PERGAMON

Personality and Individual Differences 30 (2001) 117–126

PERSONALITY AND INDIVIDUAL DIFFERENCES

www.elsevier.com/locate/paid

Dynamic spatial performance: sex and educational differences

María José Contreras *, Roberto Colom, Pei C. Shih, María Jesús Álava, José Santacreu

Facultad de Psicología, Universidad Autónoma de Madrid, 28049, Madrid, Spain

Received 24 June 1999; received in revised form 17 November 1999; accepted 24 January 2000

Abstract

A set of two dynamic tests were developed for measuring spatial orientation and spatial visualization (SODT and SVDT). These dynamic spatial tests were designed for computer administration. A printed battery including reasoning and spatial tests was also administered to a sample of 602 university graduates, 300 females (mean age = 27.17) and 302 males (mean age = 28.41). The participants were applicants for an air traffic control training program. Therefore, they were highly motivated to do their best. The present study is based on three main questions: (1) do the new dynamic spatial tests measure the same ability irrespective of sex?; (2) are performance differences between the sexes negligible for spatial tasks that closely resemble 'real' spatial orientation activities?; and (3) is type of education related to dynamic spatial performance? (to our knowledge, a question not directly addressed in the previous literature). The findings suggest that: (1) the factor structure is the same for both sexes; (2) males have an overall higher dynamic spatial performance than females; and (3) neither males' nor females' type of education makes any difference to their dynamic spatial performance. When males and females have the same type of education, dynamic spatial performance is still higher in males.

Keywords: Spatial orientation; Spatial visualization; Dynamic spatial ability; Educational differences; Sex differences

1. Introduction

In a highly quoted Technical Report, Lohman (1979) defined spatial ability as "the ability to generate, retain, and manipulate abstract visual images. At the most basic level, spatial thinking requires the ability to encode, remember, transform and match spatial stimuli" (Lohman, 1979, p. 126). Lohman (1979) identified three basic spatial ability factors. (a) Spatial relations: mental rotation is the common element in tests measuring this factor; (b) Spatial orientation: the ability to imagine how a stimulus array will appear from another perspective. The subject must imagine that he/she is in a different location, and make some judgment about the situation. There is often

* Corresponding author. Tel.: +34-91-397-87-51; fax: +34-91-397-52-15.
E-mail address: mjose.contreras@uam.es (M.J. Contreras).

0191-8869/00/$ - see front matter
PII: S0191-8869(00)00015-5

a left–right discrimination component in these tasks. This factor is difficult to measure because tests designed to assess it are often solved by mentally rotating the stimulus rather than by reorienting an imagined self. (c) Visualization: the tests for assessing this factor share two elements, they are usually administered under relatively unspeeded conditions and they are complex.

Spatial tasks require that objects, forms or symbols are perceived as laid out in space, whether in real-life interactions between the individual and his/her surroundings or in pictorial or printed representations. In a broad sense, spatial abilities are concerned with an individual's abilities to search the visual field, apprehending the forms, shapes, and positions of objects as visually perceived, forming mental representations of those forms, shapes, and positions, and manipulating such representations mentally (Carroll, 1993; Juan-Espinosa, Abad, Colom & Fernández-Truchaud, 2000).

> Hunt, Pellegrino, Frick, Farr and Alderton (1988) pointed out more than a decade ago the limitations of printed tests for the assessment of the ability to deal with real movement. They postulated a 'dynamic spatial ability' for reasoning within dynamic tasks, based on moving objects (Hunt & Pellegrino, 1985; Pellegrino, Hunt, Abate & Farr, 1987; Pellegrino & Hunt, 1989; Law, Pellegrino & Hunt, 1993a; Law et al., 1993b). Dynamic spatial reasoning concerns "the prediction of *where* a moving object is going and *when* it will arrive at its predicted destination" (Pellegrino & Hunt, 1989, p. 181). Since the work of these authors, an increasing number of publications have addressed the issue of dynamic spatial ability, comparing static vs dynamic spatial performance (the latter measured through computer presentations; see Juan-Espinosa et al., 2000). A number of important questions have been raised in relation to: (a) the construct validity of the new dynamic tasks; and (b) their predictive validity for occupations in which decision-making is based on moving objects and events — air traffic controllers, aircraft pilots, car drivers, and so forth (Schiff & Oldak, 1990; Mead & Drasgow, 1993; Jackson, Vernon & Jackson, 1993; Larson, 1996; Sacuzzo, Craig, Johnson & Larson, 1996).

