

INTERFERENCE BETWEEN VERBAL CONCEPT FORMATION AND SPATIAL MENTAL ROTATION IN FEMALE SUBJECTS¹

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Summary.- In this study the relationship between spatial cognition and verbal intelligence abilities was examined in case of 52 female subjects. Interference between mental rotation performance and verbal intelligence scores was found. Subjects with good verbal abilities have lower scores in mental rotation tasks than subjects with poorer verbal abilities. This finding accords with some basic models of a dual-coding system. The spatial functions represented in mental rotation interfered with verbally based concept formation and lexical knowledge in female subjects.

Spatial cognition is considered a complex cognitive process that includes perception, orientation, manipulation, and motion. There are major individual differences in spatial abilities between subjects in those cognitive functions that involve perceptuo-motoric coordination or mental imaginary processes (Kimura, 1999). Wechsler intelligence test (WAIS) studies (Tulsky, Zhu & Prifitera, 2000; Handler, 1998) show that these functions are dominant in picture completion, block design, and object assembly, although direct connection to spatial abilities has not yet been proven.

Research on intelligence has always been controversial. In spite of this discrepancy, intelligence tests are valuable instruments, for example in army recruitment, job employment, and clinical practice. Various definitions of intelligence exist in the literature, but the most comprehensive is David Wechsler's (1955) definition that emphasizes an aggregate or global capacity of the individual to perform purposefully with rational thinking, which helps to deal adaptively with the environment. If we accept intelligence as a complex quality, then different cognitive processes, thinking methods, and perceptual and motional components have to be accepted as well. Therefore, if a correlation between spatial and intellectual abilities is found, it must in fact represent the linkage ratio between these two functions.

A major index of spatial ability has traditionally been performance on psychometric test involving mental rotation (Shepard & Metzler, 1971). There are two main types of well-characterized mental rotation paradigms. The first is mental rotation of objects (Vandenberg & Kuse, 1978); the second is hand mental rotation (Bonda et al., 1995; Karadi et al., 1999).

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These two tests assess different cognitive functions and frames of reference in the brain (Kosslyn et al., 1998). Hand Mental Rotation requires an egocentric spatial reference frame (with body-centered reference points), and Object Mental Rotation represents an allocentric reference frame (with extrapersonal reference points).

In the present experiment, both types of subjects' mental rotation abilities were compared to their intellectual patterns as assessed by the WAIS test. The cognitive functions involved in the WAIS subtests correlated with mental rotations prove the presence of spatial functions in intelligence.

Method

Subjects

52 female university students (age: $M=21$ yrs., $SD=1.43$ yrs.) from the University of Pécs, Hungary, participated in the present study. In terms of academic disciplines, there were 21 students from medicine, 18 from the humanities, 7 from technical disciplines and 6 from the sciences.

Tasks

The subjects completed two computerized mental rotation tests and, at a different time, their intelligence scores were measured by the standardized Hungarian Wechsler Intelligence Scale (WAIS-H). For the mental rotation tests a personal computer was used with the guidance of the experimenter. First, the subjects completed 5 practice trials of each test on which they received feedback about their answers. In the experimental testing, when data was collected, the subjects were given no feedback. Performance time and number of errors were measured.

Hand Mental Rotation

In the hand mental rotation task, the subjects saw a randomly ordered sequence of 98 human hand pictures with different finger positions rotated by 0, 30, 60, 90, 120, 150 and 180 degrees. The task was a simple discrimination task, in which subjects judged whether the pictures was a left or a right hand (Bonda, et al., 1995; Karádi, et al., 1999).

Object Mental Rotation

In this task, 45 pairs of geometric cubes were shown on the computer screen. The right cube was rotated by the above-mentioned degrees. The cubes were identical to the 3D

perspective pictures of the original Shepard & Metzler (1971) test. The subjects had to decide if the two cubes were identical or not.

Hungarian Wechsler Intelligence Scale

The standardized Hungarian Wechsler Intelligence Scale (WAIS-H) was used to measure intelligence scores (Kun & Szegedi, 1996, in Hungarian). The test consisted of verbal and performance scale subtests. Verbal subtests measure concept formation, lexical knowledge, comprehension, verbal short-term memory, arithmetic and verbal fluency abilities. Performance subtests measure perceptual and motor coordination, picture arrangement, object assembly, block design and picture completion. The collection of data fulfilled the requirements of the Hungarian standards.

Results

Table 1 shows the mean performance time and number of errors for the Hand Mental Rotation task and the Object Mental Rotation task. The results of the WAIS-H intelligence test were in the normal range (IQ=117.7, SD=6.04).

Correlational analysis was used to examine the relationship between mental rotation ability and the intelligence subtests. The results indicate a negative correlation between verbal abilities (Information and Verbal Fluency subtests) and rotation time at each mental rotation tasks (Table 2). Positive correlations were found in the case of performance intelligence subtests and mental rotations. These correlations mean that subjects with good verbal abilities perform mental rotations slower and that mental rotation tasks can be interpreted as a performance intelligence-dependent process.

After these results, the subjects were divided into four groups according to the means of total performance time in both mental rotation tests. The values of intelligence subtests were compared between these groups with a one-way ANOVA (see Table 3).

We found that faster performers of the Hand Mental Rotation task received lower scores in the Verbal Information intelligence subtest ($F_{1,51}=6.67$; $p<0.05$) than slower rotators. They also outperformed slow rotators in the Picture Completion subtest ($F_{1,51}=4.04$; $p<0.05$), the Block Design subtest ($F_{1,51}=6.19$; $p<0.05$) and in their overall Performance Intelligence Quotient ($F_{1,51}=8.53$; $p<0.001$). We did not find the same pattern in the case of Object Mental Rotation.

