Sense of Direction: One or Two Dimensions?

Clare Davies[1], Lucy Athersuch[2], and Nikki Amos[3]

1 **Department of Psychology, University of Winchester, Winchester, UK**
`clare.davies@winchester.ac.uk`
2 **University of Winchester, Winchester, UK**
3 **University of Winchester, Winchester, UK**

Abstract

The Santa Barbara Sense of Direction scale (SBSOD) has been an invaluable research tool for over 15 years. Previous studies with non-US populations, despite supporting the scale's internal validity, suggested national differences in individual item responses and possibly the factor analytic structure, although translation differences were confounded with cultural and environmental factors. Using a pooled British sample (N=151) – avoiding linguistic translation, yet reflecting 'old world' environmental experience and strategies – this paper revisits the SBSOD's validity and structure. While largely supporting the scale's internal validity across cultures and spatial environments, findings from this population suggest at least a two-factor structure underlying the scores, with the first factor explaining less than half of its variance, supporting the oft-discussed division between survey- and route-oriented strategies. We conclude by proposing a more nuanced, efficiency-based theory of 'sense of direction'.

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1 Introduction

Since its publication in 2002 [11], the Santa Barbara Sense of Direction Scale (SBSOD) has proved invaluable in a wide range of studies whose authors wanted to include a simple measure of human spatial cognition. Thanks to the generosity of the University of Santa Barbara research team who created the SBSOD, the scale has been freely available online for the past 15 years. Used by cartography and GI technology researchers (e.g., [21, 2]), psychologists (e.g., [14]) and neuroscientists ([9, 23]) alike, to try to link its basic concept of 'sense of direction' to other behaviours and variables, like many psychometric measures it has shown differing degrees of predictive power to its expected correlates in different studies. Despite its authors' careful separation of its key construct from others in spatial cognition ([11, 10, 3]), the scale is often taken on trust as a general unitary measure of what is vaguely imagined to be 'large scale spatial ability' (e.g., [8]).

Beyond the SBSOD, however, studies have often suggested that human spatial performance involves a range of different strategies, influenced by a number of predictors, and that tasks reflecting it do not always correlate particularly well with one another [24]. This suggests that sense of direction may not be quite such a unitary construct. In parallel, over the decades since the 1970s discoveries concerning hippocampal place cells, neuroscience has shown that spatial navigational abilities actually involve a battery of complementary cell types, locations and pathways within the brain ([26, 6]). This tallies with decades of behavioural evidence that people typically solve environmental-scale spatial problems by drawing on and integrating multiple cues in different ways, depending upon the task and individual differences [25].

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Often, however, research in this field still seems to be influenced by Siegel and White [22], in making the implicit assumption that an accurate survey representation of environmental-scale[1] space is still the ultimate goal for spatial cognition, even if we no longer subscribe to a similarly 'staged' theory of spatial learning where this is the final level. Yet it appears likely that for many purposes, short-cut strategies such as encoding a simpler topological cognitive map may not necessarily be inferior to a full topographic and metric, cardinal direction-aligned, survey. (Such a topological map would be based on landmarks and/or route knowledge, rather than more accurately metric 2D spatial topography.) High SBSOD scores have been repeatedly argued to indicate the latter, rather than the former, type of representation [13].

For the sake of modelling and predicting human spatial performance more closely, which in turn must inform spatial information theory and provision, we need to be clear as to how many dimensions or factors might underpin individual differences in 'sense of direction'. Recent work in Germany ([19, 18]) has suggested that the types of self-rated abilities in the SBSOD actually split into egocentric versus allocentric representation or knowledge, and separate knowledge of cardinal directions. This contrasts with the unitary 'sense of direction' construct generally claimed for the SBSOD. The contradiction was noted in the German work, but without offering clear explanations for it.

One potential reason might be the observation of Montello and Xiao [17],that people dealing with different types of environment might show more affinity with alternative problem-solving strategies that work better in their situation. In Europe and other 'old world' cultures, regular grid-pattern environments are far less common; where existing, they are not necessarily as predictable or north-aligned as many US cities. People from such cultures might find survey representations and cardinal directions too difficult to apply, yet still develop what they imagine to be a good mental map. If certain aspects of 'sense of direction' were thus of greater or lesser relevance in different populations, then in statistical terms we might expect the SBSOD's value for Cronbach's alpha to vary, implying more or less internal reliability for the psychometric scale. We may also expect, as the above German research team indeed found, that the scale splits into more than one subscale or underlying factor; different individuals choose different spatial strategies in the absence of simple cues to the survey layout.