The dynamic spatial tasks are usually designed for computer administration. Thus, for instance, an object is presented on the computer screen. The object moves with a given speed according to a previously-fixed path. The subject estimates time, speed, the crossing of different paths, and so forth. Therefore, the subject predicts *where* a given object (or objects) is (are) going, and *when* it (they) will arrive at a given destination.

Larson (1996) has stated that the difference between static and dynamic tasks lies not in the processing of the movement itself, but in the nature of the tasks. Using printed tests of mental rotation with static and moving conditions, he found a strong relationship between the two conditions. This is important when there is a comparison between performance in printed tests (mental rotation, surface development, etc.) and performance in dynamic tests.

Another common finding is the higher performance, on average, of males. The magnitude of the male advantage is related to the kind of task: performance differences between the sexes is greatest for mental rotation, followed by spatial perception, followed by visualization (Voyer, Voyer & Bryden, 1995).

Sacuzzo et al. (1996) related differences in performance between the sexes in dynamic spatial tasks to the effect of practice. Females and males were compared at four tests: two of them were printed and the other two were computerized. One of the printed and one of the computerized tests were based on speed, while the others were based on accuracy. Males, on average, performed better, but females improved with practice much more than males. Improvement in females was especially high for the tests involving speed.

Contreras, Santacreu, Shih and Colom (1998) have developed two new dynamic spatial tests for personnel selection purposes. The first was designed for the assessment of dynamic spatial orientation (Spatial Orientation Dynamic Test, SODT), while the second one was designed for the assessment of dynamic spatial visualization (Spatial Visualization Dynamic Test, SVDT). It should be noted that the terms 'orientation' and 'visualization' do not correspond to Orientation and Visualization as studied in printed tests. These authors have studied performance in these new dynamic spatial tests together with performance in a battery of printed tests, in order to assess their construct validity. Sex differences were also analyzed: on average, males' performance was higher than females' performance in the new dynamic spatial tests.

The present study was designed to provide evidence concerning three questions related to dynamic spatial performance: (a) do the new dynamic tests measure the same ability irrespective of sex? — a question whose answer gives evidence for the construct validity of the new dynamic spatial tests; (b) are differences in performance between the sexes negligible for more 'ecological' spatial tasks than those usually employed in printed tests?; and (c) is type of education related to dynamic spatial performance?

2. Method

2.1. Participants

The participants were 602 university graduates, 300 females (mean age = 27.17, SD = 3.49) and 302 males (mean age = 28.41, SD = 4.15). All were applicants for an air traffic control (ATC) training program, and therefore highly motivated to do their best.

2.2. Measures and procedures

Some measures were based on printed tests, and others on computer-administered tests.

The battery of printed tests was applied collectively as part of a selection procedure. Tests included were: (1) 'BLS-IV' is a subtest of the Bonnardel Standard Battery (Bonnardel, 1970), and is designed to measure general reasoning; (2) 'Changes' (Seisdedos, 1994) is a test measuring complex reasoning; (3 and 4) 'Identical Figures' and 'Bricks' are two spatial subtests taken from the Manzione Abilities Battery (Manzione, 1978). These subtests are spatial measures of processing speed and gestalt-type relations, respectively; (5) 'Rotation of Solid Figures' (Yela, 1969) assesses mental rotation; and (6 and 7) 'Printed puzzles I and II' (Yela, 1974) assess spatial visualization. Reliabilities are shown in Table 2 (see diagonal).

