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Sense of direction: General factor saturation and associations with the Big-Five traits☆

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ABSTRACT

The ability to locate and orient ourselves with respect to environmental space is known as sense of direction ("SOD"). While there is considerable evidence for the predictive utility of self-report measures of this psychological construct, relatively little research has investigated the psychometric properties of the self-report scale by which it is most commonly measured – the Santa Barbara Sense of Direction scale (SBSOD, Hegarty et al., 2002) – or the broader personality correlates. The present study evaluated the factor structure of the SBSOD following administration to 12,155 individuals and situated it among prominent sources of individual differences, specifically the Big Five personality traits and intelligence. Findings suggest that the SBSOD scale has relatively high general factor saturation, and that a considerable portion of the variance in SBSOD scores is explained by other personality traits, including Conscientiousness ($r = 0.33$), Intellect ($r = 0.27$), Emotional Stability ($r = 0.26$), and Extraversion ($r = 0.23$). Cognitive ability was less highly correlated with SBSOD scores when measured at the level of general intelligence ($r = 0.11$) and in terms of mental rotation ability ($r = .07$). Recommendations are given for revision of the SBSOD scale based on item-level analyses.

1. Introduction

Each day that we venture into the world on foot or via wheeled vehicle, we travel over well-learned routes or enter unknown territory. Some of us approach new spatial environments with anxiety at the prospect of losing our way; others relish, and even seek, the experience of reaching a new destination aided by a map, verbal instructions, or merely a keen spatial awareness of the environment and the orientation of their body within it.

Sense of direction ("SOD") has previously been operationalized as the ability to locate and orient ourselves with respect to environmental space (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002), and there is considerable evidence for the predictive utility of self-report measures of this psychological construct. In particular, prior research has demonstrated that self-reported sense of direction is positively correlated with proficiency at: (1) estimating distances ($r = 0.00$–0.48, $n = 24$–286; Hegarty et al., 2002; Ishikawa & Montello, 2006); (2) estimating direction under various conditions ($r = 0.36$–0.45, $n = 24$–25; Hegarty et al., 2002; Ishikawa & Montello, 2006; Montello & Pick, 1993); (3) giving, following, and remembering directions (see Hund & Padgitt, 2010); (4) maintaining an accurate orientation in complex environments ($r = 0.51$–0.82, $n = 12$–31; Sholl, Kenny, & DellaPorta, 2006); and, perhaps most importantly, (5) wayfinding accuracy (Hund & Padgitt, 2010; see also Kato & Takeuchi, 2003).

Given the scope of research evaluating the utility of SOD, relatively little research has investigated either the psychometric properties of the self-report scale by which it is most commonly measured – the Santa Barbara Sense of Direction scale ("SBSOD", Hegarty et al., 2002) – or the broader personality correlates. There are two noteworthy examples. Montello and Xiao (2011) evaluated the factor structure based on administration of the SBSOD to 5 small ($n = 89$–137) culture-specific samples. Bryant (1982) explored relationships between personality and SOD but employed methods that are now outdated due to advances in theory for both constructs. Sense of direction was assessed using a 50 item self-report measure that included items relating to styles of exploration, responses to disorientation, esthetic ratings of the campus on which the data were collected, and self-estimates of spatial ability, direction-giving and direction-taking. Personality was assessed using the 18 scales of the California Psychological Inventory (Gough, 1975). None of the personality scales correlated significantly with self-reported SOD for males and females independently; only the Flexibility scale correlated significantly using the full sample ($r(64) = -.27$).

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The present study was conducted to first evaluate the factor structure of the SBSOD and then situate it within modern frameworks of individual differences (specifically the Big Five personality traits and intelligence). Analyses of the factor structure for the SBSOD were conducted in order to evaluate its general factor saturation; these analyses were motivated by the fact that SOD is typically conceptualized as a unitary construct (Montello & Xiao, 2011). To the extent that lower-order structure exists in the SBSOD, we endeavored to identify these facets and their relationship to personality. The second set of analyses – situating the SBSOD among prominent domains of individual differences – was conducted in order to explore the degree to which sense of direction reflects an ability rather than a temperamental orientation. Despite prior research on this topic (Hegarty et al., 2002; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Hund & Nazarczuk, 2009), it remains unclear whether SOD is merely a by-product of spatial and/or navigational ability or more likely to be a manifestation of "personality" as defined by an individual's stable pattern of affective, behavioral, and cognitive interaction with his or her environment (Ortony, Norman, & Revelle, 2005; Revelle, Wilt, & Condon, 2011).