One problem with interpreting such cross-cultural studies, as also noted by Montello and Xiao [17], is that language is often confounded with culture and environment. It can be difficult, then, to determine whether some differential responding to subsets of questions may be due to subtle differences in understanding of the concepts involved, even where translation has been skilfully made. Indeed, the translation process itself may be difficult when English phrases such as 'sense of direction' may not have exact equivalents in other cultures, or may themselves mean something different already. Thus we have a confound between culture and language, when trying to understand the contradictions in the sense-of-direction literature.

The present study, therefore, is an initial attempt to examine the SBSOD's underlying construct(s) of 'sense of direction' in another English-speaking country and culture, where environments and hence (perhaps) optimal strategies tend to be 'old world' like much of Germany, but the language does not (or at least, not the vocabulary used within the SBSOD). The British context has previously been shown to create different expectations and strategies in urban spatial tasks, relatively to US research participants [5]. Therefore, it is reasonable to expect that the SBSOD's items may also be subject to those differences. Below we reanalyse

[1] Based on Montello's scale distinctions, [16].

previously collected SBSOD scores from a series of research projects, all of them using British participants and conducted within England. First, however, we should look a little more closely at what we might expect from applying the SBSOD's specific items in this context.

2 The SBSOD and its items

As shown in Table 1, the SBSOD questions cover a range of self-rated abilities. Items 1 and 11 are about giving (presumably route, though this is unstated) directions to others; item 8 is about receiving and using them. Items 10 and 14 cover memory for routes, while items 7, 9 and 13 focus on using and liking maps (and possibly GPS or other technology, in the case of 'planning' in item 13). The remaining items cover other specific aspects of spatial awareness: distance (#3), cardinal directions (#5), novel environments (#6), location awareness (#12), holding some kind of 'mental map' (#15) and finally, actual 'sense of direction' as interpreted by the respondent (#4).

A common observation in environmental-scale spatial cognition studies has been that some people often demonstrate either a 'survey' knowledge of the space (with some integrated metric knowledge of distances and directions, as if in a topographic map). Others – or the same people in a less familiar or more constrained space – seem to rely more on landmarks and route topology. What SBSOD score could be obtained by a person in the latter situation, who was generally competent in most spatial situations yet never created a completely metric survey map?

This hypothetical competent-yet-topologically-constrained respondent could easily give themselves a high score on items 1, 2, 4, 6, 8, 10, 11, 12 and 14 of the SBSOD – 9 of the 15 items – because they may well have little trouble with routes or route directions in everyday life. Furthermore, at least in theory, that person could potentially interpret item 3 as pertaining to route distances, and item 15 as implying a good memory for key routes and some ability to link them up (though not necessarily into a metrically accurate 'map'), so the respondent might also score quite generously on those as well. Having thus shown confidence in 11 out of 15 items, the respondent might only score themselves more poorly on items 7, 9, 13 and 5 (although it is also conceivable to mentally align known route segments to an imagined north, even if the 'north' they imagined was not geographically true).

The above thought experiment is intended to show that a fairly high score on the SBSOD could reflect self-confidence in a landmark- or route-based spatial strategy, because it happened to work well enough in the respondent's everyday experience. It is worth remembering, of course, that in most major studies of the SBSOD to date the scale has nevertheless tended to show a significant[2] correlation with tasks which clearly required some metrically accurate cognitive mapping for successful completion. Thus in general, the most confident SBSOD respondents do seem to be those most capable of creating such mappings. Nevertheless, the varying and sometimes surprisingly low correlations with actual tasks (typically between 0.1 and 0.45) do leave room for other interpretations and strategies to be playing some part in people's SBSOD scores.

If, as the German data suggested, the SBSOD can reflect different common strategies for learning and navigating environments, then we may expect similar results with the British sample. Route-related and survey-related questions might thus show different response patterns. If the key difference between the US and German respondents is in fact local

[2] It should be noted, though, that these correlations are still usually no more than moderate, as is typical in psychology.