The dynamic spatial tests (spatial orientation and visualization), computer administered, include 10 trials each. The subject's task was to simultaneously direct two red moving points to a given destination. The destination changes from trial to trial and the two moving points could come from the north, the east, or the west (three trials for each of these three conditions). For directing the two red moving points, the subject must use a digital compass linked to each of them. The modification of the digital compass changes the direction in which the red points are moving (north = 0°; south = 180°; east = 90°; west = 270°); each time the compass arrow is pressed — using the mouse — the direction changes by 10° (Fig. 1). In the first trial, which takes

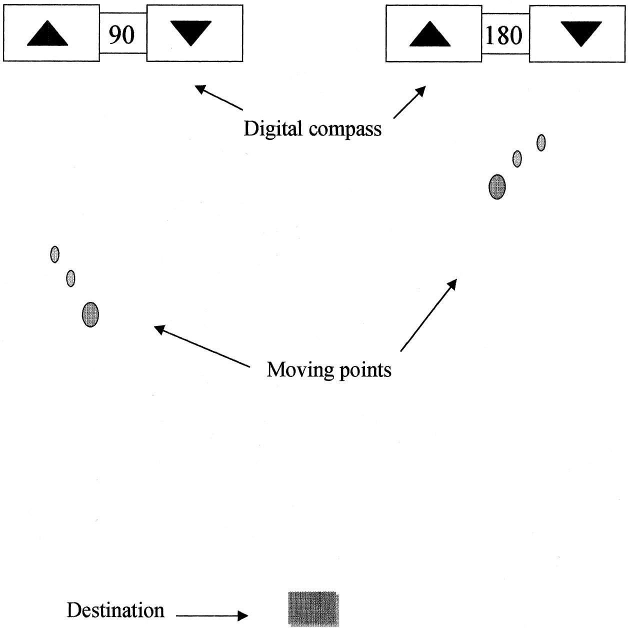

Fig. 1

50 seconds and is not statistically analyzed, the red points do not disappear from the screen until they arrive at the destination. The remaining trials take 30 s each and the subject cannot see the points arrive at their destinations.

In the Spatial Orientation Dynamic Test (SODT) the subject can see the whole screen. This is not the case for the Spatial Visualization Dynamic Test (SVDT), where the subject can see only the red points for a few seconds — depending on her/his performance — before they are hidden by a black band (thus, the subject must 'visualize' the movement of the red points after the information given by the digital compass).

The difference between the direction given by the subject and the correct direction is measured within each trial. The dependent measure is the average difference between the subject's performance and the correct performance — the greater the difference, the poorer the performance. Thus, there is only one general measure for each test.

The dynamic computerized tests were applied collectively, but in groups of no more than 10 people. The subject sat in front of a computer on which the test was displayed. Each dynamic test took between 8 and 9 min. The SODT was always applied first.

The dynamic tests were programmed in Borland C+ + to be run in a WINDOWS environment.

2.3. Analyses

Do the new dynamic tests measure the same ability irrespective of sex? In order to answer this question we performed a hierarchical factor analysis (Schmid–Leiman transformation) separately for males and females. In the Schmid–Leiman transformation, the higher order factors are allowed to account for as much of the correlation among the observed variables as they can, while the lower order factors are reduced to residual factors uncorrelated with each other and with the higher order factors. Therefore, each factor represents the independent contribution of the factor in question (Loehlin, 1992). With a hierarchical structure obtained with first and second order principal factor analysis (Promax rotation), the solution was subjected to the Schmid and Leiman (1957) orthogonalization procedure. It divides common factor variance in terms of factors with differing generality making all the factors orthogonal to one another, both between and within levels of the hierarchy. The *g* loadings of variables are proportional to their first order factor loadings 'weighted' by the second order factor loadings of these first order factors.

By comparing the factor solutions we can see whether we are measuring the same underlying abilities irrespective of sex. This is important, since the groups cannot be compared meaningfully in any given factor unless the same factor is compared across the groups (McArdle, 1996). If the factor structure is the same, then we have evidence that the tests are measuring the same underlying abilities for both sexes (Aluja, Colom, Abad & Juan-Espinosa, 2000; Colom, Juan-Espinosa, Abad & García, 2000).

The congruence coefficient (r_c) is an index of factor similarity. A value of r_c of $+0.90$ is considered a high degree of factor similarity; a value greater than $+0.95$ is generally interpreted as implying that the factors are practically identical (Cattell, 1978; Jensen, 1998). The r_c is preferred to the Pearson r for comparing factors, since r_c estimates the correlation between the factors themselves, whereas the Pearson r gives only the correlation between the two-column vectors of factor loadings. The n factor loadings of each of the n tests for each sample can be arranged as two-column vectors. The congruence coefficient is computed by means of the following formula:

$$r_c = \Sigma XY / \sqrt{\Sigma X^2 \Sigma Y^2}$$

In order to answer our second question (are sex differences negligible for tasks that are more ecological — i.e. that more closely resemble spatial orientation in real environments — than those usually employed in printed tests?), we carried out an analysis of variance.