It should be noted that the distinction between these two possibilities is spurious, as both temperament and cognitive abilities (as well as interests and other aspects of motivation among other sources of individual differences) are fundamental features of *personality*, writ large. Cognitive abilities and temperament differ from an assessment perspective in that the former typically measures maximal performance and the latter assesses typical behavior, but both are highly predictive domains of individual differences research. As such, a more precise description of the question at hand is whether sense of direction is more closely related to the cognitive abilities or temperamental variables; it is a "personality" characteristic in either case.

Based on research suggesting that various personality characteristics promote or hinder one's tendency to actively engage with the environment (Bryant, 1982), we hypothesized that individual differences in SOD would be more highly correlated with the dimensions of the Big Five (Goldberg, 1990) than cognitive ability. More specifically, the characteristics of extraversion (energy, enthusiasm, approach behavior), conscientiousness (attention to detail, organization, diligence), and openness (curiosity, ingenuity, adventurousness) were expected to show the strongest positive relationships on the grounds that these traits promote active engagement. Similarly, the avoidance processes associated with neuroticism (anxiety, withdrawal, and self-consciousness) were expected to be negatively related to SOD because they tend to hinder active engagement with the environment. No hypotheses were made about the relation between agreeableness (the tendency to be polite, cooperative, and trustful) and SOD. In the event that SOD was more closely related to ability than the Big Five traits, it was expected to be most highly associated with spatial ability.

2. Method

2.1. Participants

Participants were 12,155 individuals (64% female) who completed an online survey at SAPA-project.org (previously test.personality-project.org) in exchange for customized feedback about their personalities. The data for this sample were collected over the course of two time periods; first from August 5, 2009 to August 21, 2009 and then from November 18, 2011 to January 11, 2012. All data were self-reported. The mean self-reported age was 25.5 years ($sd = 10.6$, median = 21) with a range from 14 to 90 years. All educational attainment levels were well represented in the sample: 24% had 12 or fewer years of education; 20% had some graduate or professional school experience; the remainder had college degrees (35%) or were currently enrolled (20%). Approximately 30% of the sample ($n = 3585$) provided their country of origin data. Of this subset, 105 countries were represented overall (73% U.S.). Participants were also given the option to provide self-reported achievement test scores. Approximately 15.4% of participants provided self-reported scores for at least one of the tests. Mean combined scores for the SAT Critical Reading and Math were 1241 (median = 1260, $sd = 199$). Mean ACT Composite scores were 25.9 (median = 26, $sd = 5$).

2.2. Measures

Participants were administered items from three sets of scales using the Synthetic Aperture Personality Assessment ("SAPA") technique (Revelle, Wilt, & Rosenthal, 2010), a variant of matrix sampling procedures discussed by Lord (1955) (see also Condon & Revelle, 2014). This technique makes use of random sampling from large sets of personality and ability items in order to create synthetic correlations across a wide range of constructs even though a reasonably small subset of the items are presented to any one subject. Exclusive of questions regarding participant characteristics (i.e., gender, age, country of origin, education and achievement test scores), each participant was administered 72 to 76 items in total; variability in the total number was independent of participant characteristics.

The three sets of scales were the 15 item Santa Barbara Sense of Direction scale ("SBSOD", Hegarty et al., 2002, Table 2), the International Personality Item Pool 100-Item Set of Big-Five Factor Markers ("IPIP100", Goldberg, 1992; Goldberg, 1999), and 52 items from the International Cognitive Ability Resource ("ICAR", Condon & Revelle, 2014). Each participant was administered 10 of the 15 SBSOD items at random, 50 of the IPIP100 items (10 items each for Conscientiousness, Agreeableness, Emotional Stability, Extraversion, and Intellect), and 12 to 16 of the 52 ICAR items assessing Three-Dimensional Rotation, Verbal Reasoning, Matrix Reasoning, and Letter and Number Series item types.