Table 1 SBSOD items and descriptive statistics from current sample, with (n=151) and without (n=132) the surveyor group.

[0.5ex] No.	Item (simplified)	Mean(sd) With	Mean(sd) Without
1	Good at giving directions	4.17(1.72)	3.93(1.68)
2	Good memory for where I left things	4.24(1.70)	4.27(1.70)
3	Very good at judging distances	3.97(1.70)	3.70(1.59)
4	My ‘sense of direction’ is very good	4.26(1.81)	4.02(1.75)
5	Think in terms of cardinal directions	2.57(1.77)	2.24(1.52)
6	Don’t easily get lost in a new city	3.83(1.76)	3.67(1.75)
7	Enjoy reading maps	3.54(2.08)	3.08(1.79)
8	No trouble understanding directions	4.28(1.73)	4.07(1.65)
9	I am very good at reading maps	3.83(2.00)	3.43(1.81)
10	Remember routes very well as car passenger	4.05(1.99)	3.95(1.99)
11	I enjoy giving directions	3.61(1.68)	3.42(1.62)
12	Important to me to know where I am	5.30(1.56)	5.15(1.57)
13	Do navigational long-trip planning	4.13(2.03)	3.80(1.96)
14	Usually remember new route first time	4.30(1.84)	4.12(1.81)
15	Very good ‘mental map’ of my environment	4.48(1.81)	4.23(1.77)
Total	Mean score across items	4.04(1.16)	3.81(1.03)

environment and culture, rather than translation issues, we might expect a UK sample to resemble the Freiburg and Saarbruecken samples more closely than the US data.

Therefore, the present analysis had three aims: (1) to complement the Montello and Xiao cross-cultural analysis [17] with a British sample, to help disambiguate linguistic from environmental or cultural differences between the previous samples; (2) to see whether the British data supported the unitary (one underlying factor) nature of the SBSOD claimed by previous studies by the creators at UCSB, or whether it indicates the additional factors claimed by the German studies; and (3) if not, to try to tease out whether this could indicate different strategic approaches – but equal spatial confidence – by separate subgroups within our participant sample.

3 Participants, Age and Sex

The pooled sample used here was collated from five datasets collected in three UK locations over the past few years. Two, comprising two-thirds of the total sample (97 participants), were from student research projects at the University of Winchester, in the south of England, and used undergraduate psychology students as participants. Any students who took part in both studies were omitted, to avoid overlap in the data. Two more (totalling 35 participants) were collected previously at the University of Huddersfield, in the north of England, consisting of one staff and one student psychologist sample. The fifth sample consisted of 19 professional surveyors employed by Ordnance Survey and located in various locations around Great Britain, but mostly in the southern half of England. Thus the total N was 151.

Due to the predominance of psychology students in the sample, as in previous studies, the sample was largely female (124), with 27 males (including all of the OS surveyors). While the mean age was 29 (sd 13.3), this reflected an inevitable skew towards college-age participants: 61 per cent (92 participants) were aged 18-22. (Even so, this means that almost 40 per cent were above the typical age, making this sample perhaps more representative of the population than in many studies.)

Across the whole sample, age was found to strongly correlate with total SBSOD score: Spearman's rho (151) = .38, p<.001. When this analysis was repeated without the group of surveyors, however, the correlation became small and non-significant: Spearman's rho (132) = .14, p=.11. The group of surveyors may also have been largely responsible for a found sex difference in the responses: t(149) = 7.84 (with equal variances), $p < .001$. There were only 8 males in the non-surveyor sample, so the professional status of the all-male surveyors was inevitably confounded with gender in this case.

4 Analyses and Results

4.1 Analysis 1: Group Differences

The data was first assessed for homogeneity, by performing an independent analysis of variance on the SBSOD total scores. Study (group) was the independent variable. While Levene's test showed that homogeneity of variance could be assumed, the omnibus F test was highly significant: F(4,146) = 16.34, $p < .001$, partial eta squared = .31. Tukey post hoc comparisons showed that this was entirely due to the surveyors having a far higher mean SBSOD score (5.65, 95 per cent CI[5.21,6.10]) than all other groups, the highest of which was the older group of Huddersfield participants (psychology staff: mean SBSOD = 4.24, 95 per cent CI[3.77,4.71]). There were no significant differences between the university-based groups. For this reason, most of the analyses below were run at least once without the surveyors as well as with, to check that the results were not skewed by this unsurprisingly (but of course, unusually) expert group.

