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Revisiting the Santa Barbara sense of direction scale, mental rotations, and gender differences in spatial orientation

Abstract

Angular direction estimation to landmarks of varying distance in the physical environment was utilised to investigate the ecological validity of the Santa Barbara sense of direction scale (SBSOD). Two- and three-dimensional MR measures were included to enable further the scale applicability. Results showed a moderate correlation between SBSOD and angular deviation from landmarks in the immediate landscape, but not with local or distant landmarks. Moreover, the findings suggest that skills which underlie three-dimensional MR better relate to pointing accuracy (PA) of distant landmarks and the cardinal direction, North. Results also showed a gender-related systematic biases in landmark estimation.

Introduction

Successful navigation in the physical environment is an essential life-skill which appears to heavily rely on landmark information (see Mallot & Gillner, 2000; Foo, Warren, Duchon, & Tarr, 2005; Zhao & Warren, 2015) and the ability to update one's location and orientation within the environment (Sholl, 1988). Some have suggested that the human organism has access to a non-visual ability in orientation, a sense of magnetoreception, however this has been met with scepticism (see Baker, 1987). Instead what appears agreed, is that sense of direction (SOD) is the often-considered term which seeks to conceptualise the necessary abilities required for successful navigation (Liu, Levy, Barton, & Iaria, 2011; Chai & Jacobs, 2012). Sense of direction has been defined as *'knowledge of the body's facing direction relative to a stable spatial framework anchored to the environment'* (Sholl, Kenny, & DellaPorta, 2006, p. 516). Underlying this knowledge are the perceived relations between known geographical

features and how they are utilised to provide a spatial framework that can be applied across different locations (Cornell, Sorenson, & Mio, 2004).

Key to scientific investigation of human cognition is the availability of reliable SOD measures. Historically, psychometric measures, such as mental rotation (MR), and perspective taking (PT) tests have been used as a proxy for spatial cognition and SOD (e.g. Allen, Kirasic, Dobson, Long, & Beck, 1996). However, Hegarty, Richardson, Montello, Lovelace, and Subbiah (2002) detail how this method is generally inadequate in predicting real-world navigational abilities. This led the authors to develop and validate a self-report measure of SOD, the Santa Barbara sense of direction scale (SBSOD). Sixteen years has now passed since the publication of SBSOD and the scale has provided a valuable tool which has been implemented within a range of research disciplines from cartography to psychology and neuroscience (see Ishikawa & Montello, 2006; Davies, Athersuch, & Amos, 2017).

The current article re-visits the SBSOD focusing on the ecological validy of the scale utilising pointing accuacy (PA) to landmarks at the non-vista scale. It also reassesses the connection between scores on the SBSOD and both 2D and 3D mental rotation capabiltity. Finally, gender differences are explored across all measures. Of note is the literature which shows significant differences between male and female cognitions related to the spatial domain. With much supporting research (e.g. Parsons, et al., 2004; Malinowski, 2001), Reilly, Neumann and Andrews (2016) state, *'gender gaps in spatial ability are the largest of all gender differences in cognitive abilities'* (p. 195).

It is expected that the SBSOD's power to predict PA will diminish as landmark distance increases (e.g., immediate compared to distal landmarks). It is hypothesised that gender differences will be observed across the proposed measures particularly within MR and PA performance, with males scoring higher than females.

Method

Participants

Twenty-eight participants (*female* = 14) were recruited with a mean age of 29.71 (*SD* = 12.52).

Design & Measures

A cross-sectional design was used. Angular direction estimation was employed to compare pointing accuracy (PA) related to 11 landmarks, a self-report sense of direction measure (SBSOD) (Hegarty et al., 2002), and spatial orientation reasoning (e.g., mental rotation) measures (Ekstrom et al., 1976). Landmarks comprised immediate (campus buildings [e.g., library]), local (city-wide [e.g., cathedral]), distant (country-wide [e.g., UK cities]), participants' hometown, and cardinal north. A laboratory, with no available views of the external environment was selected to complete the trials. Locations of the laboratory and campus landmarks were recorded in the ten-figure Ordnance Survey (OS) GB reference system format using global positioning services. The remaining landmarks were recorded on the map layer to allow magnetic bearing and distance measurement from the laboratory (magnetic deviation from North was corrected for).

Procedure

Participants had to complete all psychometric scales and then mark on a piece of paper affixed a circular table their estimated direction of all 11 landmarks.

