Spatial and Object Visualization Cognitive Styles: Validation Studies in 3800 Individuals

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Abstract

The well-established dissociation between the ventral object and dorsal spatial processing streams within the visual system suggests a contrast between object and spatial visual cognitive styles. We assessed the validity of this distinction using a self-report questionnaire in a sample of 3839 online participants, and laboratory cognitive tests in a subsample of 196. We found that (1) object and spatial processing preferences were virtually uncorrelated ($r = -.05$); (2) men, science majors, and people with videogame experience preferred spatial visualization, whereas women, humanities majors, and people with visual arts experience preferred object visualization; and (3) spatial visualizers performed better on tests of mental rotation and virtual maze navigation, whereas object visualizers performed better on a difficult test of picture recognition. Interestingly, the associations among the spatial measures were stronger than those among the object measures, suggesting that spatial visualization may be the more unitary cognitive ability and style.

Introduction

The distinction between cognitive abilities that are predominantly "verbal" and "visual-spatial" is of long standing in psychology and neurology. For decades, the principal factors identified by intelligence test batteries, after the general factor, were verbal and performance sub-factors, with the performance factor consisting largely of spatial tests (such as arranging blocks to match a displayed design). Before neuroimaging technologies were developed, neurological patients were classified as having anterior or posterior lesions based on whether their language or visual faculties appeared to suffer the most impairment. The subdivision of visual cognition into processes that operate primarily on *spatial* information and relations, and those that operate on *object* properties and representations is more recent, gaining currency from animal studies (Ungerleider & Mishkin, 1982). The earliest of these studies demonstrated that lesions to the dorsal occipital-parietal pathway impaired a monkey's ability to learn spatial information but not object information, and vice-versa for lesions to the ventral occipital-temporal pathway. Subsequent research has identified cognitive tasks that differentially stress these two visual subsystems (e.g., Haxby et al.; 1991), and has shown that the distinction extends beyond perception and memory to the domain of mental imagery (Levine, Warach, & Farah, 1985; Kosslyn, 1994; Kozhevnikov, Kosslyn, & Shepard, 2005).

The verbal/visual-spatial distinction has been applied to the classification of individuals according to their "cognitive styles," or their preferred modes of information processing. That is, when a problem may be solved using either verbal or visual-spatial representations and methods, many individuals consistently choose one mode over the other, even if it is not necessarily the most efficient.[1] Note that one's *preference* for using a particular method or strategy in problem-solving is conceptually independent of one's relative *abilities* in different domains of processing. In principle, one could be strong in verbal processing but have a preference for visual-spatial strategies. It is reasonable, however, to expect that individuals will express cognitive styles that are at least somewhat consonant with their cognitive strengths.

Here we examine the distinction between cognitive preferences for spatial and object visualization (Kozhevnikov et al., 2002, 2005). In particular, we conducted two studies using the Object-Spatial Imagery Questionnaire (OSIQ; Blajenkova et al., 2006) that measures an individual's tendencies to use object and spatial visualization. Our goal is to develop the construct validity of the distinction between these two visualization cognitive styles, and thereby to support indirectly the idea that distinct cognitive styles are, like cognitive abilities, based ultimately on distinct neural systems. Specifically, these studies establish a network of relations among measures of individual preferences for spatial and object processing, computerized measures of processing ability in these two domains, measures of performance in a relatively complex "real-world" task requiring spatial and object processing, and assessment of experience in different activities that would be consistent with a preference for spatial or object processing. Moreover, given that object and spatial processing occur largely in distinct streams within visual cortex, each of which may be effective or ineffective and used more or less frequently in problem-solving and everyday cognition, we expect preferences for the two types of visualization to be essentially uncorrelated in the general population.

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1. For example, D.J. Simons and C.F. Chabris (unpublished data) tested a middle-aged man who claimed to experience no visual mental imagery whatsoever, but was able to perform complex visualization tasks such as mental rotation by using a cumbersome and slow strategy of verbally describing the geometric stimuli and "calculating" how they would be aligned after rotation.

Study 1

In Study 1, we administered the Visualizer-Verbalizer Cognitive Style Questionnaire (VVCSQ; Kozhevnikov et al., 2005), an adaptation of the Mathematical Processing Instrument (MPI; Lean & Clements, 1981), to over 3800 individuals who participated via the Internet. The VVCSQ measures the use of visual or verbal strategies in solving a set of mathematics problems and classifies individuals as verbalizers or visualizers. We then collected standardized self-report measures of spatial- and object-visualization preference (cognitive style) using the OSIQ. We also obtained reports of experience in various imagery-related activities, as well as imagery vividness. Consistent with the object and spatial scales being valid assessments of distinct individual visualization preferences, we hypothesized that: (1) spatial and object visualization scores would be uncorrelated; and (2) individuals who regularly engaged in activities involving spatial visualization (e.g., video games) would have higher spatial scores, whereas individuals who regularly engaged in activities involving object visualization (e.g. representational art) would have higher object scores.

Method

Participants

3839 individuals participated online in return for a $5 gift certificate to Amazon.com. Participants were recruited primarily with online advertisements on craigslist.com over a period of 18 months. Of these, 130 participated twice; only data from their first session was retained and analyzed, except for assessment of test-retest reliability. The sample included 1301 males and 2538 females, ranging in age from 14 to 76 years (M = 26.6, SD = 8.4).

Materials and Procedure

All data were collected using the participant's web browser via the service provided by surveymonkey.com, which enables individuals to complete custom-designed questionnaires. Each participant completed a set of measures in the following order: demographic info (sex, age, ethnicity, college major, and for one sample, handedness), activity experience questions, VVCSQ, OSIQ. One sample then completed the Vividness of Visual Imagery Questionnaire (VVIQ), a self-report measure of the vividness of mental images the participant generates in response to a series of descriptions, which was administered as described by Marks, 1972, 1973. Gift certificate codes were delivered within one week by email.