The use of SAPA administration procedures for structural analyses requires that the pairwise administration of items is high enough to provide stability in the covariance matrix (Kenny, 2012; Condon & Revelle, 2014). The number of pairwise administrations suggested more-than-adequate stability across all items ($m = 1702$; median = 1904; $sd = 1563$) and for the SBSOD items independently ($m = 1926$; median = 1925; $sd = 30$).

2.3. Analyses

Analyses were conducted in the R computing environment (R Core Team, 2014), primarily using the *psych* package (Revelle, 2014). Internal consistency measures and assessment of the omega hierarchical general factor saturation (Revelle, 2014; Revelle & Zinbarg, 2009; Zinbarg, Yovel, Revelle, & McDonald, 2006) were based on the Pearson correlations between items. The factoring method used for the omega analyses minimized the residuals of the Ordinary Least Squares ("OLS") (Revelle, 2014). The polychoric/tetrachoric correlations between items were used to score the scales and conduct analyses based on two-parameter Item Response Theory (Baker, 1985; Embretson, 1996; Revelle, 2014) as this allowed for estimation of the correlations between items as if they had been measured continuously (Revelle & Condon, in press). Note that the SAPA sampling procedure described above results in data which are "massively missing completely at random", and that the range of the confidence intervals for the correlations is dependent on the number of pairwise administrations between items. Probability values for the correlations were estimated based on bootstrapping procedures provided in the *psych* package (see 'cor.ci', Revelle, 2014).

3. Results

Internal consistencies for the IPIP100 scales and the ICAR scales are reported in Table 1. All of the IPIP scales and most of the ICAR scales demonstrated high consistency among the items. The only prominent exception were the Matrix Reasoning items ($\alpha = 0.53$, $\omega_h = 0.49$, $\omega_t = 0.58$). This likely reflects the fact that relatively few items of this type were administered.

Table 1
Internal consistencies for the IPIP and ICAR scales.

	α	ω_h	ω_t	Items
IPIP100				
Agreeableness	0.91	0.80	0.92	20
Conscientiousness	0.92	0.67	0.93	20
Extraversion	0.93	0.76	0.94	20
Emotional Stability	0.93	0.72	0.94	20
Intellect	0.88	0.58	0.91	20
ICAR				
Full ICAR	0.96	0.60	0.97	52
Letter Number Series	0.77	0.71	0.82	9
Matrix Reasoning	0.53	0.49	0.58	4
Three-Dimensional Rotation	0.97	0.60	0.99	24
Verbal Reasoning	0.76	0.64	0.78	15

Note: α = Cronbach's alpha, ω_h = omega hierarchical, ω_t = omega total.

Correlations between the items of the SBSOD and the scales for the IPIP100 and the ICAR60 are presented in Fig. 1 (full text for the SBSOD items is listed in Table 2). The standard deviation of these correlations were generally quite low (0.01 to 0.03) due the large number of pairwise administrations between items. The full distribution of the standard deviations between correlations is depicted in Fig. 2. Most of the correlations between the SBSOD items and the other scales were small to moderate in magnitude; all but one ranged between −0.28 and 0.28. The exception was SBSOD item 2 ("Have a poor memory for where I left things."), which had a high correlation (−0.45) with the Conscientiousness scale of the IPIP100. The SBSOD items were generally uncorrelated with the ICAR scales with two notable exceptions; item 7 ("Enjoy reading maps.") and item 9 ("Am very good at reading maps.") both had low, positive correlations with the ICAR scales (r = 0.15–0.25 and r = 0.14–0.21, respectively). None of the SBSOD items correlated significantly more with the spatially-oriented Three-Dimensional Rotation items than with the other cognitive ability item types. Among the correlations between SBSOD items, two items – item 2 and item 12 ("It's not important to me to know where I am.") – demonstrated notably smaller correlations with the SBSOD scale scores (r = −0.38 for item 2 and r = −0.24 for item 12) than the rest of the items in the set.

