The New Object-Spatial-Verbal Cognitive Style Model: Theory and Measurement

OLESYA BLAZHENKOVA and MARIA KOZHEVNIKOV*

Department of Psychology, George Mason University, Fairfax, USA

SUMMARY

The current study challenges traditional approaches to Visual–Verbal cognitive style as a unitary bipolar dimension, and instead suggests a new three-dimensional cognitive style model developed on the basis of modern cognitive science theories that distinguish between object imagery, spatial imagery and verbal dimensions. The results of the confirmatory factor analysis demonstrated that the overall fit to the data of the new three-dimensional model of cognitive style was significantly better than that of a traditional model. Furthermore, based on the new theoretical model, we designed and validated a new self-report instrument assessing the individual differences in object imagery, spatial imagery and verbal cognitive styles, the *Object-Spatial Imagery and Verbal Questionnaire* (OSIVQ). Across a series of studies, the OSIVQ demonstrated acceptable internal reliability as well as construct, criterion and ecological validity. The current study supports the validity of an object-spatial-verbal cognitive style dimension and related measures when developed on the basis of modern cognitive science theories. Copyright © 2008 John Wiley & Sons, Ltd.

Cognitive styles refer to psychological dimensions representing consistencies in an individual's manner of cognitive functioning, particularly with respect to acquiring and processing information (Ausburn & Ausburn, 1978; Messick, 1976; Witkin, Moore, Goodenough, & Cox, 1977). One of the most commonly acknowledged cognitive styles, which will be the focus of the present paper, is the Visual–Verbal cognitive style dimension (e.g. Paivio, 1971; Richardson, 1977) that describes consistencies and preferences in processing visual versus verbal information, and classifies individuals as either *visualizers* (also called *imagers*), who rely primarily on imagery when attempting to perform cognitive tasks, or *verbalizers,* who rely primarily on verbal-analytical strategies.

Although most of the previous studies on Visual–Verbal cognitive style were based on a general idea about the existence of two different visual and verbal processing systems, they were neither motivated by any cognitive theory that specifies how information is processed in the brain nor did they attempt to apply stringent theoretical principles in order to assess the dimension accurately. As a consequence, a variety of ways to operationalize the Visual–Verbal cognitive style have been proposed (e.g. as self-reported experiences, learning preferences, problem-solving strategies, preference for verbal vs. visual cues for recall and accuracy or response times on verbal vs. visual aptitude tasks) that have resulted in the development of numerous instruments to assess this dimension, ranging from

*Correspondence to: Maria Kozhevnikov, Department of Psychology, George Mason University, 4400 University Drive, MSN 3F5, Fairfax, VA 22030, USA. E-mail: mkozhevn@gmu.edu

measures of individuals' responses to particular stimuli to cognitive tasks underlying more complex behaviours. Among the multiplicity of the proposed instruments, two distinct approaches to assess Visual–Verbal cognitive styles could be distinguished. The first approach has focused on the development of self-report questionnaires that asked the participants to rate a variety of statements with respect to their preferred use of imagery versus verbal modes of thinking (e.g. '*I often use mental pictures to solve the problem*' or '*I am really fluent in using words*'). Examples of these questionnaires include: *Individual Differences Questionnaire* (IDQ: Paivio, 1971), *Verbalizer–Visualizer Questionnaire* (VVQ: Richardson, 1977) and *Style of Processing* (SOP: Childers, Houston, & Heckler, 1985). The main problems of these questionnaires, identified in the subsequent studies, were their relatively low internal reliability (Antonietti & Giorgetti, 1998; Boswell & Pickett, 1991; Sullivan & Macklin, 1986) and poor predictive validity (e.g. Alesandrini, 1981; Green & Schroeder, 1990; McAvinue & Robertson, 2007). For instance, factor analyses of the IDQ items identified not only imagery and verbal factors, but also a number of other factors (Paivio & Harshman, 1983). Similarly, principal components analysis failed to show that the VVQ items formed a homogenous scale (e.g. Green & Schroeder, 1990; Boswell & Pickett, 1991). Furthermore, although several studies showed a moderate correlation between the verbal subscale of such self-report instruments and performance on verbal ability tests (Green & Schroeder, 1990; Kirby, Moore, & Shofield, 1988; Mayer & Massa, 2003), their visual subscale did not correlate with any visual-spatial aptitude measures (e.g. Alesandrini, 1981; Edwards & Wilkins, 1981; Green & Schroeder, 1990; Parrott, 1986; Mayer & Massa, 2003).

