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Measure of the ability to rotate mental images

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The aim of this study was to design an innovative test to measure the ability to rotate mental images. An unfolded cube was designed, which participants had to reassemble mentally, prior to mentally rotating the image, and answering 23 questions concerning the cube. The Measure of the Ability to Rotate Mental Images (MARMI) test was administered to 354 participants. Cronbach alpha was .90, and high correlations between this test and other image rotation and spatial image tests were found. However, poor correlations were observed between test scores and the responses to the visual imagery vividness questionnaire. Both test reliability and validity underscore that it is a good instrument for measuring the ability to rotate mental images.

Medida de la aptitud para rotar imágenes mentales. El objetivo del presente trabajo era construir un nuevo test que midiese la capacidad de rotar imágenes mentales. Para ello, se construyó un cubo descompuesto que los participantes debían componer mentalmente, y después rotar, también mentalmente, y contestar a 23 preguntas referidas al cubo. Se aplicó el test, Medida de la Aptitud para Rotar Imágenes Mentales (MARMI), a un grupo de 354 participantes. Se encontró un alfa de Cronbach de .90, y altas correlaciones del test con otros tests de rotación de imágenes y de imágenes espaciales. Sin embargo, se han encontrado bajas correlaciones entre las puntuaciones del test y las respuestas a cuestionarios de viveza de imagen visual. Tanto la fiabilidad como la validez del test lo convierten en un buen instrumento para la medida de la capacidad de las personas para rotar imágenes mentales.

The choice of a psychometric instrument for measuring mental imagery remains a contentious issue among researchers. Questionnaires are widely used for measuring mental imagery (for a reviews, see McKelvie, 1995; and Richardson, 1994). Of these, the most predominant are the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) that measures vividness of visual imagery, and the Betts' Questionnaire Upon Mental Imagery (Betts' QMI; Sheehan, 1967) that measures vividness of imagery in terms of seven senses: visual, auditory, cutaneous, kinaesthetic, gustatory, olfactory and organic.

More recently, cognitive and neuroscience studies (Kosslyn, 1994; Kosslyn & Koenig, 1992) have shown that imagery is not unitary, and two types of imagery have been identified i.e., object imagery and spatial imagery (Blajenkova, Kozhevnikov, & Motes, 2006). Object imagery refers to imagery in terms of form, size, colour, etc, whereas spatial imagery refers to the relationship between objects, movement of objects, spatial transformations, and so forth (Blajenkova et al., 2006). An individual may have abilities in one type of imagery task, but less or none in others.

Factorial analysis undertaken by Carroll (1993) on a broad range of tests revealed five first order factors in spatial ability: Visualization (VZ), Spatial Relations (SR), Closure Speed (CS), Closure Flexibility (CF), and Perceptual Speed (P). Thereafter, factorial analysis undertaken by Burton and Fogarty (2003) with the results of 42 measures of visual imagery and spatial ability also revealed five factors that were termed: Visualization (VZ), Spatial Relations (SR), Speed of Closure (CS), Visual Memory (MV), and a combined Perceptual Speed-Closure Flexibility (P/CF).

To measure the speed of image rotation (SR), Burton and Fogarty's (2003) used the Card Rotation Test (Ekstrom, French, Harman, & Dermen, 1976), the Cube Comparison Test (Ekstrom et al., 1976), and the Spatial Relations Test (Thurstone & Thurstone, 1962/2002). Carroll's (1993) study and Burton and Fogarty's (2003) study agree in two of the three tests used to measure image rotation, and both studies coincide in that Visualization (VZ) was the most heavily weighted factor, followed by Spatial Relations (SR).

The three image rotation tests proposed by Burton and Fogarty (2003), together with the Mental Rotation Test (MRT; Vandenberg & Kuse, 1978) are among the most extensively used image rotation tests. Burton and Fogarty (2003) found the Cronbach alpha was .96 for the Card Rotation Test, .80 for the Cube Comparison Test, and .89 for the Spatial Relations Test. Thurstone and Thurstone (1962/2002) obtained a test-retest reliability of .73 on the Spatial Relations Test. Vandenberg and Kuse (1978) found a Kuder-Richardson of .88, and a reliability test-retest of .83 on the Mental Rotation Test.