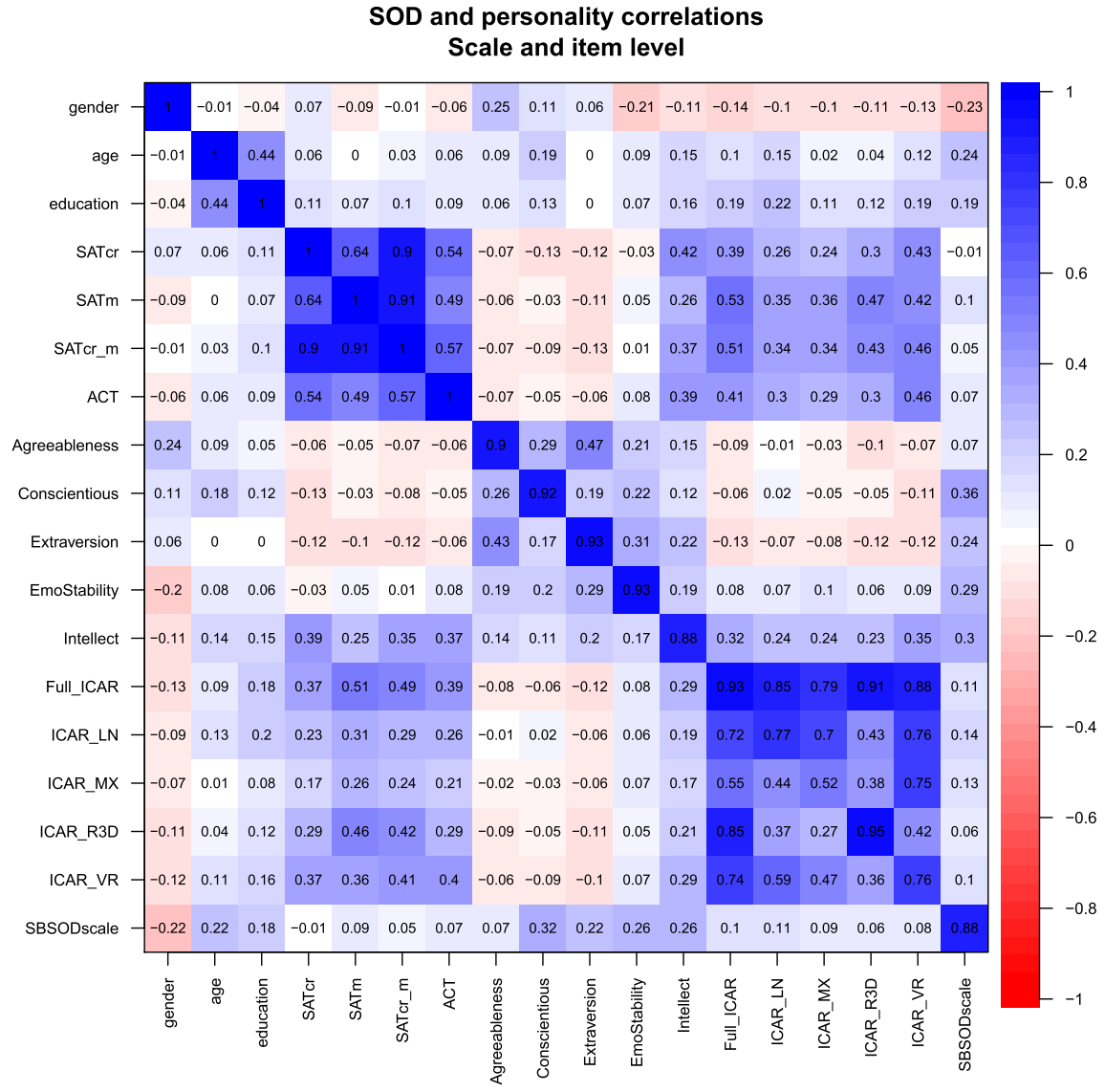

Fig. 1. SOD and personality correlations on the scale and item level. Notes: Correlations have been corrected for item overlap where necessary. Correlations above the diagonal also reflect corrections for attenuation. The SBSOD scale is based on all of the SOD items. The Full_ICAR score is comprised of four ICAR subtests. SATcr is SAT-Critical Reading; SATm is SAT-Math; SATcr_m is SAT-Combined; ICAR_LN is Letter and Number Series; ICAR_MX is Matrix Reasoning; ICAR_R3D is Three-Dimensional Rotation; ICAR_VR is Verbal Reasoning. Gender is coded as 1 for males and 2 for females.