In order to address the problems with the preceding self-report questionnaires, a second approach to measure Visual–Verbal cognitive style has been proposed that has aimed at the development of the objective measures to assess Visual–Verbal cognitive style, such as response time in solving tasks that require either visual or verbal thinking (e.g. the *Verbal-Imagery Subtest of Cognitive Styles Analysis* [CSA; Riding & Cheema, 1991] and the *Verbal-Imagery Cognitive Style Test* [VICS: Peterson, Deary, & Austin, 2005]). In CSA and VICS, for instance, statements that require imagery as well as verbal semantic processing were presented on a computer screen, and the subjects were classified into verbalizers and visualizers based on the ratio of means (in CSA) or ratio of medians (in VICS) between the time to respond to verbal and imagery questions. Another example of the objective measures to assess Visual–Verbal dimension is the *Mathematical Processing Instrument* (MPI: Lean & Clements, 1981; Presmeg, 1986a, 1986b), developed to measure the tendency to use visual versus verbal-analytical strategies when solving mathematical problems. The individuals were positioned on a 'degree of visuality' continuum, with the highest scores corresponding to the more often use of visual solutions, and the lowest scores corresponding to the more often use of verbal-logical strategies.

In contrast to most Visual–Verbal self-report questionnaires, the above objective instruments were based on more specific and constricted measures, and thus, not surprisingly, demonstrated relatively good internal reliability (e.g. Spearman rank-order correlation $r > .72$ for VISC in Peterson, and between rankings $r = .90$ for MPI, Lean & Clements, 1981). However, their construct validity has been questioned. For example, Peterson et al. (2005) reported a high correlation between an individual's response time not only to visual but also to verbal items ($r > .84$), suggesting that response time might reflect an individual speed of processing in general rather then preference for a certain mode of processing. Furthermore, the problems with the predictive validity of the visual scale have not been resolved, that is, no clear relationship between the visual measures of cognitive

style and the performance on visual-spatial tasks has been found (e.g. MPI; Lean & Clements, 1981; CSA; Massa & Mayer, 2005; see also McAvinue & Robertson, 2007 for a review).

Overall, a host of studies has challenged the validity of Visual–Verbal cognitive style. Despite the promising prospective applications (e.g. predicting complex learning behaviour, increasing the efficiency of learning by matching the individual cognitive style to appropriate instructional material), research on Visual–Verbal cognitive style has declined over the past decade due to the reported lack of construct and predictive validity as well as weak internal consistency. As noted in a number of reviews on cognitive styles (e.g. Kogan, Saarni, & Saracho, 1990; Kozhevnikov, 2007; Sternberg & Grigorenko, 1997), one of the main reasons for the preceding problems was that many of the studies on cognitive style were rather descriptive and did not attempt to relate cognitive styles to contemporary cognitive science theories.

The goal of the present work is to revise and further examine the traditional Visual–Verbal cognitive style model in accordance with current cognitive science findings (Table 1 summarizes the current literature regarding the differences between verbal and visual systems). In particular, the present research re-examines two of the main theoretical assumptions underlying the previous studies on Visual–Verbal cognitive style that are not confirmed by the current findings. First, most of the previous research has considered Visual–Verbal cognitive style as a bipolar unitary construct, with the preference to verbal or visual ways of information processing portrayed as two contrasting poles. Based on this assumption, the instruments assessing Visual–Verbal cognitive style have been classifying people as visual or verbal on a single visual–verbal scale using median split criterion (e.g. in IDQ, Paivio, 1971 and VVQ, Richardson, 1977), ratio between the Visual and Verbal scores (Peterson et al., 2005), subtractions of Visual and Verbal scores (Mayer & Massa, 2003), or a 'degree of visuality' continuum with verbal and visual preferences as opposite to each other (MPI, Lean & Clements, 1981). Yet, the assumption about the existence of the bipolar Visual–Verbal dimension is inconsistent with current neuroscience research that visual and verbal systems are relatively anatomically and functionally independent (e.g. Mellet, Bricogne, Crivello, Mazoyer, Denis, & Tzourio-Mazoyer, 2002; Gazzaniga, 2004, Thierry & Price, 2006).

The second common assumption of the previous Visual–Verbal cognitive style research that will be re-examined in the current paper is that imagery presents a unitary and undifferentiated construct, and that a given individual can be characterized as high- or low-imagery in general. Neuropsychological data, however, suggest the existence of two distinct imagery subsystems that encode and process visual information in different ways, that is, an *object imagery system* that processes the visual appearance of objects and scenes in terms of their shape, colour information and texture and a *spatial imagery system* that processes object location, movement, spatial relationships and transformations and other spatial attributes of processing. Although object imagery is related to visual appearances of individual objects, it is not limited to individual objects, but could also refer to imagery of patterns and scenes, characterizing their colour, vividness, shapes or details. Similarly, spatial imagery is not limited to spatial locations or relations between objects in spatial array, but could refer to spatial relation between parts of the object and also, it could refer to the object's movement and to the dynamic spatial transformations of different elements of the object (Cabeza & Nyberg, 2000; Farah, Hammond, Levine, & Calvanio, 1988; Levine, Warach, & Farah, 1985; Mazard, Tzourio-Mazoyer, Crivello, Mazoyer, & Mellet, 2004; Kosslyn, Ganis, & Thompson, 2001).