4.2 Analysis 2: Descriptives

European cultures such as Britain tend to place far less emphasis on cardinal directions and regular grid-pattern urban layouts than 'new world' countries such as the US. Table 1 was visually compared with Montello and Xiao's cross-cultural analysis [17], to see which pattern of responses within it was most similar to ours.

Overall, even with the surveyors included, the mean score obtained from our sample appears lower than both the Santa Barbara (USA) and Freiburg and Saarbrücken (Germany) samples analysed by Montello and Xiao – but higher than their Tokyo sample. In other respects, however, the pattern of responses between items seems quite similar to both the US and German samples, showing particular dips in score for both items 3 (distance judgement) and 5 (cardinal directions), and notably higher-than-average scores for items 12 (knowing where I am) and 15 (good mental map). Thus the pattern of descriptives in itself cannot distinguish which of the previous samples is most resembled by the current data. This is hardly surprising, as response patterns were also not very clearly differentiated between the samples in the original Montello and Xiao analysis.

The descriptives in Table 1 do suggest, however, that including the surveyor group inflated most of the mean scores (and hence also their standard deviations), despite making up less than 20 per cent of the total sample. An exception here is item 2, on remembering where one had left things; this probably reflects the older age profile of the surveyors, many of whom were nearing retirement age. To the extent that we would expect far higher self-rated abilities in professionals for whom spatial awareness and navigation are essential elements of their job, the increased scores help to validate the data, and show that participants were responding as expected.

4.3 Analysis 3: Scale Reliability

Using the university samples only (N=132), the SBSOD was assessed for inter-item reliability using Cronbach's alpha. As in previous studies ([11, 17]), the scale showed good reliability: alpha = .868.

It is obviously interesting to see whether any items in the SBSOD make a non-productive contribution to the scale – i.e., if they reduce rather than increase its inter-item reliability. For some reason, to our knowledge this statistic has not previously been reported for the individual SBSOD items. With the present sample, one might have expected item 5 (about reliance on cardinal directions) to show a less strong relationship to the rest of the scale: in most British towns it is impossible to rely on such absolute spatial cues, so much so that even when they are present locals appear to stick to other spatial strategies ([5]). Montello and Xiao [17] explicitly raised the likelihood that such environmental differences might affect cultural tendencies towards different spatial strategies.

Surprisingly, though, the item-total statistics showed that Cronbach's alpha would be slightly lower (.866) if item 5 had been omitted, suggesting that it was still contributing to the overall coherence of the scale. Item 12 ("It's important to me to know where I am") contributed similarly marginally (again at .866). Perhaps inevitably (and as noted by Montello and Xiao without quoting this statistic), item 2 on locating objects was the only item shown to reduce Cronbach's alpha, which would have been .872 without it. Similarly, item 10 (on memory for routes when a car passenger) made no apparent difference to alpha: it would still have been .868 without that item. All other items would have reduced alpha if omitted, although in most cases only marginally; the largest potential loss of reliability was from item 4 (the actual item on 'sense of direction'), reducing alpha to a still-respectable .847. (This is not surprising, since in the original development of the scale, apparently its authors deliberately chose items for their correlation with that one [11].) Thus we can confirm previous findings that although item 2 would be best dropped in any revision of the scale, in general the rest shows robust inter-item reliability.

Such results might be problematic, if they showed generalised responding by participants – a tendency to give a similarly high or low score to all questions, perhaps due to inattention to the wording. Fortunately, however, other reliability statistics (ANOVA with Tukey's test for nonadditivity, and Hotelling's T-squared test) showed that questions did tend to be quite strongly distinguished from each other by participants – while still showing some response consistency as above.

