

TECHNICAL MANUAL & USER GUIDE

REASONING - SPATIAL

This manual has been created by the psychologists from the Science and Innovation department of Central Test.

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1. Introduction

What are Spatial Abilities?

Spatial abilities refer to processes that allow individuals to identify, recognize and differentiate objects by their shape, size or orientation. It is thanks to them that individuals are able to differentiate a soccer ball from a golf ball, a cup from a bowl, or to realize that an image is upside down.

Spatial abilities intervene both in direct perception (when objects are present) and in mental imagery (when individuals create a mental representation of an object that is not physically present) (Mellet, Petit, Mazoyer, Denis, Tzourio, 1999). Through mental imagery, individuals are able to visualize the concepts of space, volume, distance, rotation and reflection. They are able to combine conceptual measures thanks to their projective skills (Bishop, 1978).

Skills Related to Spatial Abilities

Individuals with high spatial abilities tend to generate abstract and schematic mental images (Kozhevnikov, Kosslyn, & Shephard, 2005). They proceed analytically, piece by piece, which allows them to visualize the different parts of the structure of an object explicitly. Their mental images are therefore more flexible and transformable (Kozhevnikov, Hegarty & Mayer, 2002).

Thus, people with high spatial skills are more comfortable than others to read diagrams (Höffler, 2010), or to understand and interpret a graph (Kozhevnikov, Motes and Hegarty, 2007). Spatial skills have also been shown to be positively correlated with mathematical problem solving performance (Van Garderen, 2006): spatial thinking appears to be an aid in isolating the important component of a problem (Bodner and Macmillen 1986). This effect is amplified by the judicious use of schemata during reflection (Hegarty and Kozhevnikov, 1999), while individuals with low spatial skills are more likely to draw incorrect diagrams (Pribyl and Bodner 1987). In addition, spatial skills facilitate the use of data analysis and design software (Hamlon Boersma and Sorby 2006; Norman 1994), as well as understanding molecular geometry for chemistry students (Carter, Larussa and Bodner, 1987). They can also be used in a more abstract way, such as creating and manipulating models to test scientific hypotheses, or when a theory originally presented as a text or an equation is transformed into a graph or schema (Trickett & Trafton, 2007).

These skills are very important for the success and completion for STEM (science, technology, engineering, mathematics) studies and careers. Longitudinal studies have shown that spatial skills in adolescence can predict success in STEM domains (Shea, Lubinski and Benbow, 2001, Wai, Lubinski and Benbow, 2009, Webb, Lubinski and Benbow, 2007). Indeed, Wai et al. (2009), showed that participants with the highest STEM diplomas had the highest spatial abilities 11 years earlier.

The Importance of Using a Specialized Test

Spatial abilities are often neglected in the educational system, entrance examinations, or the selection of candidates. At present, individuals are primarily assessed based on verbal and numerical skills. As a result, individuals with excellent spatial abilities, but lower verbal or numerical abilities are not detected by current measures (Webb, et al., 2007). Humphreys, Lubinski and Yao (1993) report that thereby, engineering and physical sciences are missing many talents each year during the admissions.

It is for these reasons that *Central Test* has created **REASONING - SPATIAL**, providing additional information needed to assess potential candidates.

1.1. Characteristics

Questionnaire: 8 multiple choice questions

Time: 16 minutes maximum (It can be completed faster)

Time per question: 2 minutes maximum

Administration: Online

2. Psychometric Analysis

2.1. Sample Descriptives

The data presented is from a French speaking sample of 228 participants (138 male, 90 female), age range of 17 to 64 ($M=35.85$, $SD=10.86$). The data collection took place between January and June 2017. To ensure the data quality, participants who completed the questionnaire in less than 6 minutes, were excluded from the analysis.

Table 1. Descriptives based on Gender.

Gender	Percentage (%)	N
Female	39.47	90
Male	60.53	138

Table 2. Descriptives based on STEM Category.

STEM category	Percentage (%)	N
STEM ¹	31.60	72
Non-STEM	68.40	156
STEM male	23.20	53
Non-STEM male	37.30	85
STEM female	8.30	19
Non-STEM female	3.10	71

Table 3. Descriptives based on Study Level.