Table 1. The comparison between verbal and two visual processing systems

Systems	Verbal	Visual	
		Object	Spatial
Brain areas involved in processing (Cabeza & Nyberg, 2000; Gazzaniga, 2004)	Primary Auditory Cortex, Broca's area, Wernicke's area, Supramarginal gyrus, Angular gyrus	The ventral stream runs through V1, V2, V4 and to the inferior temporal lobe	The dorsal stream runs through V1, V2, V3, V5 (also known as MT area) and to the inferior parietal lobe
Functions (Farah et al., 1988; Paivio, 1991)	Representation of verbal information, comprehension and production of spoken and written language	Representation of individual objects and scenes in colour, detail and shape; object recognition	Representation of object locations, motion, spatial relationships, manipulations and transformations
Units and organization (Paivio, 1991; Richardson, 1977)	Discrete linguistic units	Integer visual scenes and discrete objects	
	Symbolic representations systematically organized semantically and grammatically	Pictorial, analogous, representations of objects and scenes	Schematic representations of objects and patterns, and their transformations
Processing (Kozhevnikov et al., 2005; Paivio, 1991)	Sequential	Holistic	Sequential
	Units have to be integrated in order to be comprehended	Units have to be identified and separated in the continuous visual field	
	Phonetically processed before assessing semantic representation	Meaningfully identified before it can be verbally named	Not necessarily identified and verbally named

The distinction between object and spatial imagery has been also found in individual differences in imagery. Recent behavioural and neuroimaging studies (Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov, Kosslyn, & Shephard, 2005; Motes & Kozhevnikov, 2007) have identified two distinct types of individuals, *object visualizers,* who use imagery to construct vivid high-resolution images of individual objects, and *spatial visualizers,* who use imagery to represent and transform spatial relations. While object visualizers excel on such object imagery tasks as recognizing degraded pictures of objects, they showed below average performance on spatial imagery tasks (e.g. three-dimensional mental rotation, imagined paper folding) and vice versa for spatial visualizers who excel on spatial imagery tasks (Kozhevnikov et al., 2005). Furthermore, Blajenkova, Kozhevnikov, and Motes (2006) developed the self-report *Object-Spatial Imagery Questionnaire* (OSIQ) that consisted of two independent scales: an object imagery scale that assesses preferences for representing and processing colourful and pictorial images of

objects and a spatial imagery scale that assesses preferences for representing and processing schematic images, spatial relations among objects and spatial transformations. The OSIQ demonstrated relatively high internal reliability (α Cronbach's $= .83$ for the object scale and .79 for the spatial scale) and clear two factor structure (object and spatial imagery). In contrast to many previous self-report questionnaires that had problems with predictive validity, the OSIQ object imagery scale was significantly correlated with the performance on object imagery tasks, while the spatial imagery scale was significantly correlated with the performance on spatial imagery tasks (see also Chabris et al., 2006; Vannucci, Cioli, Chiorri, Grazi, & Kozhevnikov, 2006). Thus, in contrast to the previous literature that considered Visual–Verbal cognitive style as a bipolar dimension (with visual and verbal poles at the end of the continuum), the main theoretical goal of the current research was to propose and test a new model of cognitive style comprising three relatively independent dimensions: two visual (object and spatial) and one verbal dimensions.

Another goal of the study was to design and validate a new self-report instrument for assessment of these three dimensions, called *Object-Spatial Imagery and Verbal Questionnaire* (OSIVQ), which combines the previously designed object and spatial scales of the OSIQ (Blajenkova et al., 2006) with the development of a new verbal scale. The design of the above self-report measure of object-spatial-verbal cognitive style was motivated by several reasons. First, a self-report cognitive style measure would allow us to assess the important subjective aspects of imagery (e.g. colourfulness and brightness of mental images) and verbal thinking (e.g. awareness of sentence structure) which is impossible to assess by the existing objective measures. Second, in contrast to time-consuming objective measures of cognitive style, which might take up to an hour to assess cognitive style of one subject (see Kozhevnikov et al., 2005), self-report measures are more efficient to use for large-scale testing and in applied settings. Third, although visual-object and visual-spatial scales have been already developed and validated (Blajenkova et al., 2006), no comparable measure existed for the verbal scale. Since most of the previous instruments (e.g. Richardson's VVQ, 1977) focused primarily on assessing verbal expression and fluency, there has been a need to expand the previous verbal assessment to other aspects of verbal cognitive style such as habitual, problem solving, learning, and professional preferences.