Activity experience. The activity experience questions required the participant to respond on a 3-point scale, with 1 representing "not at all experienced," 2 "somewhat experienced," and 3 "very experienced." The activities rated were: (1) playing virtual reality/first-person perspective video games (such as Doom or Quake); (2) playing third-person perspective or overview video games (such as Super Mario Brothers); (3) doing sculpture, painting, drawing, or other visual arts; (4) constructing verbal arguments (e.g., debate); (5) solving word puzzles; (6) solving picture puzzles.

Visual-verbalizer cognitive style. The VVCSQ was administered as described by Kozhevnikov et al. (2005, Study 1), except that 10 mathematical problems were used instead of 11. Participants solved the set of problems under no time constraint, and then were asked to describe the strategy they used to solve each problem by selecting from a set of options. These options were scored 0 for a verbal strategy, 1 for a hybrid verbal/visual strategy, and 2 for a visual strategy. Thus, participants received two scores: the total number of correct answers, and the total strategy score (with higher values indicating greater use of visual strategies).

Object-spatial imagery. The OSIQ was administered with the questions described by Blajenkova et al. (2006), along with an additional 15 questions intended to quantify the "verbalizer" dimension of cognitive style. (The questions related to the three scales were intermixed.) Because the "verbal" items are still under development, and do not relate to the primary goals of this study, we will not consider them further. We calculated a participant's object and spatial scores by summing the points allotted to each of the 15 items that form each scale; thus, an individual's score on each dimension can range from 15–75. Blajenkova et al. report one week test-retest reliabilities > .80 for the object and spatial scores.

Table 1 shows sample items from the VVCSQ and the OSIQ. To qualify as a "visualizer" for the purposes of this study, the participant had to score > 7 (out of 20) on the VVCSQ.[2] Among those individuals, spatial visualizers were those who scored at least 5 points higher on spatial than object score, and vice-versa for object visualizers; individuals whose spatial and object scores were < 5 points apart were not classified. This had the effect of requiring a separation of approximately one-half of a standard deviation (or more) between a participant's object and spatial scores for him or her to be classified.

Results and Discussion

Relationship between OSIQ scales. As predicted, spatial and object scores were virtually uncorrelated, $r = -.05$ (see **Figure 1**), though because of the very large sample size this correlation was significantly different from zero ($p < .01$). If anything, the two abilities are slightly negatively related, but in practice, this correlation means that scores on one scale account for just 0.25% of the variance in scores on the other scale. This finding suggests that these scales measure distinct attributes of cognitive preferences. This is consistent with previous findings: Blajenkova et al. (2006) reported a correlation of $r = .08$ between the OSIQ spatial and object scores, but in a much smaller ($N = 195$) sample that was also more homogeneous (mostly college students enrolled in psychology courses).

Relationship between cognitive styles and activity experiences. Participants were classified as object visualizers ($N = 1991$), spatial visualizers ($N = 582$), or verbalizers ($N = 436$); the remaining 830 were unclassified (i.e., were not classified as verbalizers, but had object and spatial scores too close to clearly classify as one or the other type of visualizer). As predicted, spatial visualizers reported more first-person "virtual reality" 3-D video game experience than object visualizers, $d = 0.37$, $p < .0001$ (see **Table 2**). A smaller difference was reported for third-person overview video games, $d = 0.14$, $p < .01$. By contrast, object visualizers reported more representational art experience, $d = 0.53$, $p < .0001$. There were no significant differences between object and spatial visualizers in argument/debate, word puzzle, or picture puzzle experience, $d < 0.04$ for all of these comparisons.

In the full sample ($N = 3839$), spatial scores correlated with video game experience more than did object scores (spatial vs. object scores: $r = .27$ vs. .01 for 3-D video games, $r = .17$ vs.

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2. Kozhevnikov et al. (2005) used a median split on the VVCSQ scores to differentiate visualizers from "verbalizers," which resulted in a lower proportion of their samples qualifying as visualizers than was found in the present study. Our primary purpose, both here and in Woolley et al. (2006), was not to compare visualizers and verbalizers, but to compare different subtypes of visualizers. Therefore, we used a somewhat less strict cutoff point than a median split (which is itself an arbitrary criterion) in order to increase the proportion of our sample that we could study further. As a consequence of the arbitrary designation of verbalizers, and our focus here on visualization cognitive styles, we will not analyze data from the verbalizer or unclassified groups.

.05 for overview video games), but vice-versa for object scores and artistic experience (spatial vs. object scores: $r = –.04$ vs. .30). Spatial and object scores predicted experience in picture puzzles equally well ($r = .22$ and .21 for spatial and object scores respectively). Spatial and object scores were equally poor in predicting experience in word puzzles ($r = .10$ and .11) and in argument and debate ($r =.07$ and .12); in each of these cases the best-predicting score explained less than one third of the variance that could be explained in picture-puzzle experience.

Taken together, these results provide new evidence for the validity of the OSIQ scores, consistent with the report of Blajenkova et al. (2006) that scientists scored higher than visual artists or humanities professionals on the spatial scale, whereas visual artists scored higher than the other two groups on the object scale. These relationships appear not to depend on the preferences of professionals, but to operate throughout a broad range of experience levels.

Sex differences. As shown in **Figure 2**, males had higher spatial scores (48.2) than females (42.6), $d = 0.61$, $t\,(3837) = 18.6$, $p < .0001$. Females had higher object scores (52.4) than males (49.8), $d = 0.28$, $t\,(3837) = 8.3$, $p < .0001$. Blajenkova et al. (2006) report a consistent male advantage in spatial scores across four studies totaling 529 participants, but an inconsistent female advantage in object scores. Because of our large sample size, both sex differences were highly significant, but the effect for spatial scores was twice as large as that for object scores. The male-female difference in spatial score is slightly smaller than the difference observed in meta-analyses of spatial tasks (e.g., Voyer, Voyer, & Bryden, 1995).