Does good internal reliability in itself imply that the scale must measure a single underlying cognitive ability across all participants? Not necessarily. In our view this would falsely imply, *post hoc ergo propter hoc*, that we could assume a single common cause for any set of items which happened to intercorrelate. Carroll [4] demonstrated how in an imaginary multi-item measure, despite strong overall consistency across the items, nevertheless different participants could be adopting different strategies or displaying multiple relevant strengths to differing degrees. Thus a psychometric scale may often have high internal reliability overall, yet also show different *patterns* of responding (reflecting different styles or strategies) by different individual respondents. Therefore, factor analysis is also helpful as below, if our goal is to test whether there may be multiple ways to achieve good scores on a given psychometric scale – as opposed to ensuring that its questions do all contribute to the overall concept.

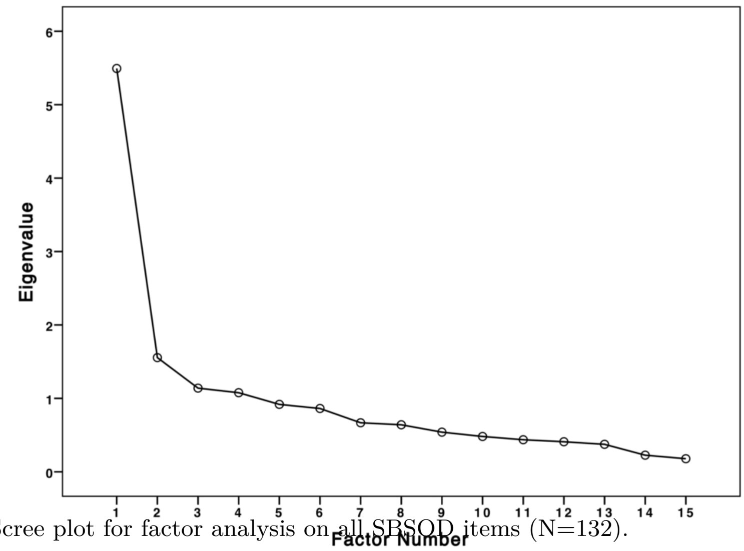

Figure 1 Scree plot for factor analysis on all SBSOD items (N=132).

4.4 Analysis 4: Factor Analysis

The data from the 132 English university participants was submitted to a factor analysis. All common assumptions for factor analysis appeared to be met by the dataset.

Principal axis factoring (PAF) was used, as this attempts to produce 'clean' factors which optimise the grouping of loadings. Whilst some previous papers (e.g., [17]) did not always specify the extraction method used in previous factor analyses of the SBSOD, they usually appear to have used a similar factorising method rather than principal components analysis. This makes logical sense: while we can expect a lot of individual variance within items in the SBSOD, the only goal of our analysis here is to assess the common links between them, not to try to explain every item-specific issue within people's responses.

The scree plot from this analysis is shown in Figure 1. While showing a strong primary factor, as is typical of factor analysis on any psychometric scale, unlike previous studies the scree plot is ambiguous about the potential role of further factors. Four factors had eigenvalues above 1.0 (the so-called Kaiser criterion), and the first one only explained 36.6 per cent of the variance in the data, with the second factor explaining 10.4 per cent, the third 7.6 and the fourth 7.2. Thus the evidence for a unitary psychological construct underpinning the scale seems to be weakened in this population, as with the previous German studies.

To enable interpretation of the factors, the analysis was repeated using orthogonal (Varimax) rotation, limiting the number of factors to the two which had explained more than 10 per cent of the data. The pattern matrix (see Table 2) suggested that while eleven items of the fifteen loaded at above .3 on the first factor, items 10, 14 and 15 loaded more strongly on the second, and loadings above .3 on that second factor were also seen in items 4, 6, 8 and 13.

Translating this into plain language, the highest loadings on the first factor were the items which one might think of as most 'surveyish' in the scale: items 7, 9 and 13 which concerned using maps and related technologies, items 1 and 11 on being able and confident in giving directions to others (which may often require more complete spatial knowledge than individual route topology), and items 3 and 5 on distance estimation and use of cardinal directions. Item 8, on understanding other people's directions, also loaded on this factor. But the latter actually loaded quite strongly onto both factors – along with general 'sense of direction' (item 4), and both the self-orientation items 6 and 12. The second factor's

Table 2 Pattern matrix for the two main factors in both the orthogonal (varimax) and oblique (direct oblimin) rotated factors, showing only loadings at 0.3 and above.