Image rotation tests are on the whole highly correlated to tests measuring rotation, and spatial imagery tests, but poorly or not correlated with questionnaires measuring mental image vividness (Blazhenkova & Kozhevnikov, 2009; Burton & Fogarty, 2003; Campos, 2009). The Card Rotation Test correlated .58 with the Cube Comparison Test, and .77 with the Spatial Relations Test. The Cube Comparison Test correlated .58 with the Spatial Relations

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Test (Burton & Fogarty, 2003). The correlations between these image rotation tests and other spatial imagery tests (Paper Form Board Test, Ekstrom et al., 1976; Paper Folding Test, Ekstrom et al., 1976; and Surface Development Test, Ekstrom et al., 1976) ranged from .40 to .55 (Burton & Fogarty, 2003). Campos (2009) found a correlation of .44 between the Spatial Relations Test and the Measure of the Ability to Form Spatial Mental Imagery (MASMI; Campos, 2009) whereas Blazhenkova and Kozhevnikov (2009) found the correlation for the Mental Rotation Test with the Paper Folding Test was .55.

The correlations between image rotation and image vividness are weak. Burton and Fogarty (2003) correlated the previously mentioned image rotation tests with the Betts' Questionnaire Upon Mental Imagery (Sheehan, 1967), and with the Vividness of Visual Imagery Questionnaire (VVIQ, Marks, 1973), and found that correlations ranged from .12 to .17. Campos (2009) found a correlation of .13 between the Spatial Relations Test and the Vividness of Visual Imagery Questionnaire-Revised Version (VVIQ-2; Marks, 1995) whereas Blazhenkova and Kozhevnikov (2009) found a correlation of -.03 between the Mental Rotation Test and the Vividness of Visual Imagery Questionnaire.

Though the results for gender differences reported in the literature are fairly consistent i.e., men have a greater ability to rotate mental images (Campos, Pérez-Fabello, & Gómez-Juncal, 2004; Delgado & Prieto,1996; Hedges & Nowell, 1995; Linn & Petersen, 1985, 1986; Voyer, 2011; Voyer, Voyer, & Bryden, 1995), issues regarding the underlying causes of gender differences are the subject of considerable controversy. Thus, some studies have focused on gender and the use of strategies (Linn & Petersen, 1985), others have centred on hormonal influence (Kimura, 1999; Hooven, Chabris, Ellison, & Kosslyn, 2004; Sanders, Sjodin, & of Chastelaine, 2002) or socialization (Oosthuizen, 1991).

The aim of this study was to construct an innovative test to measure the ability to rotate mental images with a high degree of reliability and validity. Whereas in previous image rotation tests, rotation involved searching for an image on a printed model, in the new test rotation involves searching for an image of an unprinted model, the image is the one that is in the participant's memory. This may further exacerbate the task of previous tests, but it provides a better measure of an individual's ability to rotate mental images. The participant first forms the image and then rotates the figures until their image coincides with the one they have in their memory.

Method

Participants

The sample consisted of 354 (45 men and 309 women) undergraduates of the Faculty of Psychology of the University of Santiago de Compostela, with an age range of 18 to 27 years, mean age 19.52 (*SD*= 1.95).

Materials

Participants were administered the following tests: The Measure of Ability to Rotate Mental Images, the Mental Rotation Test, the Spatial Scale of the Primary Mental Aptitudes Test, the Measure of the Ability to Form Spatial Mental Images, and the Vividness of Visual Imagery Questionnaire-Revised.