The goal of the Study 1 was to design and to examine factor structure, internal reliability and descriptive characteristics of the OSIVQ. The goals of Study 2, were to examine the criterion validity (i.e. association with other related factors) of the OSIVQ, to compare the predictive power of the three-dimensional (object, spatial and verbal) model of cognitive style to that of the traditional two-dimensional (Visual–Verbal) bipolar model, and to further explore the relationships between object, spatial and verbal dimensions. In Studies 3a and 3b, the object, spatial and verbal scales were further ecologically validated by examining the relationship between the OSIVQ scales and real-world activities (beyond the laboratory testing settings) that require object imagery, spatial imagery or verbal abilities.

STUDY 1

The first goal of Study 1 was to develop a new OSIVQ by designing a verbal scale assessing individuals' preference to process information verbally, and integrating it with the two

existing OSIQ Object and Spatial imagery scales. The second goal of Study 1 was to examine the factor structure and internal reliability of the OSIVQ.

Development of the OSIVQ

Fifteen final items were developed to assess verbal cognitive style through a series of studies where the items were formulated and selected based on content validity and internal reliability. First, in a pilot study, conducted by Kozhevnikov at Harvard University, 38 Harvard undergraduates were classified as object visualizers (N = 12), spatial visualizers (N = 13) and verbalizers (N = 13) based on a number of objective measures of verbal, object and spatial imagery ability (see Kozhevnikov et al., 2005 for more details).[1] Then, the participants were interviewed on their preferences to use object, spatial and verbal processing in their every-day life. Based on these interviews, statements for 23 initial items were developed; they included a number of verbal items from the existing visualizer–verbalizer cognitive style questionnaires (VIQ: Richardson, 1977; IDQ: Paivio & Harshman, 1983) as well as new items. These new items extended previous measures of people's preferences for verbal thinking that focused primarily on items assessing verbal expression and fluency (*I have better than average fluency in using words; IDQ*), to include more questions about such aspects of verbal cognitive style as habitual and learning preferences (e.g. *When explaining something, I would rather give verbal explanation than make drawings or sketches*), professional preferences (e.g. *My verbal abilities make a career in language arts relatively easy for me*) and self-estimates of one's verbal abilities (e.g. *My verbal skills are excellent*). The verbal statements in the new verbal scale were formulated in a format similar to visual-object and spatial-object items included in the OSIQ (that is, it consisted of a similar type of questions targeted to assess a variety of aspects of cognitive style) in order to design a full self-report instrument assessing all the three dimensions of the cognitive style in a comparable way.

Second, to provide some evidence as to the content validity of the verbal scale, three experts reviewed the verbal items with regard to their relevance to verbal cognitive style. As a result, after excluding all of the controversial items identified during the interview session in the study, and after excluding all of the items on which there was a disagreement between the judges, 19 items were retained. Finally, these items were administered to a sample of 166 undergraduates at Rutgers University-Newark along with object and spatial items of the OSIQ. The results of principal factor analysis revealed a verbal factor distinct from object and spatial factors. Based on these results, the 15 items out of 19 with the highest loadings (from .411 to .607) on the verbal factor were kept.

The object and spatial scales of the OSIVQ included 15 object and 15 spatial items of the OSIQ questionnaire, which were designed in our previous study to assess different aspects of object versus spatial imagery (see more detail in Blajenkova et al., 2006). Specifically, the items were constructed to assess various imagery processes such as image generation, maintenance, inspection and transformation, in accordance with Kosslyn' theory of

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[1]In Harvard pilot study, the subjects were classified as visualizers and verbalizers based on the modified versions of Mathematical Processing Instrument, used in mathematics education literature (Lean & Clements, 1981; Presmeg, 1986a, 1986b) for dividing people on visualizers and verbalizers. The visualizers group were further divided into object and spatial visualizers, using a number of object imagery (e.g. degraded shape recognition, self-report questionnaire on the vividness of mental images) and spatial imagery tests (e.g. mental rotation, paper folding). Subjects who scored high on spatial tests (scores in the top 33.3% of the distribution) and low on object imagery tests (scores in the bottom 33.3% of the distribution) were characterized as spatial visualizers and vice versa for object visualizers.

imagery (Kosslyn, 1994; Kosslyn, Thompson, & Ganis, 2006). Thus, the items from object and spatial scales addressed qualitative characteristics (e.g. vividness, colourfulness and detail for object scale, or abstractness and sketchiness for spatial scale) of images (e.g. object imagery items like *My mental pictures are very detailed precise representations of the real things,* and spatial imagery items like *My images are more like schematic representations of things and events*); image maintenance and transformation processes (e.g. object imagery items like *I can close my eyes and easily picture a scene that I have experienced,* and spatial imagery items like *I can easily rotate three-dimensional geometric figures*).