No.	SBSOD item	Orth F1	Orth F2	Obl F1	Obl F2
1	Good at giving directions	.629		.656	
2	Good memory for where I left things				
3	Very good at judging distances	.497		.515	
4	My ‘sense of direction’ is very good	.588	.569	.567	.389
5	Think in terms of cardinal directions	.446		.483	
6	Don’t easily get lost in a new city	.431	.361	.424	
7	Enjoy reading maps	.759		.835	
8	No trouble understanding directions	.507	.338	.511	
9	I am very good at reading maps	.864		.938	
10	Remember routes very well as car passenger		.717		.759
11	I enjoy giving directions	.477		.496	
12	Important to me to know where I am	.320		.318	
13	Do navigational long-trip planning	.585	.353	.595	
14	Usually remember new route first time		.667		.630
15	Very good ‘mental map’ of my environment		.561		.518

strongest loadings, however, were from items 10, 14 and 15. The first two of these are about memory for routes, and the third is on possession of a ‘good mental map’.

Could it be that for some participants, ‘good sense of direction’, self-orientation and a ‘good mental map’ are linked to a route-based rather than a survey-based strategy? (After all, this does not say whether the mental ‘map’ in question is more like a street plan or a subway map in its content.) The results seem to imply a clear dissociation between at least some of the questions about routes, and those about maps and cardinal directions, so the possibility seems plausible.

This pattern of loadings, with its two-factor overlap and dissociation, appeared even more strongly when the factor analysis was repeated twice more with just the two factors, and using first orthogonal but then oblique (Oblimin) rotation – the latter to allow the two factors to correlate (as, typically, psychometric aptitude factors tend to do). In the latter case, as shown on the right side of Table 2, item 4 (the actual ‘sense of direction’ item) was the only item to load on both factors; the other loadings on factor 2 were items 10, 14 and 15. Once again, this implies that some participants may consider themselves to have a good sense of direction and mental map, yet rely on route memory rather than constructing a survey representation. Correlation between the factors was .448.

Figure 2 shows the factor plot in rotated factor space (though showing the factors orthogonally, and thus slightly distorting the actual shape). The ‘route’ and the ‘map’-related questions seem to lie along two separate dimensions, but with ‘sense of direction’ loading similarly on both, and with ‘good mental map’ closer to the route-memory items than to the items about reading cartographic maps. For these participants, perhaps, a ‘good mental map’ is apparently a collection of well-memorised routes and landmarks, possibly linked into a framework which is more topologically than topographically accurate – but apparently so efficient for everyday use that participants consider it to be a ‘good mental map’ and showing ‘good sense of direction’.

When the analysis was rerun including the group of surveyors, it showed a very similar pattern of communalities and loadings, but with slightly higher correlation and less distinct-

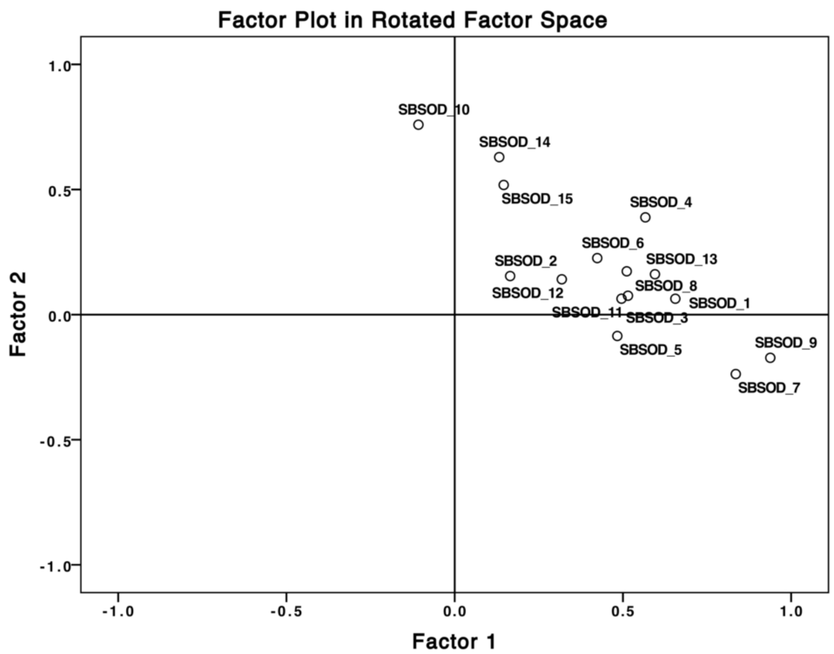

Figure 2 Factor plot for the two factors from the final factor analysis (N=132).

iveness between the factors – probably because the surveyors tended to have high scores on all items anyway.