Discussion

Former studies have shown that mental rotation is an excellent task with which to measure spatial abilities (Vandenberg & Kuse, 1978; Cohen et al., 1996). It is suggested that there are two reference frames that are used during spatial cognition. An egocentric reference frame is used when objects have emotional or self-related aspects, which usually means close proximity to the body. In an allocentric reference frame, the objects can exist independently from the self and its mental consequences, such as emotions and motivations. This representational form records longer distances and inter-object relations. In the present experiment, two mental rotational tasks were used in order to measure these two frames. The Hand Mental Rotation task measures an egocentric frame of reference (Bonda et al., 1995), while the Object Mental Rotation task measures an allocentric frame of reference (Cohen et al., 1996).

In this study, it is suggested that spatial cognition is a process that is dependent on Performance Intelligence. Results from correlational and variance analyses suggest that good verbal ability is associated with poorer spatial functioning. The subjects who performed faster rotations had significantly lower scores on the verbal-based subtests (Information and Verbal Fluency). These subtests measure basic lexical and conceptual knowledge, where the subjects have to give definitions for certain concepts. In the present study, the existence of interference between concrete (e.g. spatial) and abstract (e.g. verbal, conceptual) cognitive process is claimed, but only in the case of an egocentric reference frame. Our findings are in accordance with some earlier results and may give an extended view for them (e.g. Paivio, 1986; Nicholson & Kimura, 1996; Poslusny & Barton, 1981).

Generally, the results presented here suggest that the egocentric spatial functions measured by Hand Mental Rotation tasks interfere with verbally based concept formation skills and lexical knowledge in female subjects, and as a contradictory function limits the balance between them.

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Appendix

Table 1 – Mean Performance Time and Number of Errors of Hand Mental Rotation and Object Mental Rotation.

Table 2 – Statistically Significant Correlations of Hand and Object Mental Rotation tasks to WAIS Intelligence Subtests. ($p < 0.05$)

Table 3 – One-Way ANOVA Between Slow and Fast Mental Rotator Subjects Related to WAIS Intelligence Subtests.

Table 1 – Mean Performance Time and Number of Errors of Hand Mental Rotation and Object Mental Rotation.

	Performance Time (sec.)		Number of Errors	
	M	SD	M	SD
Hand Mental Rotation task				
0 ⁰	2.25	0.79	0.29	0.64
30 ⁰	2.23	0.73	0.23	0.55
60 ⁰	2.25	0.89	0.29	0.54
90 ⁰	2.49	1	0.47	0.92
120 ⁰	2.56	0.98	0.37	0.66
150 ⁰	3.11	1.2	1.31	2.4
180 ⁰	3.68	1.5	1.82	2
Object Mental Rotation task				
0 ⁰	5.5	2.4	0.5	0.67
30 ⁰	6	2.4	0.6	0.67
60 ⁰	6.2	2.6	0.7	0.61
90 ⁰	7.16	3.4	0.8	0.8
120 ⁰	7.19	3.1	1	0.84
150 ⁰	8.54	4.9	1.2	1
180 ⁰	8.1	4.1	1.11	0.84

Table 2 – Statistically Significant Correlations of Hand and Object Mental Rotation tasks to WAIS Intelligence Subtests. (p<0.05)

Hand Mental Rotation task	Verbal Subtests	Performance Subtests		Overall Performance Intelligence Quotient
	<i>Information</i>	<i>Digit Symbol</i>	<i>Block Design</i>	
Total Time	-0.49	0.46	0.37	0.38
0 degree	-0.39	n.s.	0.30	0.31
30 degree	-0.37	0.35	0.35	0.34
60 degree	-0.38	0.43	0.32	n.s.
90 degree	-0.44	0.47	0.40	0.35
120 degree	-0.43	0.43	0.34	0.37
150 degree	-0.53	0.44	0.29	0.30
180 degree	-0.48	0.45	0.30	0.35

Object Mental Rotation task	Verbal Subtests	Performance Subtests			Overall Performance Intelligence Quotient
	<i>Verbal Fluency</i>	<i>Digit Symbol</i>	<i>Block Design</i>	<i>Picture Completion</i>	
Total Time	-0.30	0.46	0.28	0.42	0.32
0 degree	-0.31	0.35	n.s.	0.28	0.36
30 degree	-0.28	0.43	n.s.	0.38	0.32
60 degree	-0.31	0.47	0.31	0.35	n.s.
90 degree	-0.28	0.43	0.33	0.50	0.39
120 degree	n.s.	0.44	n.s.	0.39	n.s.
150 degree	n.s.	0.45	n.s.	0.46	0.33
180 degree	n.s.	0.39	n.s.	n.s.	n.s.

Table 3 – One-Way ANOVA Between Slow and Fast Mental Rotator Subjects Related to WAIS Intelligence Subtests.

		Rotator	N	Mean	F	Sign.
Verbal Subtests	<i>Information</i>	Fast	25	13.7	6.66	p<0.05
		Slow	27	14.9		
Performance Subtest	<i>Picture completion</i>	Fast	25	13.8	4.04	p<0.05
		Slow	27	12.3		
	<i>Block design</i>	Fast	25	15.5	6.19	p<0.05
		Slow	27	14.4		
Overall Performance Intelligence Quotient		Fast	25	124.4	8.53	p<0.001
		Slow	27	117.9		