Other individual differences. Object visualizers scored higher on the VVIQ than spatial visualizers ($d = 0.79$, $p < .0001$) and VVIQ score correlated positively with object score ($r = .56$, $p < .0001$, $N = 2493$), which indicated that individuals who preferred to use object imagery reported experiencing more vivid images, consistent with the findings of Blajenkova et al (2006). VVIQ score was not correlated with spatial score ($r = .02$). Interestingly, in a study of mental imagery in chess masters and novices, Chabris (1999) found that masters reported significantly less vivid mental imagery than novices, which supports the idea that chess skill stresses spatial rather than object visualization abilities.

We had no expectation of handedness effects, and in our 1337 participants who reported a hand use preference, no significant differences on any measure were observed between left-handers ($N = 161$) and right-handers ($N = 1176$).

Reliability. We analyzed the data from the 130 individuals who participated twice to assess the test-retest reliability of the OSIQ scales, the activity experience ratings, and the classification of individuals as object or spatial visualizers. The interval between the two sessions ranged from 115 to 516 days ($M = 317$, $SD = 90$). On their first session, these 130 individuals were representative of the full sample based on their spatial and object scores: Full sample spatial $M = 44.5$, $SD = 9.3$; reliability sample spatial $M = 44.8$, $SD = 9.8$. Full sample object $M = 51.6$, $SD = 9.3$; reliability sample object $M = 50.6$, $SD = 9.7$. However, within the reliability sample, the correlation between object and spatial scales was $r = –.19$ (first session) and $r = –.10$ (second session), both slightly higher than in the full sample (where $r = –.05$).

As shown in Table 2, the object and spatial scales both exhibited good reliability, especially in light of the average 10.5-month delay between test sessions: Test-retest $r = .82$ for spatial, $r = .72$ for object. We performed a median split on the delay times and observed that reliability was negligibly higher when the inter-test interval was less than 322 days: $r = .84$ for spatial, $r = .74$ for object. The classification of individual cognitive styles was less reliable: 56% of individuals were classified the same way at both sessions; however, only 5 individuals "switched" between being classified as object and spatial visualizers on the two occasions; most switches were to or from "unclassified" or "verbalizer" categories. Consistent with this, we noted that the VVCSQ score, which measures how often participants used verbal strategies in solving mathematics problems, and was used to classify verbalizers, had lower reliability than the OSIQ scores (test-retest $r = .28$), perhaps because strategies were likely to change the second time participants solved the exact same set of problems.

The activity experience questions were nearly as reliable as the OSIQ scales in the cases of the activities predicted to relate to visualization preferences: virtual-reality video games $r = .72$, third-person overview video games $r = .67$, representational art $r = .71$. Reliability was somewhat lower for argument/debate experience (.60), word puzzle experience (.51), and picture puzzle experience (.40). It is possible that these low correlations represent actual changes in the participants' experience levels during the 10 months between sessions.

Study 2A

Study 1 provided evidence for the independence of the object and spatial visualization dimensions, and for their relationships with sex differences and individual differences in activity preferences. Next we examined whether preferences for object and spatial visualization were manifested as increased ability in the domains of object and spatial information processing. Specifically, we invited 200 of the participants in Study 1—half classified as "spatial visualizers" and half classified as "object visualizers"—to come into the laboratory for a two-part study. In part A, described in the following, they completed two cognitive tasks and a measure of general cognitive ability. We hypothesized that spatial visualizers would perform better than object visualizers on the mental rotation task, and vice-versa for a task of identifying degraded pictures.

Method

Participants

196 individuals from the sample described for Study 1 also participated in this laboratory study (data from an additional four participants were incomplete and were not used in these analyses). This subsample included 69 males and 127 females, and ranged in age from 18 to 60 years ($M = 27.9$, $SD = 8.9$). Spatial and object visualizers did not differ significantly in age ($d = 0.00$), nor did age correlate with either spatial or object OSIQ scores in this sample ($r < .02$ in each case). Participants were invited in pairs, but they completed the measures for Study 2A individually. Each participant received a base payment of $20, and was told that he or she could gain or lose money based on his or her dyad's performance in the task described in Study 2B (see below). Total payment "earned" ranged from $14.90 to $26.80 per participant (mean $20.39), but participants were guaranteed to take home the $20 base payment.

Materials and Procedure

We administered three cognitive measures, in the following order: (1) A version of the three-dimensional *mental rotation* task developed by Shepard and Metzler (1971), which was intended to measure spatial visualization ability; (2) a computerized version of the *snow pictures* task developed by Kozhevnikov et al. (2005), based on Ekstrom (1976), in which the participant must identify objects obscured by visual noise, which was meant to measure object visualization ability; (3) a short form of Raven's Advanced Progressive Matrices (RAPM; Bors & Stokes, 1998), which provided a measure of fluid cognitive ability.

Each trial of the mental rotation task presented two three-dimensional "cube" stimuli from the Shepard and Metzler (1971) set, and the participant was instructed to decide whether the two stimuli represented the Same object or two Different objects, and to respond by pressing "b" ("both the same") or "n" ("not the same") on the keyboard accordingly. The stimuli remained on the screen until the participant responded. There were eight different objects, each presented at four rotation angles (0, 80, 120, and 160 degrees) and in two trial types (Same and Different), for a total of 64 trials. There were 8 practice trials, using different stimuli from the experimental trials, followed by clarification of the instructions. Performance was indexed by error rate (ER) and response time (RT). Mean RTs were calculated after excluding incorrect responses and iteratively trimming out RTs greater than 2.5 times the mean of the other trials in each cell of the design (trial type x angle) for each participant. The slope and intercept of each participant's rotation function, relating ER and RT to angle, were also estimated with simple regression, separately for Same and Different trial types. (For more details on a very similar 80-trial version of this task, including reliability estimates, see Hooven et al., 2004, 2006).