Table 2
SBSOD items and their factor loadings on the general factor and three oblique secondary factors.

Items by secondary factor	General			
	Factor	Factor 1	Factor 2	Factor 3
Orientation				
Item 14. Can usually remember a new route after I have traveled it only once.	0.57	*0.51*	−0.01	−0.03
Item 10. Don't remember routes very well while riding as a passenger in a car. (R)	0.54	*0.51*	−0.06	−0.02
Item 4. Have a very good sense of direction.	0.73	*0.40*	0.10	0.08
Item 6. Very easily get lost in a new city. (R)	0.58	*0.35*	0.12	0.03
Item 15. Don't have a very good "mental map" of my environment. (R)	0.47	*0.30*	0.05	0.03
Item 8. Have trouble understanding directions. (R)	0.58	*0.23*	−0.01	0.16
Item 3. Am very good at judging distances.	0.47	*0.22*	0.08	0.07
Item 2. Have a poor memory for where I left things. (R)	0.26	*0.16*	−0.05	0.05
Engagement with maps				
Item 7. Enjoy reading maps.	0.51	−0.03	*0.73*	−0.02
Item 9. Am very good at reading maps.	0.64	0.10	*0.51*	0.06
Item 5. Tend to think of my environment in terms of cardinal directions (N, S, E, W).	0.38	0.10	*0.26*	0.03
Item 13. Usually let someone else do the navigational planning for trips. (R)	0.60	0.15	*0.20*	0.12
Engagement with directions				
Item 1. Am very good at giving directions.	0.80	0.00	0.00	*0.40*
Item 11. Don't enjoy giving directions. (R)	0.61	−0.02	0.00	*0.32*
Item 12. It's not important to me to know where I am. (R)	0.14	0.06	0.05	0.05

Note: (R) indicates that the item was reverse scored.
Italics indicate the secondary factor on which each item has the highest loading.

Internal consistency measures of the SBSOD indicated a high degree of general factor saturation, with an $\omega_{hierarchical}$ of 0.73. Other common indicators of general factor saturation were uniformly high: Cronbach's $\alpha = 0.88$, Guttman's $\lambda_6 = 0.89$, and McDonald's $\omega_{total} = 0.90$. Loadings of each item on the general factor as well as the group factors that emerged from analyses of the general factor saturation are shown in Table 2. The correlations between the three secondary factors are shown in Table 3. Three group factors were chosen in order to facilitate interpretation of the underlying structure of the items. In addition to high general factor saturation, the moderate to high correlations between secondary group factors also provide evidence for unidimensionality among the items.

Table 3
Correlations between the secondary factors of the SBSOD.

	Factor 1	Factor 2	Factor 3
Factor 1	1.00		
Factor 2	0.48	1.00	
Factor 3	0.69	0.56	1.00

Consistent with the raw correlations, items 2 and 12 were the only SBSOD items that did not load highly on the general factor as all other items had loadings of 0.38 or higher. The first group factor appears to be well-defined by items assessing the tendency to remember routes and maintain one's orientation. The second and third group factors were defined by items assessing enjoyment and skill related to reading maps and giving directions, respectively. Note that item 12 demonstrated consistently low loadings on all of the secondary factors as well as the general factor (0.14).

Results from the analyses based on Item Response Theory are given in Fig. 3 and Table 4. The information functions for each item are summarized for several levels of the latent trait in Table 4. All of these analyses presume unidimensionality in the underlying construct as supported by the high general factor saturation. The information function for the scale as a whole (plotted in Fig. 3) reflects high reliability at low levels of the latent trait and lower (though still adequate) reliability at the higher end of the range.

