

Relationship between different spatial ability questionnaires, spatial orientation, and mental rotation

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Abstract:

The optimization of map design and readability represents a critical domain of experimental investigation within cartography. It requires assessing performance in spatial tasks, such as orientation and navigation, based on the provision of different map designs. However, as spatial performance is also affected by individual differences in spatial abilities, these individual differences need to be measured and controlled for. There are some tests and tasks to examine different spatial abilities. One standardized questionnaire is the Santa Barbara Sense of Direction Scale (SBSODS), which captures the orientation ability of participants via self-assessment with 15 items (Hegarty et al., 2002). In addition, there is a German self-report questionnaire, which captures four different navigational strategies (e.g., cardinal direction, overview) in five different environments (e.g., nature, hometown) and three global items. All 19 items of the Fragebogen Räumliche Strategien (Questionnaire on Spatial Strategies, FRS) can also be combined into a single value for the overall spatial ability (Münzer & Hölscher, 2011). A standardized task for examining spatial orientation ability is the Spatial Orientation Test (SOT), where participants must indicate their gaze directions in relation to different objects (Hegarty & Waller, 2004; Kozhevnikov & Hegarty, 2001). A less specific spatial measure is the Mental Rotation Test (MRT), which assesses people's mental rotation ability based on the choice of matching three-dimensional objects (Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). The spatial tests and tasks mentioned above aim to measure various spatial skills. This study investigated whether and to what extent these skills are related and whether the assessment of different concepts (e.g. rotation, orientation) is necessary to control for individual differences in spatial abilities.

We conducted spatial questionnaires and standardized spatial orientation tests during two separate self-designed spatial experiments. In total, 98 participants completed these questionnaires and tests during the experiment breaks. One group of participants conducted all four tests/tasks while the other group did not conduct the MRT due to time constraints. 50 participants conducted the SBSODS, FRS, SOT, and MRT ($M_{age} = 24,22$, $SD_{age} = 5,14$, 56% males). 48 additional participants conducted the SBSODS, FRS, and SOT ($M_{age} = 23,90$, $SD_{age} = 3,99$, 42% males). To prevent carryover effects between the questionnaires, one questionnaire was conducted at the beginning of the survey, and the other at the end. All questionnaires and tasks were done in the paper-and-pencil version to keep the experimental design as consistent as possible.

We examined the relationships between the two spatial questionnaires to determine the extent to which they capture the same concept. In addition, we examined the relationships between the questionnaires and the conducted spatial ability tests, as well as the relationship between SOT and MRT. We also looked at the different scales of FRS and their relationships with the different measurements, as well as the impact of the individual questionnaire items on the identified correlations. All variables were z-scored before analysis to eliminate potential distortions arising from differences in scale. Higher values indicate better self-reported spatial orientation ability in the questionnaires (SBSODS, FRS) and better mental rotation (MRT), while lower values in ROT indicate less angular error and therefore better performance. We used Spearman-Rho as a nonparametric correlation coefficient, as not all z-transformed variables were normally distributed. These correlation analyses aimed to obtain a comprehensive picture regarding the questionnaires and their relationship to spatial abilities.

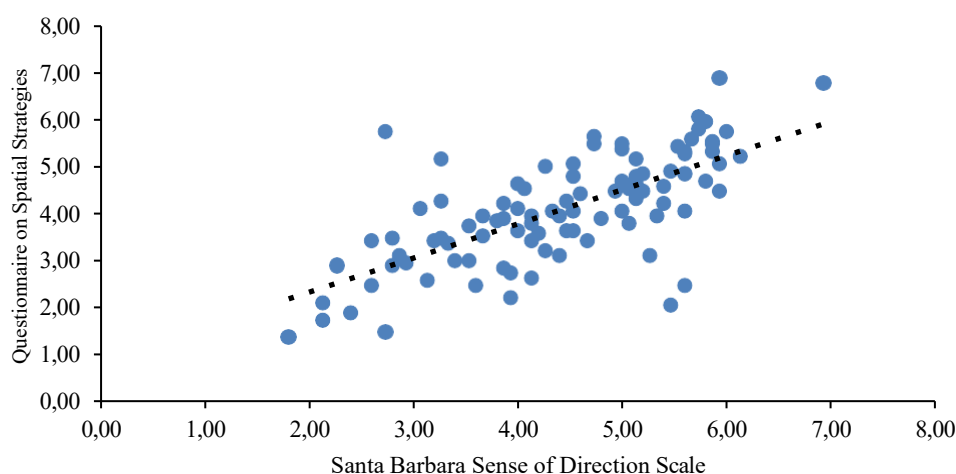


Figure 1. Scatterplot between values of Santa Barbara Sense of Direction Scale and Questionnaire on Spatial Strategies.

Correlation analysis between SBSODS, FRS (overall evaluation), ROT, and MRT revealed a strong, significant positive relationship between the two spatial ability questionnaires ($r(96) = .692, p < .001$, see Fig. 1), indicating that both questionnaires assess similar but not identical concepts of spatial orientation. All factors of the FRS showed a significant positive correlation with SBSODS. Both questionnaires demonstrated a significant negative correlation with Spatial Orientation Tests (SBSODS: $r(96) = -.369, p < .001$; FRS: $r(96) = -.232, p = .022$), meaning that the higher participants rated their sense of direction, the smaller their angular error in SOT. For the different navigational strategies of the FRS, there was no significant relationship between overview and cardinal direction with SOT. The analysis between MRT and the questionnaires showed a moderate, significant relationship between FRS and MRT ($r(48) = .292, p = .040$), with no relationship between SBSODS and MRT. The navigational strategies (FRS) direction, overview, and cardinal direction showed no significant relationship with MRT performance. The correlation analysis between the two spatial tasks revealed a significant negative relationship ($r(48) = -.583, p < .001$), indicating that better mental rotation ability is associated with less angular error and, therefore, better performance in SOT.

Our results show a clear relationship between the two questionnaires and the two standardized spatial tasks. Despite the limitations of this paper-and-pencil design, the present findings suggest that the two questionnaires only partially assess overlapping spatial performance constructs. Specifically, the SBSODS appears to exhibit a more pronounced relationship with spatial orientation performance, while the FRS seemingly extends beyond this domain to additionally capture mental rotation ability as a distinct spatial construct. Mental rotation constitutes a key spatial ability that enables individuals to transform and rotate mental representations of maps. Based on these findings, spatial performance tests/tasks with low overlaps can be selected to assess individual spatial abilities across varying concepts. This might lead to an improvement in spatial tasks when designs are adapted to individual abilities. In addition, questionnaires could be used, as they provide a time-efficient and good reflection of spatial orientation and rotation performance. Consequently, it is possible to distinguish between the effects of individual abilities and the effects of map design on performance in spatial tasks.

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