Each trial of the snow pictures task presented a line drawing of a common object that was rendered very difficult to identify by superimposing visual noise (see Kozhevnikov et al., 2005 for sample stimuli). The stimulus remained on the screen until the participant pressed the spacebar to indicate that he or she had identified the object, after which he or she typed its name using the keyboard. There were no practice trials. Performance was measured by ER and by the mean RT across *all* trials. (Note that because this test presents very degraded pictures and asks for open-ended identifications in response, error rates tend to be high. Therefore, excluding all incorrect trials would result in very few trials being included in the mean RT computations.)

Each trial of the RAPM presents a 3x3 array of abstract figures in which the bottom right cell is missing. The participant must select which of eight alternatives is the correct figure to fill in the blank. Trials increase in difficulty; following two very easy practice trials with feedback, the participant has 15 minutes to complete a booklet of 12 items at his or her own pace, responding via a paper form. Performance was scored as the total number of correct items; because each question has eight alternative responses, chance performance is 1.5 correct.

Results and Discussion

Mental rotation. As predicted, spatial visualizers performed better than object visualizers, but only in accuracy: 7.3% errors vs. 16.2% errors, $d = 0.85$, $t\,(194) = 6.58$, $p < .0001$ (for overall RT, $d = 0.00$; see **Figure 3**). In the subcomponents of the mental rotation task, slope and intercept, spatial visualizers had lower ER slopes on Same trials (0.06% vs. 0.10% errors per degree of rotation), $d = 0.50$, $t\,(194) = 3.58$, $p < .001$. The largest difference was in the ER intercept on Different trials (5% versus 19% for spatial and object visualizers), $d = 0.83$, $t\,(194) = 6.36$, $p < .0001$, a pattern of results strikingly similar to the sex differences observed on a similar version of this task (Hooven et al., 2006). Same intercept and Different slope measures were comparable between groups. In the RT measures for Same trials, object visualizers had lower slopes than spatial visualizers (36 vs. 43 ms/deg; $d = 0.29$, $t\,(194) = 2.02$, $p < .05$) but higher intercepts (3206 vs. 2605 ms; d = 0.36, $t\,(194) = 2.54$, $p < .05$). No significant RT differences were observed on Different trials.

The object visualizers apparently adopt a different strategy for mental rotation, taking longer on the non-rotation elements of the task that are reflected in the intercept (e.g., encoding the stimuli, preparing to rotate, comparing representations after rotation, producing a keypress response) but "catching up" to the spatial visualizers in total RT with a faster rotation process.

However, this strategy does not compensate for a lower overall accuracy in task performance, especially in the processes reflected in the Different intercept, where the object-spatial visualizer difference is as large as it is for overall error rate.

To determine whether these results coincided with the sex differences reported by Hooven et al. (2006), we considered males and females in separate analyses. Among the 98 spatial visualizers, 52 were men and 46 were women; among the 98 object visualizers, the ratio was skewed: 17 were men and 81 were women. (Thus, a greater proportion of men than women are spatial visualizers; our overall sample consisted of about twice as many women as men.) The pattern described for the overall group also described the males ($N = 69$): a large object-spatial visualizer difference in overall ER ($d = 0.58$), attributable mostly to a difference in the intercept on Different trials ($d = 0.63$), plus a smaller difference in RT intercept for Same trials ($d = 0.40$). Within the females ($N = 127$), by contrast, there were no differences between object and spatial visualizers on any mental rotation measure except RT intercept for Same trials, which was lower for spatial visualizers ($d = 0.40$).

In short, visualization style predicts mental rotation performance for both men and women, but it is a better overall predictor for men, where it predicts aspects of ER and RT intercepts, as opposed to just RT intercept for women.

Snow pictures. Spatial and object visualizers made comparable numbers of errors in this task, despite our use of four different methods, of varying leniency, to score ambiguous answers ($d < 0.15$ under all scoring procedures). Figure 3 illustrates the results with the most liberal scoring criterion. This result held when we considered only the object visualizers with the highest object scores, or only those with the greatest object-spatial score differences (based on a median split in each case). However, object visualizers performed the task significantly faster than spatial visualizers (15.6 vs. 20.4 sec/trial), $d = 0.29$, $t\,(194) = 2.06$, $p < .05$; this difference was also evident in the comparisons using individuals with the highest object-scores or object-spatial disparities. This pattern of RT and ER results also held in the separate male and female samples, though the RT difference was not significant within either of these groups ($d = 0.25$ for men, $d = 0.11$ for women). The fact that the object visualizers achieved equal accuracy while using nearly 25% less time than the spatial visualizers is consistent with their having greater object processing ability.

Raven's APM. Spatial visualizers performed better on the 12-item RAPM (8.5 items correct versus 7.4 items for object visualizers), $d = 0.42$, $t\,(194) = 2.97$, $p < .01$. This difference was also observed by Blajenkova et al. (2006), but it is not clear whether it results from spatial visualizers having higher fluid reasoning ability, or from the Raven's being partly a test of spatial ability. According to an analysis by Carpenter et al. (1990; see also Prabhakaran et al., 1997), several of the items on the full Raven's APM require spatial reasoning; because we used only one third of the total items, we lacked the statistical power to directly compare spatial and non-spatial items. However, the spatial-object visualizer difference on the Raven's is half the size of the difference in mental rotation performance, so it is possible that the partially spatial nature of the test accounts for the difference rather than any difference in fluid intelligence.