The fifteen final Verbal items were intermixed with the fifteen OSIQ Object and 15 OSIQ Spatial items to construct a new three-scale OSIVQ instrument (the items were presented in random fixed order, see Table 2).

In the current study, in order to examine the descriptive characteristics, factor structure and internal reliability of the OSIVQ, the questionnaire was administered to an independent sample of the participants.

Method

Six hundred and twenty-five participants (374 females, M age $= 24$) were recruited from student participant pools at Rutgers University-Newark (NJ) and George Mason University (VA) for credit reimbursement, and other participants were students from New Jersey Institute of Technology (NJ), New York Institute of Fashion and Design (NY) and Stevens University (NJ) as well as professionals from various fields, who were given monetary compensations for their participation.

Participants were tested individually and in groups of up to 30. They were administered the OSIVQ items with the following instructions: 'This is a questionnaire about the way you think. Please, read the following statements and rate each of them on a 5-point scale. Circle '5' to indicate that you absolutely agree that the statement describes you, and circle '1' to indicate that you totally disagree with the statement. Circle '3' if you not sure, but try to make a choice. It is very important that you answer all the items in the questionnaire'. There was no time limit for the completion of the questionnaire.

Results and discussion

For each participant, the 15 item ratings from each factor were averaged to create object, spatial and verbal scale scores ($M = 3.63$, SD $= 0.62$ for the object scale, $M = 2.83$, SD $= 0.66$ for the spatial scale, and $M = 2.99$, SD $= .57$ for the verbal scale). The one-sample Kolmogorov–Smirnov test of goodness-of-fit provided no evidence against the null hypothesis that the sample has been drawn from a normal population for spatial ($D = .040$; $p = .277$) and verbal scales ($D = .039$; $p = .297$). However, object scale was not normally distributed ($D = .060$; $p = .021$); the distribution of object scores appeared to be negatively skewed (Skewness $= -.392$; SE $= .098$). Figure 1 represents the correspondence of raw OSIVQ scores to percentiles to make it easier to interpret and compare the scores on the three scales. As seen in the figure, the participants tended to rate themselves higher on Object imagery than on Spatial imagery or Verbal dimensions. This trend is consistent with the findings of Blajenkova et al. (2006) and Chabris et al. (2006) that people rate themselves higher on the object scale than on either spatial or verbal scales. Figure 1

Table 2. Principal component loadings, after Varimax rotation, for the OSIVQ items

	OSIQ items[a]	Object Factor 1	Spatial Factor 2	Verbal Factor 3
1	I was very good in 3D geometry as a student	.05	**.67**	−.01
2	I have difficulty expressing myself in writing	.16	−.17	**.55**
3	If I were asked to choose between engineering professions and visual arts, I would prefer engineering	−.39	**.45**	−.06
4	My verbal abilities would make a career in language arts relatively easy for me	.04	−.39	**.45**
5	Architecture interests me more than painting	−.18	**.56**	−.02
6	My images are very colourful and bright	**.55**	.12	.05
7	I prefer schematic diagrams and sketches when reading a textbook instead of colourful and pictorial illustrations	−.27	**.48**	.010
8	I tell jokes and stories better than most people	.04	.09	**.42**
9	Essay writing is difficult for me and I do not enjoy doing it at all	.07	−.15	**.53**
10	My images are more like schematic representations of things and events rather than like detailed pictures	−.41	**.13**	.07
11	When reading fiction, I usually form a clear and detailed mental picture of a scene or room that has been described	**.54**	.09	.05
12	If I were asked to choose among engineering professions, or visual arts, I would choose visual arts	**.38**	−.49	.14
13	I have a photographic memory	**.37**	.11	.28
14	I can easily imagine and mentally rotate three-dimensional geometric figures	.18	**.70**	.01
15	I enjoy pictures with bright colours and unusual shapes like the ones in modern art	**.21**	−.15	.03
16	My verbal skills are excellent	.15	−.08	**.66**
17	When thinking about an abstract concept (or building), I imagine an abstract schematic building in my mind or its blueprint rather than a specific concrete building	.00	**.40**	.01
18	When entering a familiar store to get a specific item, I can easily picture the exact location of the target item, the shelf it stands on, how it is arranged and the surrounding articles	**.40**	.21	.21
19	Putting together furniture kits (e.g. a TV stand or a chair) is much easier for me when I have detailed verbal instructions than when I only have a diagram or picture	−.12	−.20	**.19**
20	My images are very vivid and photographic	**.65**	.14	.24
21	When explaining something, I would rather give verbal explanations than make drawings or sketches	−.19	−.38	**.46**
22	If someone were to give me two-digit numbers to add (e.g. 43 and 32) I would simply do the adding without visualizing the numbers	−.15	.28	**.12**
23	My mental images of different objects very much resemble the size, shape and colour of actual objects that I have seen	**.43**	.23	.10
24	I usually do not try to visualize or sketch diagrams when reading a textbook	−.39	.00	**.24**
25	I normally do not experience many spontaneous vivid images; I use my mental imagery mostly when attempting to solve some problems like the ones in mathematics	−.49	**.19**	.11
26	When I imagine the face of a friend, I have a perfectly clear and bright image	**.45**	.03	.16