The Measure of the Ability to Rotate Mental Images (MARMI) test was designed to measure the ability to rotate mental imagery using an unfolded cube (see Figure 1) that participants had to mentally reassemble and rotate before responding to 23 questions about the cube. Each question consisted of 4 multiple choice options; two were true and two false. Total test score was obtained by adding all of the correct responses and subtracting the incorrect ones. Participants were given a maximum 10-minute time limit to complete the test.

Mental Rotation Test (MRT; Vandenberg & Kuse, 1978). The test consisted of 10 items, each one was a three-dimensional geometric figure of small cubes. Each item consisted of a criterion figure and two correct and two incorrect options. The task required participants to rotate the figures to see if they matched the criterion figure. For corrective purposes, Vandenberg and Kuse recommend giving two points for a line with both choices correct, none if one choice is correct but the other one incorrect, or if both are incorrect. If only one design was chosen and it is correct, one point is given. Participants were given a 3-minute time limit to complete the test.

The Spatial Scale of the Primary Mental Aptitudes Test (PMA; Thurstone & Thurstone, 1962/2002) measured the ability to imagine and rotate two or three-dimensional objects. The test consisted of 20 items, each one being a two-dimensional geometric model with six similar figures. The task involved determining which figures, as seen from different angles, matched the model, even when it is rotated on its own axis. Participants were given a five-minute time limit to complete the task.

The Measure of the Ability to Form Spatial Mental Images (MASMI; Campos, 2009) test consisted of an unfolded cube that participants had to reassemble before replying to 23 questions within a 10-minute time limit. Each question had four options, two

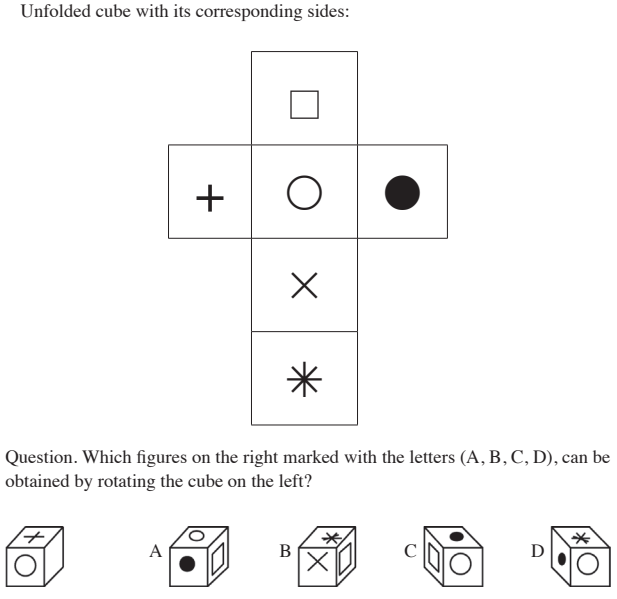

Figure 1. *Example of a MARMI item.*
Note: The test can be obtained for free by requesting a copy directly from the author or from PsycTESTS (Database of the American Psychological Association)

were correct and two incorrect. The total test score was calculated by adding the correct options and subtracting the incorrect ones; thus, the total score could range from - 46 to 46. Campos obtained a Cronbach alpha of .93.

The Spanish Version (Campos & Pérez-Fabello, 2009) of the Vividness of Visual Imagery Questionnaire-Revised Version (VVIQ-2, Marks, 1995) consisted of a 32-item questionnaire referring to different situations where participants had to visualize and score their imagery vividness on a five-point scale where 5 indicated imagery was perfectly clear and as vivid as normal vision, and 1 indicated the absence of imagery, you only know you are thinking about the object. No time limit was given for completing the test. Campos and Pérez-Fabello (2009) obtained a Cronbach alpha of .94.

Procedure

The tests were carried out in groups of approximately 20 students in two sessions in their usual classrooms. Participants were given instructions for each of the tests. All participants freely volunteered in the experiment, and were awarded points in an academic subject. The order of presentation of the tests in each group was counterbalanced, and all participants were assured their data would remain anonymous and confidential.