Relationship between OSIQ scores and cognitive tasks. Treating spatial and object cognitive style scores as continuous variables, and including VVIQ and Raven's APM scores, multiple linear regression analyses revealed that spatial score was the best predictor of mental rotation ER ($\beta = 0.30$, $p < .0001$), with object score (negatively) and Raven's score also significant ($\beta = -0.24$ and 0.20, $p < .01$ in each case). The full regression explained 29% of the variance in ER on the task. For mental rotation RT, there were no significant predictors, and the full regression explained only 2% of the variance.

The corresponding analyses for snow pictures showed that object score was *not* a significant predictor of snow pictures RT ($\beta = 0.07$), but spatial score was a significant *negative* predictor ($\beta = -0.19$, $p < .05$). Higher VVIQ scores—indicating more vivid imagery—were also associated with faster RT ($\beta = 0.20$, $p < .05$). For ER on the snow pictures task, only Raven's APM was a significant predictor ($\beta = 0.20$, $p < .01$), and this was true regardless of how leniently we scored accuracy on this task. For both ER and RT, the full regression models explained less than 7% of the total variance in snow pictures performance.

Field of study. Participants reported their college major, which we categorized as clearly falling into the broad fields of humanities ($N = 60$; 15 male, 45 female) or sciences ($N = 74$; 32 male, 42 female), or as being ambiguous or falling into another field ($N = 62$; 22 male, 40 female). Science majors had higher spatial scores (51.1) than humanities majors (38.9), $d = 1.01$, $t\,(132) = 6.73$, $p < .0001$. Humanities majors had higher object scores (54.0) than science majors (45.0), $d = 0.79$, $t\,(132) = 4.95$, $p < .0001$. Thus, these results parallel the sex differences reported for our full sample earlier, as well as the pattern of larger individual differences in the spatial scale than in the object scale.

Study 2B

The results of Study 2A demonstrated that object and spatial visualizers have distinct patterns of cognitive abilities that are consistent with their cognitive styles. In this final study we ask whether the OSIQ object and spatial scales can predict individual performance in a novel task specifically designed to stress object and spatial information processing, and whether the OSIQ scales have more or less predictive power than the cognitive ability measures themselves.

Specifically, the participants from Study 2A now worked together in pairs on a task that required them to navigate through a virtual maze and the "tag" distinctive objects in the maze; following this, they then individually completed tests of spatial and object visualization abilities. We previously have shown that teams composed of one spatial and one object visualizer performed better than homogenous teams (i.e., teams of two spatial visualizers or two object visualizers), but only when the team members were assigned to the roles appropriate for their cognitive styles: These heterogeneous teams performed well when the spatial visualizer controlled maze navigation and the object visualizer controlled the tagging of remembered objects, but not when these roles were reversed (Woolley et al., 2006). Here we hypothesized that: (1) within each of these conditions, the individual performance of the maze navigator would correlate positively with his or her spatial OSIQ score, but not with his object OSIQ score; (2) by contrast, the individual performance of the object tagger would correlate with his or her object but not spatial score; and (3) in comparing the ability of the OSIQ scores and performance on the rotation and picture-identification tasks to predict performance in the maze task, the OSIQ scores would be inferior to the cognitive tests themselves as predictors.

Method

The participants from Study 2A also took part in Study 2B. The materials and procedure for this study are described in full by Woolley et al. (2006). Briefly, participants worked in two-person teams in the laboratory to complete a task that required them to navigate a three-dimensional virtual "maze" and to "tag" Greebles found twice in the maze (i.e., to mark an object when it was found in two separate locations in the maze, but to leave it unmarked if it was found only once). Teams were paid according to how many Greebles they tagged (or left untagged) correctly in three minutes. We chose Greebles (Gauthier & Tarr, 1997), an artificial category of similar novel three-dimensional objects, to make the task of remembering how many of each one were seen demanding of object processing skill. Although each team completed multiple mazes, here we report data only from the first maze, in which verbal and nonverbal collaboration was not permitted. This allows test of the individual capabilities of the assigned navigator and tagger.

There were four conditions: heterogeneous congruent (the navigator was a spatial visualizer and the tagger was an object visualizer), heterogeneous incongruent (object navigator, spatial tagger), homogeneous object (two object visualizers), and homogeneous spatial (two spatial visualizers). The rationale for the discussion period following Maze 1 and the comparison of overall *team* performance across conditions are presented in Woolley et al. (2006). Here we focus on the use of the OSIQ scores and the spatial and object cognitive test scores (mental rotation and snow pictures) as continuous predictors of *individual* performance in one's assigned role in the maze task. That is, because individuals were assigned to their roles, and were not allowed to communicate with their partners before or while working on the first maze, we were able to obtain relatively pure measures of how well the navigator was able to traverse the maze, and how well the tagger was able to remember the greeble objects. This enabled us to test further the validity of the object and spatial cognitive style dimensions as predictors of task performance, and to compare the predictive power of OSIQ scores and cognitive tests.

Results and Discussion

Maze navigation. We considered two dependent variables that measured the performance of the navigator in the maze task: Absolute Ground (the number of different "squares" in the maze that the team visited) and Total Ground (the total amount of movement, including any backtracking, or revisiting of squares already seen), which were correlated $r = .64$. For each of these we conducted a multiple linear regression using the navigator's object and spatial scores as independent variables. There were 98 observations (teams). For both Absolute and Total Ground, spatial score was a positive predictor of navigation performance ($\beta = 0.25$, $p < .05$ for Absolute Ground; $\beta = 0.33$, $p < .01$ for Total Ground), and object score was not a significant predictor in either case.