(*Continues*)

Table 2. (Continued)

	OSIQ items[a]	Object Factor 1	Spatial Factor 2	Verbal Factor 3
27	I have excellent abilities in technical graphics	.12	**.73**	−.01
28	When remembering a scene, I use verbal descriptions rather than mental pictures	−.28	−.17	**.39**
29	I can easily remember a great deal of visual details that someone else might never notice. For example, I would just automatically take some things in, like what colour is a shirt someone wears or what colour are his/her shoes	**.56**	−.04	.10
30	I can easily sketch a blueprint for a building I am familiar with	.16	**.60**	−.06
31	In school, I had no problems with geometry	−.24	**.44**	−.02
32	I am good in playing spatial games involving constructing from blocks and paper (e.g. Lego, Tetris, Origami)	.07	**.35**	−.04
33	Sometimes my images are so vivid and persistent that it is difficult to ignore them	**.51**	.22	.05
34	I can close my eyes and easily picture a scene that I have experienced	**.56**	.13	.10
35	I have better than average fluency in using words	.16	.05	**.66**
36	I would rather have a verbal description of an object or person than a picture	−.11	.00	**.38**
37	I am always aware of sentence structure	.09	.13	**.44**
38	My images are more schematic than colourful and pictorial	−.46	**.26**	.07
39	I enjoy being able to rephrase my thoughts in many ways for variety's sake in both writing and speaking	.22	−.06	**.58**
40	I remember everything visually. I can recount what people wore to a dinner and I can talk about the way they sat and the way they looked probably in more detail than I could discuss what they said	**.50**	.01	.05
41	I sometimes have a problem expressing exactly what I want to say	.04	−.12	**.45**
42	I find it difficult to imagine how a three-dimensional geometric figure would exactly look like when rotated	.10	**.46**	−.07
43	My visual images are in my head all the time. They are just right there	**.53**	.21	−.01
44	My graphic abilities would make a career in architecture relatively easy for me	.15	**.70**	−.15
45	When I hear a radio announcer or a DJ I've never actually seen, I usually find myself picturing what he or she might look like	**.46**	−.12	.02

Note: Loadings in bold within the Object Factor 1 column identify items that were designed to measure object imagery. Loadings in bold within the Spatial Factor 2 column identify items that were designed to measure spatial imagery. Loadings in bold within the Verbal Factor 3 column identify items that were designed to measure verbal preferences and abilities.
[a]The OSIVQ questionnaire is copyrighted by Rutgers University. All rights reserved. No part of this questionnaire may be reproduced without prior permission of Rutgers University. Copies of the questionnaire can be obtained from MM Virtual Design (www.mmvirtualdesign.com).

also presents the suggested cut-offs for interpretation of individual scores as high- or low-object, spatial and verbal.[2]