Finally, we looked for evidence concerning the third question: is type of education related to dynamic spatial performance? We used four educational groups: (1) Humanities (Philosophy, History, etc.); (2) Social Sciences (Psychology, Economics, etc.); (3) Science (Medicine, Biology, Physics, etc.); and (4) Engineering. The number of males and females within each educational group was very similar (Figs. 2 and 3). We analyzed whether there were differences in performance between sexes within each educational group and whether there were differences within sex but between groups with different types of education. To this end, we used a 2×4 design (sex and type of education). These analyses were performed through analysis of variance.

3. Results

Table 1 shows the descriptive statistics for the nine tests, separately for males and females, as well as the standardized sex difference (*d*).

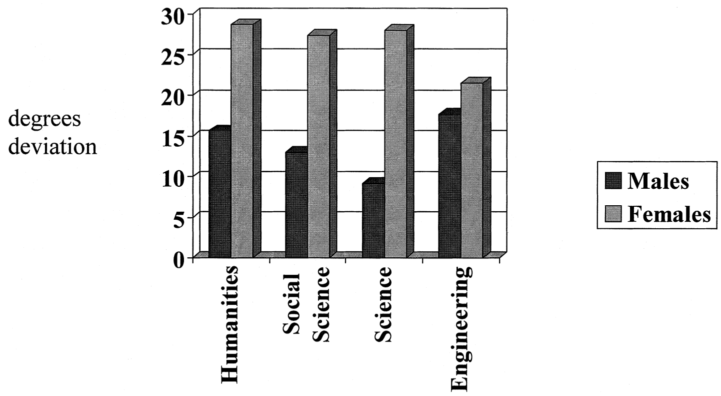

Fig. 2. Spatial Orientation Dynamic Test. Humanities: males (n = 112, mean = 15.68, SD = 15.62), females (n = 106, mean = 28.7, SD = 25.79). Social Science: males (n = 102, mean = 13.02, SD = 12.22), females (n = 98, mean = 27.42, SD = 24.2). Science: males (n = 32, mean = 9.15, SD = 3.7), females (n = 34, mean = 28.02, SD = 22.65). Engineering: males (n = 40, mean = 17.75, SD = 17.93), females (n = 44, mean = 21.6, SD = 15.72).

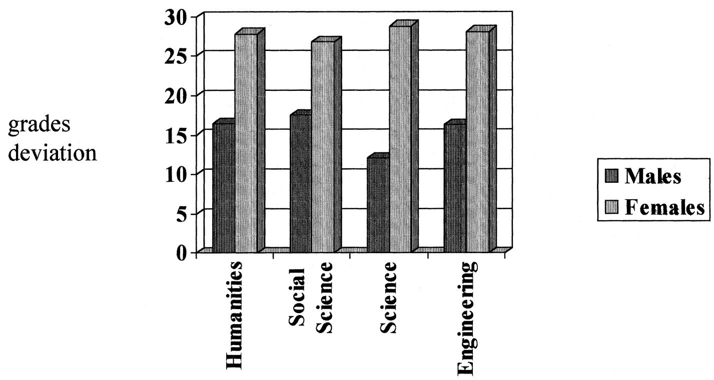

Fig. 3. Spatial Visualization Dynamic Test. Humanities: males (n = 112, mean = 16.42, SD = 11.39), females (n = 106, mean = 27.86, SD = 20.02). Social Science: males (n = 102, mean = 17.51, SD = 15.46), females (n = 98, mean = 26.8, SD = 15.87). Science: males (n = 32, mean = 12.05, SD = 8.59), females (n = 34, mean = 28.78, SD = 14.73). Engineering: males (n = 40, mean = 16.32, SD = 14.58), females (n = 44, mean = 28.1, SD = 15.53).

Figs. 2 and 3 show the performance in the dynamic spatial tests separately for sex and type of education. These data were analyzed both within sex (between educational groups) and between the sexes (within educational groups) through an analysis of variance.

Table 2 shows the correlation matrix. The dynamic tests' correlations have been reflected (signs changed) so that better performance on any test will result in a positive correlation with better performance on any other test in this battery. Male correlations are in the top half and female correlations in the bottom half.