Study Level	Percentage (%)	N
Student	7.50	17
Level 1 – Master's, PhD	42.50	97
Level 2 – Bachelor's Degree	17.50	40
Level 3 - Two Years Vocational Study	14.00	32

¹ STEM: science, technology, engineering, mathematics

Level 4 - High School Diploma	9.60	22
Level 5 – Trades/No training	8.80	20

2.2. Descriptive Statistics

The first item being a training item to get familiar with the task, only 7 out of 8 items are being taken into account to calculate the score.

The following analysis was done by dividing the sample into STEM vs. Non-STEM and male vs female. The groups were randomly matched to obtain comparable sample sizes.

Table 4. Descriptive Statistics.

Factor	Mean	SD	Median	SE
STEM (n=72)	4.82*	3.11	4.28	0.36
Non-STEM (n=72)	3.91*	2.07	4.28	0.24
Male (n=90)	4.58***	2.57	4.28	0.27
Female (n=90)	3.36***	2.24	2.86	0.24

*: The t-test shows a significant (.05) difference between STEM and non-STEM participants.

***: The t-test shows a significant (.001) difference between male and female participants.

In line with our hypothesis, STEM show better performances than non-STEMs. Furthermore, a gender effect was observed with men performing better than women. This is also reflected in the literature (Blajenkova, Kozhevnikov and Motes, 2006, Harris, Hirsh-Pasek and Newcombe, 2013). Nevertheless, as Sorby (2009) points out, spatial skills are very malleable and sensitive to training, so regular practice can dispel these differences.

- The indicated central tendency measures (mean and median) are the mathematical mean of all observed scores. They give us an estimate of the difficulty and adaptation of the instrument to the population. Mathematically, they indicate at which level of the scale most scores are found.
- The standard deviation of the scale is the mathematical mean of all the standard deviations of individuals. It is an indicator of dispersion of scores against the mean. A high standard deviation is an indicator of high dispersion, while a low standard deviation is an indicator of low dispersion.
- The standard error of the mean gives us an estimate of the error variance that is likely to be found in the population. The lower the error compared to the mean, the more accurate the test is to evaluate this characteristic.

2.3. Reliability

Reliability measures the extent to which an assessment is free from error and the degree to which items on a scale measure the same construct.

A primary concern, when developing and using assessments, is the extent to which random measurement errors influence test performance. If a test is unreliable, it is impossible for it to be valid, as accuracy of results (validity) depends on the consistency (reliability) with which the same results are produced. Reliability enables test users to be confident that the results accurately reflect the test taker's attitude, aptitude or behavior in the workplace.

Internal reliability measures the extent to which items on a scale are internally consistent and all measure the same construct. Internal reliability is measured by calculating Cronbach's Alpha (α) for each factor, which computes the average of all possible inter-item correlations without relying on a single indicator of reliability, which may contain large amounts of error.

Table 5. Cronbach's Alpha.

Factor	Cronbach's alpha
STEM (n=72)	0.74
Non-STEM (n=72)	0.30
Overall	0.57

The results indicate a difference in reliability between the STEM and non-STEM groups. The most probable interpretation is that SPATIAL-REASONING is a specific tool that is well suited for evaluating a STEM population but is less suitable for evaluating a non-STEM population.

2.4. Validity

Validity is the extent to which an assessment measures that which it is supposed to measure. This is a subjective judgment made on the basis of experience and empirical indicators. The validity of this assessment was assessed using two methods:

- **Construct Validity:** If an assessment has construct validity, it implies that it measures the domain that it seeks to measure. In order to establish construct validity, this domain needs to be carefully defined, then items that are relevant to that domain must be carefully chosen and incorporated, and finally their relevance must be evaluated.
The items on this assessment were chosen by a team of psychologists, senior corporate executives, university academicians, statisticians, and other relevant personnel after numerous consultations. These items are continuously re-evaluated and updated in relation to relevant statistical data.
- **Consequential Validity:** DIF – Differential Item Functioning
An item functions differently, or displays differential item functioning (DIF), if respondents from different groups have different probabilities of endorsing the item, despite having the same level of the trait. The data analysis showed no DIF for gender nor study level.

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