[2]We recommend the 16% high and low cut-offs based on 1 SD criterion, since it is the standard estimate of the average deviation from the expected value, and it includes the majority of the distribution scores (68% of all scores). The slope of the destitution changes at the points of ±1 SD, and these points segregate scores, below and above 1 SD.
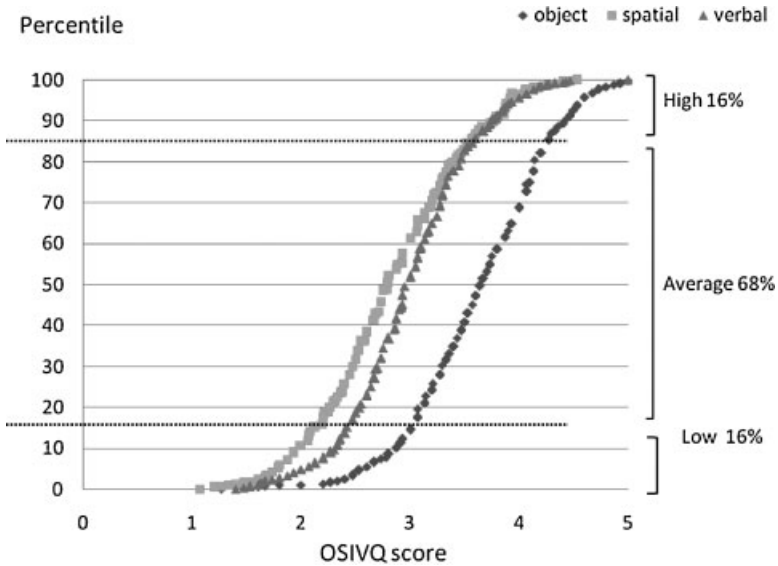
Figure 1. The correspondence of raw OSIVQ scores to percentiles. The distribution of the raw scores on the three scales of OSIVQ in terms of percentiles. For example, raw score of 3 on the object scale means that 10% of participants scored below, but the same raw score of 3 on the spatial scale is higher since it means that 50% of participants scored below

Internal reliabilities
For the verbal scale, Cronbach's $\alpha = .74$, for the object scale, $\alpha = .83$ and for the spatial scale, $\alpha = .79$, all three are below McKelvie's (1994) recommended coefficient of .85 but above other recommended minimum coefficients (ranging from .60 to .85) as reviewed by McKelvie.

Principal component analysis
The data were analysed by using principal components analysis with Varimax rotation. One spatial and three verbal items were negatively formulated and therefore reversed for the analysis.

   The initial Principal Components analysis revealed 18 factors with eigenvalues above 1. Only three factors, however, had eigenvalues markedly higher (5.76, 5.54 and 3.08) than the others (ranging from 1.06 to 1.85), and these first three factors explained 31.95% of the variance (12.80%, 12.31% and 6.84%). None of the other factors met the recommendations for component saturation (see Guadagnoli & Velicer, 1988); the highest loading was .44, and most of the items very weakly loaded on the remaining factors, and therefore were not considered further. Based on the results from the initial Principal Components analysis, a second Principal Components analysis with Varimax rotation was performed. The 45 OSIVQ items and their loadings on the object, spatial imagery and verbal factors are presented in Table 2. The first factor was identified as *object imagery factor*, since all of the items designed to assess object imagery experiences were positively loaded on this factor, whereas most of the items designed to assess spatial imagery or verbal preferences either did not load or loaded negatively. The second factor was identified as *spatial imagery factor*, since all of the items designed to assess spatial imagery preferences loaded positively on the second factor, whereas most of other items did not load or loaded negatively on this factor. Finally, the third factor was identified as *verbal factor*, since all of

the items designed to assess verbal preferences loaded positively on the third factor, whereas most of other items were not loaded or loaded negatively on this factor.

Gender differences

Previous studies on gender differences in spatial ability reported that males perform better than females on spatial tasks (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995) as well as they reported higher spatial imagery ratings (Blajenkova et al., 2006). In opposite, females tend to report higher object imagery and imagery vividness ratings (Blajenkova et al., 2006; Richardson, 1995; McKelvie, 1995). The gender differences in verbal ability indicated a female advantage (reviewed in Halpern, 2000; Hyde & Linn, 1988), however, according to Hyde & Linn's meta-analysis, this difference appears to be negligible.

We examined the effect of gender on object-spatial-verbal preferences for information processing, using repeated measures ANOVA, with gender as a between-subject variable, and three OSIVQ scales as within-subjects variables. The repeated measures ANOVA demonstrated a significant but small effect of gender, $F(1, 622) = 6.505$, $p = .011$, $\eta^2 = .010$, the significant and moderate difference between three scales of OSIVQ, $F(2, 1244) = 243.977$, $p < .001$, $\eta^2 = .282$, and the significant Gender X OSIVQ interaction, $F(2, 1244) = 61.057$, $p < .001$, with $\eta^2 = .089$ representing a small effect. Males were higher than females on OSIVQ spatial scores, $F(1, 623) = 105.57$, $p < .001$, M males $= 3.13$, SD $= 0.59$, M females $= 2.62$, SD $= 0.61$, but females had higher OSIVQ object imagery scores than males, $F(1, 623) = 23.118$; $p < .001$, M females $= 3.72$, SD $= 0.57$, M males $= 3.48$, SD $= 0.66$, and we found no significant differences on OSIVQ verbal scores. Thus, consistent with previous studies, the gender differences were found only on imagery dimensions. Although our results showed that females tend to report themselves as object visualizers and males as spatial visualizers, the differences between spatial and object visualizers, however, cannot be reduced to gender differences (see also Blajenkova et al., 2006; Kozhevnikov et al., 2005). For instance, 33% of all the females from Study 1 reported above average spatial imagery preferences and abilities, while 40% of males reported above average object imagery preferences.