These correlations were subjected to a Schmid–Leiman hierarchical factor analysis separately for males and females. Three first-order factors were extracted: the first one included the dynamic spatial tasks, the second one included the printed reasoning tests, and the third one included the printed spatial tests. This is true for both sexes (Table 3).

The congruence coefficients (r_c) were computed for each factor. The r_c for g (called the 'general spatial factor', since the correlation matrix is heavily dominated by spatial tests) was $+0.984$, for factor 1 (dynamic spatial tests) it was $+0.959$, for factor 2 (printed reasoning tests) it was $+0.82$, and for factor 3 (printed spatial tests) it was $+0.84$. Therefore, the dynamic spatial tests measure the same underlying ability irrespective of sex.

With respect to the average sex differences in the dynamic spatial tests, we found that males outperform females in the dynamic test of spatial orientation [$F(1,\ 578) = 65.863$; $P < 0.01$] as well as in the dynamic test of spatial visualization [$F(1,\ 579) = 79.308$, $P < 0.01$].

With regard to sex, type of education and the interaction between sex and type of education, the analysis of variance for the Spatial Orientation Dynamic Test (SODT), showed that sex was significant [$F(1,\ 567) = 47.627$, $P < 0.001$], type of education was not significant [$F(3,\ 567) = 0.908$, $P = 0.437$], and the interaction between sex and type of education was not

Table 1
Descriptive data for the nine tests and for each sex

Tests	Males			Females			d[a]
	Mean	SD	N	Mean	SD	N	
SODT	14.065	13.984	292	27.106	23.559	287	0.67
SVDT	16.295	13.113	293	27.590	17.197	287	0.74
BLS IV	15.165	3.944	302	13.636	4.242	300	0.37
Changes	18.758	5.438	302	17.306	4.852	300	0.28
Identical Figures	14.278	2.389	302	13.790	2.211	300	0.21
Bricks	8.397	2.727	302	7.606	2.712	300	0.29
Solid Figures	10.824	4.671	302	10.053	4.442	300	0.17
Puzzles I	5.923	2.200	302	5.426	2.097	300	0.23
Puzzles II	7.033	2.224	302	6.623	2.284	300	0.18

[a] d = standardized sex differences.

Table 2
Correlation matrix for males (top half) and females (bottom half). Reliabilities on the diagonal[a]

	SODT	SDVT	BLS IV	Changes	Identical Figures	Bricks	Solid Figures	Puzzles I	Puzzles II
SODT	0.918	0.714**	0.374**	0.303**	0.167**	0.342**	0.149**	0.287**	0.240**
SDVT	0.634**	0.841	0.501**	0.364**	0.177**	0.323**	0.156**	0.354**	0.361**
BLS IV	0.350**	0.391**	–	0.553**	0.327**	0.328**	0.252**	0.390**	0.432**
Changes	0.311**	0.331**	0.474**	0.87	0.432**	0.387**	0.247**	0.412**	0.405**
Identical Figures	0.296**	0.333**	0.355**	0.350**	0.751	0.298**	0.198**	0.307**	0.323**
Bricks	0.286**	0.295**	0.411**	0.362**	0.350**	0.751	0.275**	0.405**	0.340**
Solid Figures	0.078	0.130*	0.256**	0.224**	0.215**	0.268**	0.87	0.313**	0.337**
Puzzles I	0.178**	0.145*	0.292**	0.303**	0.222**	0.229**	0.195**	0.72	0.417**
Puzzles II	0.222**	0.328**	0.288**	0.250**	0.292**	0.330**	0.217**	0.178**	0.72

[a] –, reliability is not available. **$P < 0.01$, two-tailed; *$P < 0.05$, two-tailed.

