium, easy-hard, and medium-hard ($p<0.001$, for all). Reaction times for the left side visuals were found to be longer ($t=2.56$; $p=0.012$) (Figure 2).

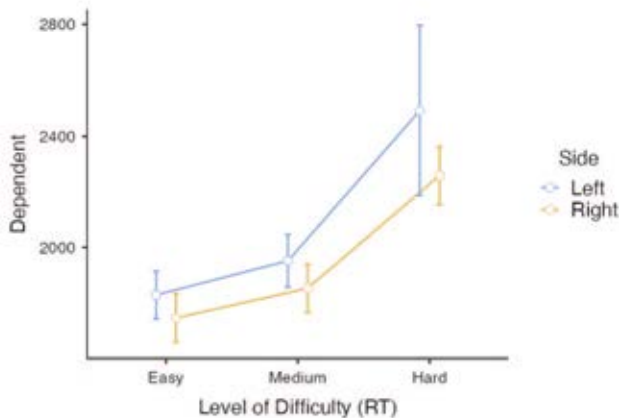


Fig. 2. Reaction time according to level of difficulty

Lastly, a significant difference was found between the levels in terms of test completion time ($p<0.001$). According to post-hoc comparisons, statistically significant differences were identified between the easy-medium ($p=0.035$), easy-hard ($p<0.001$), and medium-hard ($p<0.001$) categories.

IV. CONCLUSION

In this study, a mobile application assessment method was developed in which the right-left discrimination was categorized within the concept of mental rotation. The

investigation focused on examining differences in users' responses to hand images presented at various rotation angles. Since attentional mechanisms for mental rotation and right-left recognition are different, it is important to assess these cognitive tasks separately.

Our findings regarding the effect of mental rotation degree on reaction time were consistent with previous studies [1,2,4,7]. Reaction time was longer for the difficult category, indicating that participants spend more time for cognitive processing of rotated hand visual. Various studies have reported that it is more difficult to rotate the right hand clockwise (45° , 90° , and 135°) and the left hand counterclockwise (225° , 270° , and 315°) [1,2,4,7]. Considering these results, the mobile application we presented in here is functional to use. In addition, in this mobile application, hand visuals have been distinctly categorized and designed in a way that participants can easily perform. Since, attentional mechanisms of mental rotation and right-left recognition cognitive tasks are different, by presenting a system where mental rotation tasks are categorized from easy to difficult is essential. As a result, clinicians can easily follow the individuals' performance and integrate them to the specific therapeutic training programs by using the hand laterality paradigm which is categorized within the concept of mental rotation.

ACKNOWLEDGEMENT

This study was supported by Scientific and Technological Research Council of Türkiye (TUBITAK) under Grant Number 222S133. The authors thank TUBITAK for their Support.

V. REFERENCES

- [1] Nico, D., Daprati, E., Rigal, F., Parsons, L., & Sirigu, A. (2004). Left and right hand recognition in upper limb amputees. *Brain*, 127(1), 120-132.
- [2] Parsons, L. M. (1987). Imagined spatial transformation of one's body. *Journal of experimental Psychology: general*, 116(2), 172.
- [3] Lyu, Y., Guo, X., Bekrater-Bodmann, R., Flor, H., & Tong, S. (2017). An event-related potential study on the time course of mental rotation in upper-limb amputees. *Clin Neurophysiol*, 128(5), 744-750. doi:10.1016/j.clinph.2017.02.008.
- [4] Yan, J., Guo, X., Jin, Z., Sun, J., Shen, L., & Tong, S. (2012). Cognitive alterations in motor imagery process after left hemispheric ischemic stroke.
- [5] Heil, M. (2002). The functional significance of ERP effects during mental rotation. *Psychophysiology*, 39(5), 535-545. doi:10.1017/S0048577202020449
- [6] Moseley, G. L. (2006). Graded motor imagery for pathologic pain: a randomized controlled trial. *Neurology*, 67(12), 2129-2134. doi:10.1212/01.wnl.0000249112.56935.32
- [7] Moseley GL. Imagined movements cause pain and swelling in a patient with complex regional pain syndrome. *Neurology* 2004; 62:1644.
- [8] De Simone, L., Tomasino, B., Marusic, N., Eleopra, R., & Rumiati, R. I. (2013). The effects of healthy aging on mental imagery as revealed by egocentric and allocentric mental spatial transformations. *Acta Psychologica*, 143(1), 146-156.
- [9] Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., ... & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, 53(4), 695-699.
- [10] Sekiyama, K. (1982). Kinesthetic aspects of mental representations in the identification of left and right hands. *Perception & psychophysics*, 32, 89-95.