Results

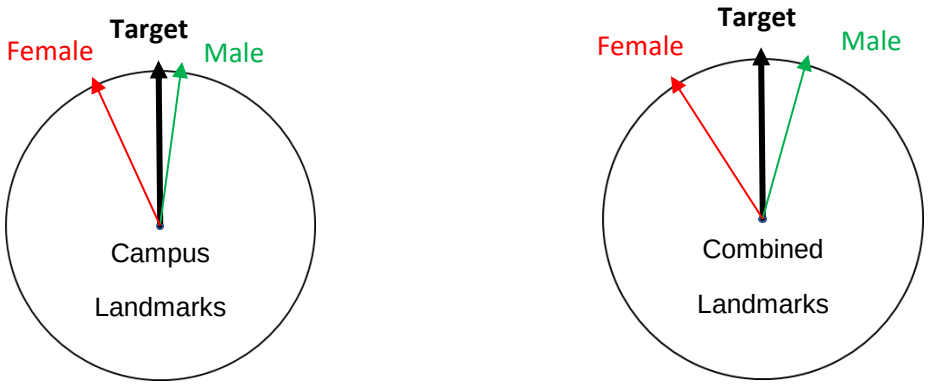
Angular deviation from each target landmark was calculated and then averaged across each distance category (i.e., immediate, local, distant). Angular deviation from the participants hometown and cardinal north was also calculated.

No significant correlations were found between SBSOD score and MR ability; SBSOD-2D MR [$r_s(28) = .244$, $p = .211$]; SBSOD-3D MR [Pearson's $r(28) = .136$, $p = .489$]; SBSOD-total MR [Pearson's $r(28) = .253$, $p = .195$]. A significant moderate correlation was revealed between SBSOD and angular deviation from immediate landmarks (i.e., campus) [$r_s(28) = -.495$, p = .007]. Correlations between SBSOD and the remaining landmarks (local, UK city, hometown & north) were non-significant.

Three-dimensional mental rotation abilities significantly correlated with three of the landmark groups; UK city [$r_s(28) = -.388$, $p = .041$]; North [$r_s(28) = -.451$, $p = .016$]; and the combined landmark total [Pearson's $r(28) = -.420$, $p = .026$]. Combined MR abilities significantly correlated with both; North [$r_s(28) = -.386$, $p = .042$], and the combined landmark total [Pearson's $r(28) = -.374$, $p = .049$].

Independent *t*-tests and Mann-Whitney *U*-tests, were conducted to determine if any gender differences between SBSOD score and MR measures were statistically significant. Such a difference was found between 2D MR data [$t(20.12) = 2.203$, $p = .039$] and 3D MR data [$U = 51.00$, $Z = -2.166$, $p = .031$]. No significant differences were found between SBSOD data [$t(1,26) = 1.675$, $p = .106$]. Finally, plot inspections of the median signed angular deviation data revealed a pattern which showed female direction indication to be biased West of target, and males to the East of target for most landmarks (see Figure 1) (campus [$U = 54.00$, $Z = -2.022$, $p = .044$]; combined [$U = 44.00$, $Z = 2.481$, $p = .012$]).

Figure 1. Gender deviation for campus and combined landmarks



Discussion

In its current form the predictive nature of SBSOD appears limited to SOD in the immediate environment. Correlations between SBSOD and PA to campus landmarks are comparable to that of previous work (Hegarty et al., 2002) (*r* .49 and *r* .44 respectively). The lack of evidence for a relationship between the SBSOD and PA to landmarks, other than those in the immediate landscape, supports the hypothesis that SBSOD is not predictive of spatial orientation abilities at a localised or national spatial frame. Similarly, there is little support for a relationship between SBSOD and three-dimensional MR. There is, however, evidence to that 3D MR skills appear more predictive of PA to distant national landmarks and true North (Vashro and Cashdan, 2015), suggesting the utilisation of alternative orientation strategies at this scale such as MR tasks, over the Santa Barbara Sense of Direction Scale.

The most intriguing findings suggest a bias for females to indicate West (left) of a target landmark and for males to indicate East (right) of a target, with median angular deviation values of +16° for males and -32° for females. The current literature base does not at present discuss this effect. Although research shows that males may rely on left-hemispheric processing more than females (Parsons et al., 2004), employ different strategies for solving spatial orientation problems (Boone & Hegarty, 2017), rely more readily on ego-centric representations (Lambrey

and Berthoz, 2007), and simplify the process of aligning test stimuli to the surrounding environment (Brandner & Devaud, 2013).

The findings of the current study show that the self-report Santa Barbara Sense of Direction Scale is not related to mental rotation ability and limited to measuring sense of direction in the immediate environment. The results also suggest that sense of direction for distant landmarks (e.g., nationwide cities) and true North are related to mental rotation ability. Further research is necessary to; first, investigate the current SBSOD format and whether additional items could be included to account for SOD outside of the immediate environment. Second, to account for the relationship between MR and SOD in a large reference frame. Third, investigate the phenomenon which suggests a tendency for males and females to bias their estimate either to the right or left of target landmarks respectively and whether cognitive processes or distinct strategies may be responsible.

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