Data analysis

Statistical analysis was performed using the SSPS 18.0 software programme. The internal consistency of the MARMI was calculated with Cronbach's alpha. Student's t-test was performed to determine any statistically significant differences in the scores obtained by women and men. Percentiles were obtained for the scoring of responses on the MARMI, and finally, the Pearson product-moment correlation coefficient correlated the MARMI with other imagery tests.

Results

In the initial analysis of internal consistency of the MARMI the Cronbach alpha was .90. The descriptive statistics of the measures used in this study, and the correlations between the MARMI and other measures are shown in Table 1. The MARMI correlated significantly with measures of mental imagery rotation, and a low correlation was obtained between the MARMI and the VVIQ-2, a questionnaire that measures imagery vividness.

Table 1
Correlations, means and standard deviations of measures of imagery

	PMA	MRT	MASMI	VVIQ-2	MARMI
1. PMA					
2. MRT	.48**				
3. MASMI	.55**	.44**			
4. VVIQ-2	.05	.04	.13*		
5. MARMI	38**	.40**	.48**	.10	
M	28.30	7.17	22.49	3.74	8.90
SD	12.67	4.58	12.62	.53	8.57

* p<.05; ** p<.01

The difference between the scores for women (M= 8.36, SD= 8.05) and men (M= 12.02, SD= 10.67) on the MARMI was significant, $t(352)$= 2.24, p<.05. In order to match sample size for both genders, a total of 45 women were randomly selected, and the mean difference was calculated using the t test for independent samples that revealed a statistically significant difference.

In order for the test to be useful for assessing an individual's ability to rotate images, percentiles were obtained for both genders given that significant differences were found between both women and men.

Table 2
Percentiles of males and females

Percentile	Score	
	Males	Females
100	46.0	46.0
90	26.2	17.8
80	18.0	12.0
75	16.0	11.0
70	14.6	9.0
60	10.0	8.0
50	9.0	6.0
40	7.2	5.0
30	5.4	4.0
25	4.0	3.0
20	4.0	3.0
10	2.0	2.0

Discussion

The Cronbach alpha obtained is high, and is greater than that reported by Burton and Fogarty (2003) for the Cube Comparison Test (.80), and the Spatial Relations Test (.89), and is higher than the results obtained by Vandenberg and Kuse (1978) for the Mental Rotation Test (.83). Notwithstanding, internal consistency was slightly below the score reported by Burton and Fogarty for the Card Rotation Test (.96).

Men obtained significantly higher image rotation scores than women. This finding agrees with the results obtained by most studies that have analyzed gender differences in the ability to rotate mental images (Campos et al., 2004; Delgado & Prieto, 1996; Hedges & Nowell, 1995; Linn & Petersen, 1985, 1986; Voyer, 2011; Voyer et al., 1995).

The correlations between the MARMI and other measures of mental imagery rotation (PMA and MRT) were significant, which agrees with the results obtained by other authors who correlated different image rotation tests among themselves (Burton & Fogarty, 2003; Campos, 2009; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001; Richardson, 1977). The MARMI was also significantly correlated with the MASMI that measures spatial imagery, and substantiates the results of previous studies that correlated image rotation and spatial imagery (Blazhenkova & Kozhevnikov, 2009; Burton & Fogarty, 2003; Campos, 2009; Miyake et al., 2001; Richardson, 1977). Nevertheless, there was a weak correlation between the MARMI and the VVIQ-2, which

is in agreement with the findings of other studies (Blazhenkova & Kozhevnikov, 2009; Burton & Fogarty, 2003; Campos, 2009; McKelvie, 1995; Richardson, 1977).

Both the reliability and validity of the MARMI as well as its potential as a measure of gender differences in the ability to rotate mental imagery underscore that this test is a good instrument for assessing an individual's ability to rotate mental images. Further studies are required to assess the efficacy of this new test in different populations and age groups and as a diagnostic tool for gauging an individual's ability to rotate mental imagery.

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