Next we regressed the two task performance measures (in separate analyses) onto the two cognitive task scores and the two cognitive style measures as predictors of navigation performance. We used total error rate (ER) on the mental rotation task, and total response time (RT) on the snow pictures task, because these were the measures that differentiated the object and spatial visualizers (see Figure 3). For Absolute Ground, mental rotation ER was the only significant predictor of navigation performance ($\beta = 0.35$, $p < .01$). For Total Ground, however, the spatial cognitive style score was the most significant predictor ($\beta = 0.30$, $p < .05$), with snow pictures RT also significant—slower performance on snow pictures predicted better performance on navigation ($\beta = 0.21$, $p < .05$). Mental rotation ER had nearly the same effect as snow pictures RT ($\beta = 0.18$) but did not reach significance at the $p < .05$ level. Across these two dependent measures, mental rotation performance was the most consistent predictor of navigation performance.

Object tagging. We considered two dependent measures of the tagger's performance in the maze task: Number Correct (the number of objects correctly tagged and untagged) and Net Correct (the number of objects tagged correctly minus the number tagged incorrectly), which were correlated $r = .69$. For each of these we did the same analyses as for the navigation measures. In the first analysis, using only object and spatial scores, there were no significant predictors of either measure of tagger performance.

When we added the cognitive task performance measures to the cognitive style measures in these analyses of tagger performance, we found significant predictors only for the Net Correct measure. The tagger's spatial cognitive style score was negatively related to performance (higher spatial scores predicted lower tagging performance), $\beta = 0.29$, $p < .05$; paradoxically, the tagger's RT in the snow pictures task also negatively predicted performance (slower performance on snow pictures predicted better performance on tagging), $\beta = 0.20$, $p < .05$. The four predictors here collectively explained just 13% of the variance in tagging performance; by contrast, they predicted 16–21% of the variance in navigation performance.

General Discussion

This study used data from over 3800 participants to validate the distinction between object and spatial visualization cognitive styles. We used an established method to classify individuals as visualizers or verbalizers, and then tested a relatively new questionnaire designed to measure preferences for object and spatial forms of mental imagery. We found that object and spatial visualization scores are virtually uncorrelated (and if anything, are slightly negatively related), which suggests that they measure distinct dimensions of cognitive preference. Object and spatial visualizers participated in expected patterns of activities: men, science majors, and people with experience playing videogames scored higher on the spatial visualization scale of the OSIQ, whereas women, humanities majors, and people with experience in visual arts scored higher on the object visualization scale. Spatial visualizers performed better on a test of mental rotation, and on navigating a virtual maze, whereas object visualizers performed better on a difficult test of picture recognition. Overall, our hypotheses were well-supported by this pattern of results, and they comport well with the finding reported by Woolley et al. (2006) that teams composed of one spatial visualizer and one object visualizer who are assigned to roles congruent with their cognitive styles perform a group task better than similar teams with incongruent role assignments, or teams with two spatial or two object visualizers.

However, we also noted a difference between the object and spatial scales of the OSIQ: Across the range of validation tests we performed, the spatial scale tended to the more powerful predictor of individual differences. For example, the effect size for object versus spatial visualizers on the mental rotation test was $d = 0.85$ in favor of the spatial visualizers, but on the snow pictures test it was only about one third as large, $d = 0.29$ in favor of the object visualizers. When we used OSIQ scores as continuous predictors of performance on these tasks, spatial score was the best predictor of *both* mental rotation and snow pictures performance (positively for mental rotation, negatively for snow pictures), despite Raven's APM being included to control for possible differences in fluid intelligence. Even the VVIQ measure of imagery vividness, which is generally viewed as a low-power individual differences scale, was a better predictor of snow pictures performance than was the OSIQ object scale. This general pattern occurred again for performance on the maze task: the spatial scale significantly predicted both dependent measures of navigation, whereas the object scale predicted neither measure of tagging. The field of study difference (humanities versus sciences) and the sex difference were both larger for the spatial scale than for the object scale.

It is possible that the spatial scale is a superior predictor because it has higher variance or is more reliable. In our overall 3839-participant sample the standard deviations are 9.2 for the spatial scale and 9.3 for the object scale (range of possible values is 15–75 for each scale), and in our 196-participant subsample for Studies 2A and 2B the corresponding standard deviations were 11.5 and 11.1. We found comparable 10-month test-retest reliabilities for the spatial ($r = .82$) and object ($r = .72$) scales, and Blajenkova et al. (2006) found comparable internal reliabilities (Cronbach's $\alpha = .79$ for spatial, .83 for object) and one-week test-retest reliabilities ($r = .95$ for spatial, .81 for object). Although it is possible that the object scale's apparent predictive weakness could be an artifact of the weakness of the other measures we used to validate it (i.e., the snow pictures task and the Greeble-tagging task), this is unlikely, given that the same pattern appears across a wide variety of measures.

Taken together, these findings suggest that the OSIQ spatial scale is superior to the object scale at identifying a distinct cognitive style, which is consistent with there being many fewer individuals in our sample who qualified as spatial than object visualizers, *even though the criteria were symmetrical* (a difference of at least five points in either direction between the two scores).

In addition, individual performance in the maze task was generally better predicted by individual performance on the two cognitive tests (mental rotation and snow pictures) than by OSIQ scores. We suspect this is because the OSIQ scores measure cognitive *preferences,* whereas the mental rotation and snow pictures tests measure cognitive *abilities,* which are more relevant predictors of task performance. This is also why the near-zero correlation between object and spatial scales does not contradict the Law of General Intelligence (Chabris, in press; see also Jensen, 1998), which states that measures of cognitive ability tend to correlate positively given a sufficiently diverse set of measures and sample of participants. Object and spatial visualization cognitive styles are correlated with cognitive abilities, but measures of them are not themselves tests of cognitive ability.[3]

Combined with the results of Blajenkova et al. (2006), our findings validate the distinction between object and spatial visualization as cognitive styles and cognitive abilities, and by extension, support the distinction drawn between object and spatial mental imagery. They also add to the evidence in favor of the OSIQ as a useful tool for measuring preferences for different types of visualization. Future research should address the practical implications of this typology of individual differences for education and other fields, and should explore the possibility that spatial visualization (and the preference for using it in cognition) is more unitary than object visualization, which may be a complex ability with its own underlying structure.