4. Discussion

These findings suggest that scores on the Santa Barbara Sense of Direction scale demonstrate a clear general factor, and that a considerable portion of the variance in these scores is explained by other aspects of personality. They also suggest that revision of the SBSOD may be in order.

All of the Big Five traits except Agreeableness correlated with SBSOD scores in the hypothesized direction. In other words, SBSOD scores were positively correlated with Conscientiousness ($r = 0.32$, $p < .001$), Extraversion ($r = 0.22$, $p < .001$), Intellect ($r = 0.26$, $p < .001$), and Emotional Stability (low Neuroticism) ($r = 0.26$, $p < .001$). The correlations between SBSOD and the cognitive ability measures were notably lower than those of personality (*r*'s between .07 and 0.13). While the ICAR

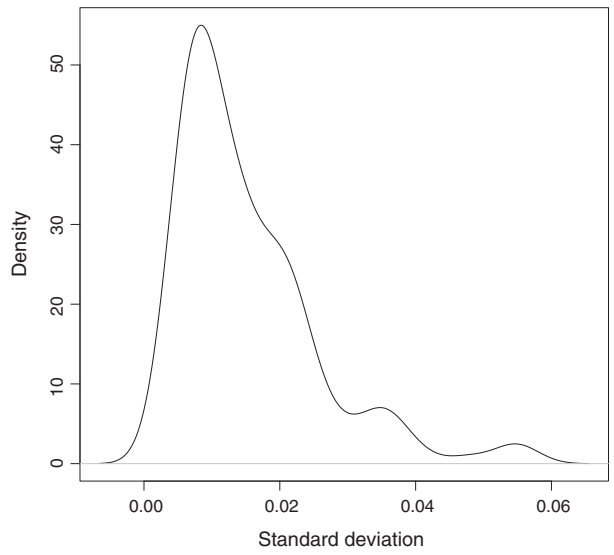

Fig. 2. Distribution of the standard deviations of the correlations shown in Fig. 1.

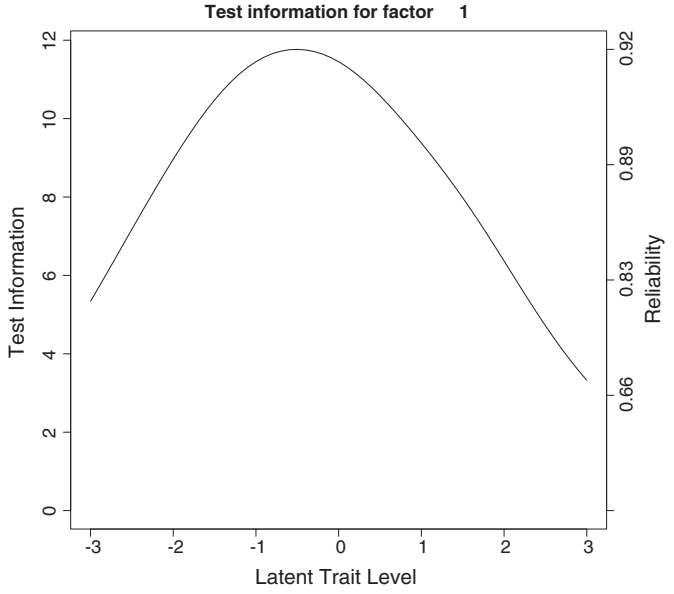

Fig. 3. SBSOD test information function.

Table 4
Item and test information for the SBSOD.