The inclusion of both orthogonal and oblique rotation results above was usefully questioned by one reviewer of this paper. In brief, it seems more intuitively plausible (as with any psychometric scale) that some of the unique variance of any item will be due to conceptually irrelevant 'error' variance, which is why factor analysis is generally favoured. However, at present there seems to be insufficient evidence to make a theoretical decision as to whether or not the underlying factors in sense of direction would be expected to correlate; e.g., some people may have strong knowledge of both the topology and topography of familiar spaces (given the above-cited neuroscience evidence for multiple spatial representations in the brain). Yet alternatively, these might be viewed as competing strategies, of which only one might be used in a given scenario. Without a theoretical reason to select either option, both have been explored here. Obviously, further confirmatory and theory-based studies are needed. In the meantime, we turn to a comparison of participants who tended to score more highly on one, rather than the other, subset of questions as identified above.

4.5 Analysis 5: Comparing route- and map-oriented participants

To check the above arguments, participants with a 'route' pattern of responses (scoring higher on items 10 and 14) were identified, and compared to those showing more affinity with cartographic survey maps (items 9 and 7), the two highest-loading items on the primary factor above. Participants were grouped according to whether their scores were higher on the former two questions (summed together) or on the latter two. 76 participants scored higher on the two 'route' questions, 55 on the two 'map' questions, and 20 had scored equally on the two question pairs. Excluding the surveyors, these figures were 76, 39 and 17 respectively.

Excluding the group of surveyors, whose obvious map bias and generally high scores across the board would be likely to skew the results, the 'route' and 'map' groups' scores on individual SBSOD items and on its total score were compared using t-tests. As this made for 16 tests, familywise error was corrected for using the Bonferroni heuristic – i.e., the tests were only counted as significant if $p < .05/16$, i.e. $<.003125$. (However, as this is rather a conservative correction, p values close to this value would also be reported.) Equal variances could be assumed in all tests reported below, except where stated.

Results showed that the 'map'-oriented group scored significantly higher on item 1 (good at giving directions: $t(113) = 3.29$, $p = .001$, mean difference = 1.02 with 95pc CI[0.41,1.64]). They also scored higher, of course, on the two items used as the basis for the grouping: item 7 (enjoy reading maps: with unequal variances, $t(56.2) = 7.17$, $p < .001$, md = 2.26, 95pc CI[1.63,2.89]) and item 9 (good at reading maps: $t(113) = 7.66$, $p < .001$, md = 2.17, 95pc CI[1.61,2.74]). However, they differed only very slightly and non-significantly on their overall SBSOD score: $t(113) = 2.16$, $p = .033$, md = .39, 95pc CI[.03,.75].

An additional t-test to compare the two groups' age profiles suggested that, even without the surveyor group, the more map-oriented group was generally slightly older: with significantly unequal variances due to the skew in the age distribution, $t(50.4) = 3.16$, $p = .003$, md = 7.6 years, 95pc CI[2.8,12.5].

5 Discussion

The above series of analyses suggest that at least for British participants, as with Münzer et al.'s German participants, there is more than one way to score highly on the SBSOD, indicating confidence in your large-scale spatial ability. The participants whose sense of good spatial ability rested more on their memory for routes were nevertheless scoring equally well on the SBSOD to those with more affinity to topographic 'survey' representations. Although the third factor (concerning cardinal directions) was not strongly supported, it was impossible to support a single-factor interpretation of the scores in this sample, while still explaining at least around half of the variance in the data. Thus we suggest that a two-factor model may better represent the range of spatial strategies, for at least this British population.

Consequently the SBSOD cannot, for all respondents, be assumed to indicate their degree of survey-like cognitive mapping. Furthermore, where it correlates with a given spatial task, this should not be taken as support that a survey representation is the key to good performance on that task. Arguably, the SBSOD is conflating two sometimes equally valued spatial strategies, broadly characterised as 'route' (compiling and linking egocentric information) or 'survey' (deriving integrated allocentric spatial knowledge) in most of the literature. Indeed, these two have already been specifically teased apart in other psychometric scale developments [20], possibly even with the 'survey' ability being split further into 'allocentric-survey' versus 'egocentric-survey' [27].