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3. When the four objective measures of cognitive performance in this study are examined together (for the 196 participants in Study 2A, who completed mental rotation, snow pictures, short-form Raven's APM, and the 10-item math test that is part of the VVCSQ), the average correlation among tests is $r = .24$, 5 out of 6 correlations are significant at $p < .05$ or better, and the first principal component accounts for 44% of the variance, consistent with the Law of General Intelligence and with typical data for human cognitive tasks, as reviewed by Chabris (in press).

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Table 1. Sample Items from the VVCSQ and OSIQ.

Sample VVCSQ Items

Jack, Paul, and Brian all have birthdays on January 1st, but Jack is one year older than Paul and Jack is three years younger than Brian. If Brian is 10 years old, how old is Paul?

At each of the two ends of a straight path a man planted a tree and then every 5 feet along the path he planted another tree. The length of the path is 15 feet. How many trees were planted?

Sample OSIQ Items

I was very good in 3-D geometry as a student. [spatial]
Architecture interests me more than painting. [spatial]
I have a photographic memory. [object]
My visual images are in my head all the time; they are just right there. [object]

Note: On the VVCSQ, participants first solved 10 mathematics problems, then described whether they used visual or verbal methods during the solution process. On the OSIQ, participants rated each of 45 statements (15 related to spatial visualization, 15 related to object visualization, and 15 related to verbalization [which were not analyzed in this study]) on a 1–5 scale, with 1 = "totally disagree" through 5 = "totally agree."

Table 2. Results of Study 1: Reliability, Comparisons of Object and Spatial Visualizers, and Comparisons of Males and Females.

Measure [range]	***r***	**Object *M* (*SD*)**	**Spatial *M* (*SD*)**	**O–S *d***	**Male *M* (*SD*)**	**Female *M* (*SD*)**	**M–F *d***
OSIQ Object [15–75]	.72	56.1 (7.2)	41.2 (8.2)	1.53****	49.8 (9.2)	52.4 (9.2)	–0.28****
OSIQ Spatial [15–75]	.82	39.5 (7.4)	53.2 (7.9)	–1.45****	48.2 (8.6)	42.6 (9.0)	0.61****
VVCSQ # correct [0–10]	.41	7.9 (2.2)	9.0 (1.7)	–0.49****	8.4 (2.3)	8.0 (2.3)	0.20****
VVCSQ strategy [0–20]	.28	14.6 (3.9)	13.4 (3.9)	0.31****	12.9	13.2	–0.06
VVIQ [16–80]	—	65.6 (10.3)	56.7 (11.6)	0.79****	61.6 (11.4)	63.5 (11.2)	0.17***
3-D video games [1–3]	.72	1.45 (0.65)	1.71 (0.75)	–0.37****	2.00 (0.74)	1.35 (0.57)	0.93****
Overview video games [1–3]	.67	2.04 (0.70)	2.14 (0.69)	–0.14**	2.31 (0.68)	1.98 (0.67)	0.47****
Representational art [1–3]	.71	2.09 (0.69)	1.72 (0.66)	0.53****	1.82 (0.70)	2.03 (0.69)	–0.30****
Argument and debate [1–3]	.60	2.16 (0.66)	2.16 (0.66)	0.00	2.21 (0.66)	2.13 (0.66)	0.12***
Word puzzles [1–3]	.51	2.25 (0.59)	2.26 (0.62)	–0.02	2.17 (0.61)	2.28 (0.59)	–0.18****
Picture puzzles [1–3]	.41	2.12 (0.58)	2.10 (0.62)	0.03	2.09 (0.59)	2.13 (0.59)	–0.08*
Age	—	26.8 (8.5)	26.9 (8.7)	–0.01	26.7 (8.7)	26.6 (8.1)	0.01

* $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$ (all from two-tailed *t*-test).

Note: Range, reliability (test-retest *r*, $N = 130$), means for object ($N = 1991$) and spatial ($N = 582$) visualizers, and means for males ($N = 1301$) and females ($N = 2538$) are presented for the two OSIQ scales, the two VVCSQ measures, the VVIQ, and the six activity experience questions, and age. *d* values indicate effect sizes (Cohen's *d*) for the comparisons between object and spatial visualizers (O–S) and between males and females (M–F); positive *d* indicates a higher score for object visualizers or males, respectively. Note that only 2495 participants completed the VVIQ (1255 object visualizers and 385 spatial visualizers; 824 males and 1669 females); no participants took the VVIQ twice, so reliability could not be estimated.

Figure 1. Distributions of OSIQ object and spatial scores, and the correlation between them. The 45-degree parallel lines indicate the cutoffs for participants to be classified as object or spatial visualizers; individuals represented by points between these two lines were unclassified.