Table 3
Hierarchical (Schmid–Leiman) factor analysis. Male loadings and female loadings (in parentheses)

Tests	General factor	Factor 1	Factor 2	Factor 3
SODT	0.46 (0.49)	0.60 (0.57)	0.02 (0.05)	0.02 (0.07)
SDVT	0.53 (0.56)	0.78 (0.64)	0.01 (0.06)	0.04 (0.05)
BLSIV	0.63 (0.61)	0.18 (0.07)	0.24 (0.31)	0.04 (0.04)
Changes	0.70 (0.57)	0.03 (0.04)	0.45 (0.38)	0.05 (0.04)
Identical Figures	0.46 (0.51)	0.09 (0.08)	0.21 (0.13)	0.10 (0.16)
Bricks	0.51 (0.55)	0.09 (0.01)	0.05 (0.14)	0.23 (0.21)
Solid Figures	0.37 (0.35)	0.06 (0.13)	0.04 (0.11)	0.33 (0.19)
Puzzles I	0.56 (0.37)	0.05 (0.06)	0.03 (0.24)	0.32 (0.03)
Puzzles II	0.58 (0.46)	0.00 (0.06)	0.09 (0.04)	0.28 (0.31)
% Variance	29.4 (25.3)	11.3 (8.5)	3.4 (3.9)	4 (2.33)

significant [$F(3,\ 567) = 1.832$, $P = 140$]. The analysis of variance for the Spatial Visualization Dynamic Test (SVDT) showed that sex was significant [$F(1,\ 568) = 69.516$, $P < 0.001$], type of education was not significant [$F(3,\ 568) = 0.248$, $P = 0.863$], and the interaction between sex and type of education was not significant [$F(3,\ 568) = 0.972$, $P = 406$].

Thus, there was no difference within sex nor more than for different types of education, while between the sexes the differences were all significant. What this might mean is that type of education has no relation with spatial dynamic performance in either sex, but that the difference between the sexes is significant irrespective of the type of education. Put another way: type of education bears no relation to spatial dynamic performance with respect to differential performance between the sexes. Moreover, the respective male and female performance do not appear to be affected by differences in the type of education.

4. Discussion

The overall performance differences between the sexes found in the present study add to the findings reported in other studies: males, on average, have a higher level of dynamic spatial performance (Law et al., 1993a; Sacuzzo et al., 1996; Schiff & Oldak, 1990). However, there is an important question that is not directly addressed in the previous literature: is type of education related to dynamic spatial performance?

We divided the subsamples of males and females according to their type of education, making four clusters for each of the newly-developed dynamic spatial tests. Thus, we had four educational groups (Humanities, Social Science, Science, and Engineering). For each of these educational groups we separated the data for males and females.

We found no differences in spatial dynamic performance related to type of education for either males or females (all of them being university graduates). Thus, dynamic spatial performance appears to be unrelated to the type of past educational experiences. Furthermore, males outperform females within each of the educational groups.

Hence, we have failed to find a difference within each sex related to differences in the type of education. Furthermore, within each educational group, males outperform females in both of the dynamic spatial tests.

Apart from the sex and educational differences in the dynamic spatial tests, we found that factor structure is the same for both sexes. This is an important finding, since factors represent the underlying abilities that are tapped by the tests (Carroll, 1993, 1997; Jensen, 1998). Therefore, the dynamic spatial tests measure the same underlying ability, which is a useful finding in terms of researching test bias (Jensen, 1980). If the tests measure the same underlying ability irrespective of sex, then we have some support for the conclusion that the new tests are not biased against female (or male) performance.

In summary, it can be stated that the new dynamic spatial tests (SODT and SVDT) measure the same underlying ability irrespective of sex, that the factor structure is the same for both sexes, and that, on average, males demonstrate an overall higher level of dynamic spatial performance than females. Males having several types of education do not show differences in their dynamic spatial performance, and the same can be said for females. Finally, when males and females have the same type of education, male spatial dynamic performance is still higher.

References

Aluja, A., Colom, R., Abad, F. J., & Juan-Espinosa, M. (2000). Sex differences in general intelligence defined as *g* among young adolescents. *Personality and Individual Differences, 28*(4), 813–820.

Bonnardel, R. (1970). *B.L.S. IV — Test d'intelligence générale*. Paris: EAP

Carroll, J. B. (1993). *Human cognitive abilities: a survey of factor analytic studies*. Cambridge: Cambridge University Press.

Carroll, J. B. (1997). Psychometrics, intelligence and public perception. *Intelligence, 24*(1), 25–52.

Cattell, R. B. (1978). *The scientific use of factor analysis*. New York: Plenum.

Colom, R., Juan-Espinosa, M., Abad, F. J., & Garcia, L. F. (2000). Negligible sex differences in general intelligence. *Intelligence, 28*(1), 57–68.