Why, then, have previous studies shown the SBSOD to be more closely related to performance on tasks which clearly *do* require an integrated, and at least approximately metrically accurate, 'survey' representation? The answer to this may partly lie in the population sampled for those studies. It is reasonable to assume that participants in the original US West Coast student population are more familiar with environments where a survey representation is relatively easy to acquire, and reliable for drawing inferences (such as alternative routes through a known street grid). As noted by Montello and Xiao [17], where this is very much not the case – as in European and other 'old world' cities, and where people are more used to any highly irregular environments – participants may often obtain good spatial performance by relying on a more topologically-based heuristic.

In addition, the evidence from the present sample suggests that in general, those who have the strongest reliance on a survey representation will, like the group of Ordnance

Survey surveyors examined here, obtain high scores across most aspects of the scale. Thus in a mixed sample which includes (say) geographers or other map-proficient subgroups, the most extremely map-oriented participants will probably tend to perform the best on survey-demanding tasks, as well as scoring the highest on the SBSOD overall. However, across a less extreme and more typical population, such as we like to think is represented by psychology students, the present data suggests that the participants with the highest confidence in their spatial skills will *not* necessarily be more inclined towards survey-based strategies.

In other words, where the present study goes further than previous analyses is in showing that any lack of a fully metric, survey-based representation may not necessarily reduce participants' confidence in their 'sense of direction', because for them a route-based strategy has been performing well, and may actually work better. This may also help to explain why an advantage for highly 'survey'-oriented participants was not found in at all in a German indoor study by Hölscher et al. [12], and why Meilinger's extensive studies on spatial strategies [15] similarly posited a 'network of reference frames' (memorised scenes from individual vista-scale spaces) as apparently the most common cognitive mapping strategy.

Neuroscience evidence also supports this, suggesting that in environmental (as opposed to vista) spaces the processing of landmarks from visual and other sensory data in the parahippocampal place area is particularly focused on decision points, and that the outputs from such processing are then linked in the retrosplenial cortex to place knowledge and head-direction information, to indicate which way to turn ([7, 1]).

Ishikawa and Montello [13] characterised an imperfect, largely qualitative and only metrically approximate, mental representation as "undoubtedly desirable in the face of the limited cognitive capacity of humans" [p. 124]. Indeed, this would seem to be a key point in understanding people's spatial cognition of large, complex spaces. Network topology is undoubtedly more computationally efficient for many tasks, even including relative distance and direction estimates, than a 'survey' perspective drawing on topographically accurate maps.

Modern environments, unlike the open savannah where our ancestors apparently evolved, do not allow either simultaneous viewing nor free roaming over the entire area. Unless the shape and pattern of the space is quite predictable, as in grid cities, distortions in our understanding (when based solely on experience) are inevitable, but not necessarily problematic. Many readers from 'old-world', less regular, environments may well have had the disorienting experience, like the present author, of eventually viewing a cartographic map of an environment which they learned solely through repeated route experience (e.g., the town they grew up in). They may find it very hard to relate their own undoubted local expertise to the projected 2D topography in front of them. Yet their stored metric inaccuracies and simplifications may have caused them no problems over extended periods of time, and have proved repeatedly efficient not only at route-finding but also at giving and receiving directions, and otherwise sharing place knowledge with fellow locals. Perhaps this helps to explain why particularly the younger participants in the present (relatively intelligent and educated) sample were apparently quite reluctant map users, even when claiming a strong 'sense of direction' and a good 'mental map' for themselves.

Overall, then, many survey-demanding tasks are rare and irrelevant to everyday life for many people, so a true survey representation of complex, irregular spaces would be a waste of cognitive resource. The spatial information community may therefore do better to focus on simulating and supporting simplified, more efficient cognitive mapping, both by humans and by robots or simulated agents, rather than attempting to encourage or impose metrically accurate (but in many situations, cognitively inefficient) mental representations. There is a good reason why, in the chaotic geography of cities like London, the classic Tube map's simplicity is greeted with relief.

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