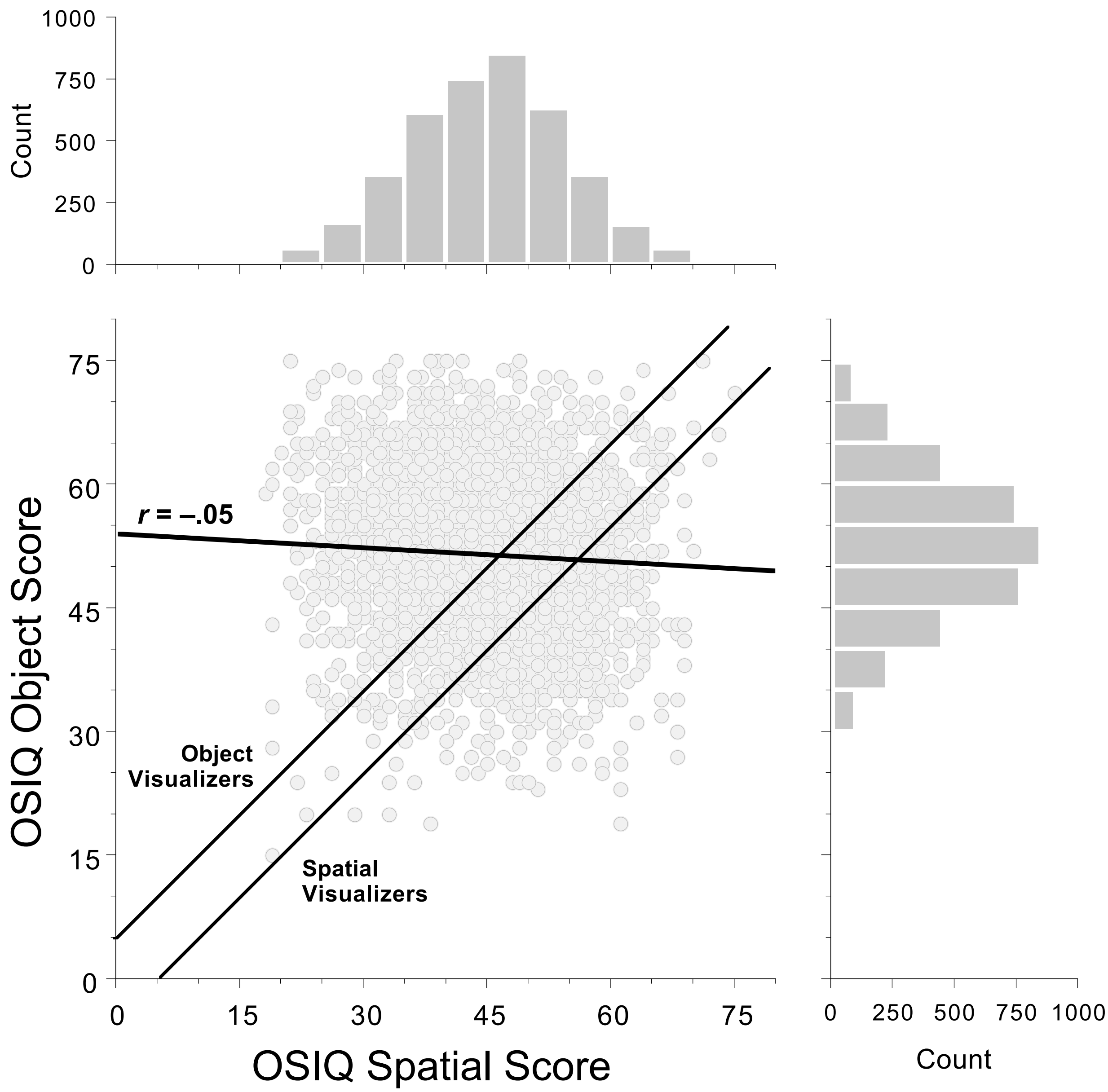

Figure 2. Sex differences in OSIQ object and spatial scores from Study 1. *Note:* Standard error bars are not displayed because they would be smaller than the symbols used to indicate the point estimates (all *SEM* < 0.26).

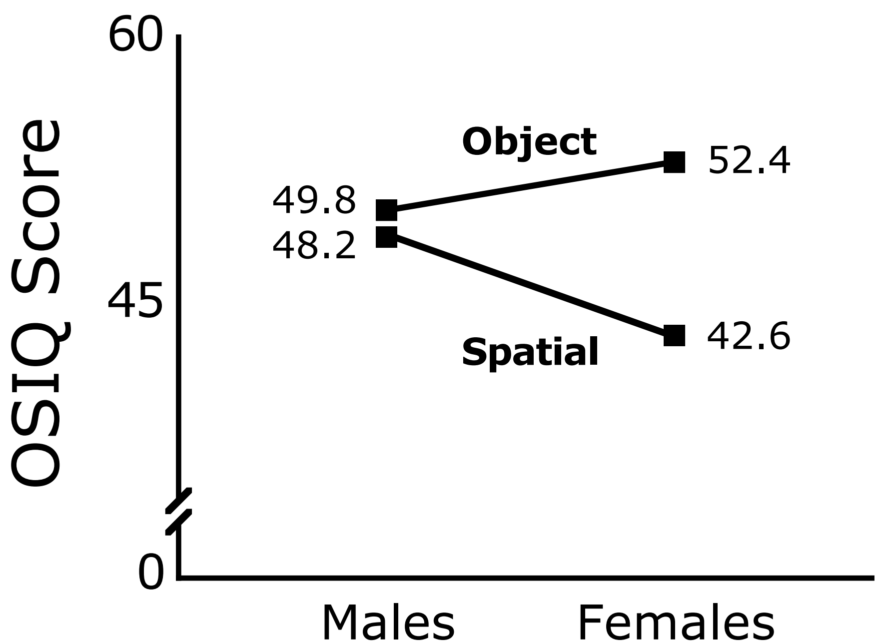

Figure 3. Performance of object and spatial visualizers (*N* = 98 each) in Study 2A on the snow pictures task, a test of object-processing ability, and the mental rotation task, a test of spatial processing ability. *Left:* error rates. *Right:* mean response times. *Note:* Error bars indicate standard errors of the mean.