Contreras, Ma. J., Santacreu, J., Shih, P., & Colom, R. (1998). TIDOE y TIDVI: tests informatizados dinámicos para evaluar la orientación y la visualización espacial [Dynamic computerized tests for the assessment of spatial orientation and spatial visualization]. Technical Report. Facultad de Psicología. Universidad Autónoma de Madrid

Hunt, E., & Pellegrino, J. W. (1985). Using interactive computing to expand intelligence testing: a critique and prospectus. *Intelligence, 9*, 207–236.

Hunt, E., Pellegrino, J. W., Frick, R. W., Farr, S. A., & Alderton, D. (1988). The ability to reason about movement in the visual field. *Intelligence, 12*, 77–100.

Jackson, D., Vernon, P., & Jackson, D. (1993). Dynamic spatial performance and general intelligence. *Intelligence, 17*, 451–460.

Jensen, A. (1980). *Bias in mental testing*. New York: Free Press.

Jensen, A. (1998). *The g factor*. London: Praeger.

Juan-Espinosa, M., Abad, F. J., Colom, R., & Fernández-Truchaud, M. (2000). Individual differences in large-spaces orientation: *g* and beyond? *Personality and Individual Differences, 29*(1), 85–98.

Larson, G. E. (1996). Mental rotation of static and dynamic figures. *Perception & Psychophysics, 58*, 153–159.

Law, D. J., Pellegrino, J. W., & Hunt, E. B. (1993a). Comparing the tortoise and the hare. Gender differences and experience in dynamic spatial reasoning tasks. *Psychological Science, 4*, 35–40.

Law, D. J., Pellegrino, J. W., Mitchell, S. R., Fischer, S. C., Mcdonald, T. P., & Hunt, E. B. (1993b). Perceptual and cognitive factors governing performance in comparative arrival-time judgments. *Journal of Experimental Psychology: Human Perception and Performance, 19*, 1183–1199.

Loehlin, J. C. (1992). *Latent variables models: an introduction to factor, path, and structural analysis* (2nd ed.). Hillsdale, NJ: Erlbaum.

Lohman, D. (1979). *Spatial ability: a review and reanalysis of the correlational literature*. Technical Report, No. 8. Stanford University, Aptitude Research Project, School of Education

Manzione, J. M. (1978). *BFA — Batería Factorial de Aptitudes* [FAB, Factorial Abilities Battery]. Madrid: MEPSA

McArdle, J. J. (1996). Current direction in structural factor analysis. *Current Directions in Psychological Science, 5*, 11–18.

Mead, A., & Drasgow, F. (1993). Equivalence of computerized paper-and-pencil cognitive ability tests: A meta-analysis. *Psychological Bulletin, 114*, 449–458.

Pellegrino, J., Hunt, E., Abate, R., & Farr, S. (1987). A computer-based test battery for the assessment of static and dynamic spatial reasoning abilities. *Behavior Research Methods, Instruments and Computers, 19*, 231–236.

Pellegrino, J., & Hunt, E. (1998). Computer-controlled assesment of static and dynamic spatial reasoning. In R. Dillon, & J. Pellegrino, *Testing: theoretical and applied perspectives*. New York: Praeger.

Sacuzzo, D. P., Craig, A. S., Johnson, N. E., & Larson, G. E. (1996). Gender differences in dynamic spatial abilities. *Journal of Personality and Individual Differences, 21*, 599–607.

Schiff, W., & Oldak, R. (1990). Accuracy of judging time to arrival: effects of modality, trajectory and gender. *Journal of Experimental Psychology: Human Perception and Performance, 16*, 303–316.

Schmid, J., & Leiman, J. M. (1957). The development of hierarchical factor solutions. *Psychometrika, 22*, 53–61.

Seisdedos, N. (1994). *Cambios, test de flexibilidad cognitiva [Changes, test of cognitive flexibility]*. Madrid: TEA.

Voyer, D., Voyer, S., & Bryden, M. (1995). Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. *Psych. Bull., 117*(2), 250–270.

Yela, M. (1969). *Rotación de Figuras Macizas [Solid Figures Rotation]*. Madrid: TEA.

Yela, M. (1974). *Test de Rompecabezas Impresos [Printed Puzzles]*. Madrid: TEA.