Item	Latent trait level (normal scale)						
	−3	−2	−1	0	1	2	3
Item 14	0.43	0.77	1.01	0.99	0.76	0.46	0.22
Item 10	0.30	0.59	0.91	1.02	0.85	0.53	0.26
Item 4	1.04	1.71	1.86	1.54	1.15	0.84	0.26
Item 6	0.32	0.64	0.95	1.06	0.91	0.61	0.31
Item 15	0.40	0.54	0.61	0.56	0.43	0.29	0.17
Item 8	0.53	0.77	0.87	0.78	0.57	0.34	0.17
Item 3	0.28	0.41	0.51	0.53	0.47	0.36	0.24
Item 2	0.11	0.12	0.13	0.13	0.13	0.12	0.10
Item 7	0.23	0.37	0.52	0.61	0.58	0.45	0.30
Item 9	0.44	0.81	1.09	1.09	0.85	0.51	0.23
Item 5	0.16	0.22	0.30	0.35	0.36	0.32	0.26
Item 13	0.30	0.57	0.83	0.94	0.81	0.53	0.28
Item 1	0.51	0.98	1.28	1.23	0.97	0.62	0.27
Item 11	0.30	0.46	0.59	0.63	0.55	0.40	0.25
Item 12	0.04	0.04	0.04	0.04	0.04	0.04	0.04
TIF	5.34	8.96	11.45	11.45	9.38	6.37	3.32
SEM	0.43	0.33	0.30	0.30	0.33	0.40	0.55
Reliability	0.81	0.89	0.91	0.91	0.89	0.84	0.70

correlations with SBSOD were all similar in magnitude, it was notable that the smallest of these correlations involved the most spatially related item type — the Three-Dimensional Rotation items; this is consistent with prior findings of relatively low correlations between sense of direction and mental rotation (Bryant, 1982; Hegarty et al., 2002; Hegarty et al., 2006). When considered together, this combination of results suggests that sense of direction is less related to cognitive ability (including mental rotation ability) than to Big Five traits, and that the direction of these associations is consistent with active engagement with the environment. Although it is also possible that the positive correlations between the Big Five and SBSOD scores result from socially desirable responding, correlations were relatively lower between SBSOD and Agreeableness ($r = 0.07$, $p < .001$), the Big Five scale which is most typically influenced by social-desirability response patterns.

SBSOD scores were also positively associated with several demographic characteristics, including gender (towards males), age, and higher educational attainment. The association with age, though not explicitly hypothesized, is consistent with the possibility that SOD is associated with active engagement in that an integral by-product of engagement is experience. In other words, both the degree and frequency of engagement with the environmental space should be expected to affect one's sense of direction. It is likely that the positive association between SBSOD and educational attainment is a function of the association with age as these two demographic variables are often highly correlated. The fact that SBSOD scores are higher for males is consistent with prior research (Bryant, 1982; Hegarty et al., 2006; Kozlowski & Bryant, 1977; Lawton, 1994; Prestopnik & Roskos-Ewoldsen, 2000; Sholl, Acacio, Makar, & Leon, 2000). Identifying the mechanism that underlies this association, however, remains an important topic for future research.

With regards to the item-level factor structure, SBSOD items assessing the propensity to actively engage with maps and directions form somewhat distinct – though highly related – sub-factors of the sense of direction construct. The two most highly-loaded items in the "Engagement with Maps" sub-factor (see Table 2) also had the highest loadings with the cognitive ability scales (see Fig. 1). Further, all four of the items in this sub-factor demonstrated higher-than-average correlations with gender, age and education. The two items comprising the third sub-factor, "Engagement with Directions," both had high loadings on the general factor but were uncorrelated with the other sub-factors. These items suggest that one's attitude about giving directions is a reasonable proxy for sense of direction.

Factor analyses also provided strong support for the removal of two items from the SBSOD scale. Item 12 does not contribute meaningfully to either the general factor or any of the secondary factors. In the case of item 2, the general factor loadings are marginal while its correlations with Conscientiousness are unusually high. While the 13 items remaining after removal of items 2 and 12 are likely to be few enough for most assessment purposes, further reduction could be achieved by using the item information characteristics from the IRT analyses. The IRT-based item parameters suggest that a subset of the most informative items listed in Table 4 would provide adequate assessment for sense of direction with little reduction in reliability across the range of the latent trait.

5. Conclusion

These data suggest that engagement (and resultant experience) with one's environment may play a role in shaping attitudes about sense of direction, and this in turn suggests the need for future research which explores the degree to which sense of direction is amenable to manipulation based on engagement behaviors that correlate with personality traits such as Conscientiousness. The results presented here clearly demonstrate that, while cognitive ability was positively correlated with sense of direction, larger correlations were evident between sense of direction and the Big Five and demographic characteristics, including age.

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