In conclusion, in Study 1 we developed the new OSIVQ self-report instrument which integrated a new verbal scale with two imagery, object and spatial, scales. One of the important findings of Study 1 is that the distribution of self-assessments on object, spatial and verbal dimensions may differ, that is, people might rate themselves higher on one scale than on the others. This finding questions the previous scoring procedures, which inferred the dominant cognitive style by subtracting or creating ratios of raw visual and verbal scores before normalizing them. The second important finding of Study 1 is that the OSIVQ demonstrated acceptable internal reliability for all three scales. Unlike many previous self-report cognitive style instruments which have been criticized for unclear factor structure (Boswell & Pickett, 1991; Edwards & Wilkins, 1981; Kirby et al., 1988), in the current study, principal components analyses revealed three distinct major factors (object, spatial and verbal). These findings challenge the idea of a single bipolar dimension of Visual–Verbal cognitive style and support the existence of its three different dimensions.

STUDY 2

The first goal of Study 2 was to assess the criterion validity (predictive and discriminant) of the OSIVQ verbal, object and spatial scales as well as to examine its test–retest reliability.

The second goal of Study 2 was to compare the predictive power of the three-dimensional model of cognitive style to that of the traditional Visual–Verbal bipolar model and further explore the relationships between object, spatial and verbal dimensions.

Method

Participants
One hundred and twenty-eight students (93 females, *M* age = 24) were recruited from the student participant pool at Rutgers University-Newark, and from George Mason University for credit reimbursement.

Procedure
Participants were tested in groups of 6–30. They were administered a background questionnaire that included questions about demographics and their self-reported SAT verbal scores and the following paper-and-pencil assessments: the OSIVQ, two spatial imagery tests (Paper folding test: Ekstrom, French, & Harsman, 1976 and mental rotation test: Vandenberg & Kuse, 1978), an object imagery assessment (vividness of Visual Imagery Questionnaire: Marks, 1973), and two verbal tests (advanced vocabulary test: Ekstrom et al., 1976 and the verbal ability arranging words test: Ekstrom et al., 1976) described below. The order of tests was randomized.

Mental rotation test (MRT). MRT measures mental rotation transformation ability (Vandenberg & Kuse, 1978). The test consisted of 10 items. Participants compared two-dimensional line drawings of three-dimensional geometric figures composed of cubes. Each test-item consisted of a criterion figure and four comparison figures. Two of the comparison figures were rotated versions of the criterion figure, and the other two comparison figures were rotated mirror images of the criterion figure. Participants were to indicate which two of the four figures were rotated versions of the criterion figure, and they had 3 minutes to complete the test. Mental rotation scores were calculated as the number of items in which both rotated images of the criterion figure were correctly identified. Internal reliability for the MRT was K-R 20 = .88 (Wilson et al., 1975).

Paper folding test (PFT). According to Ekstrom et al. (1976), the PFT measures spatial visualization ability, which is the ability to apprehend, encode and mentally manipulate abstract spatial forms. The PFT consisted of 10 items. Each item consisted of successive drawings of two or threefolds made to a square sheet of paper and a final drawing showing the folded paper with a hole punched through it. The participants were to select from among five drawings the one depicting how the paper would look when fully opened. They had 3 minutes to complete the test, and the scores were calculated by the number of correct answers minus the number of incorrect answers divided by four. Reliability estimates in a normal sample for this task ranged from .75 to .84 (Ekstrom et al., 1976).

Vividness of Visual Imagery Questionnaire (VVIQ). The VVIQ (Marks, 1973) is a frequently used self-report measure of the vividness of visual mental images. The VVIQ consisted of 16 items in which the participants rated the vividness of mental images they were asked to create (e.g. *The sun is rising above the horizon into a hazy sky; and a strong wind blows on the trees and on the lake, causing waves*). VVIQ scores were created by summing the 16 ratings, and for the VVIQ, Cronbach's $\alpha \approx .88$ (see McKelvie, 1995).

Advanced vocabulary test (AVT). The AVT consisted of 18 items in which participants were to choose which word among five had the same meaning or nearly the same meaning as a target word. The AVT measures 'availability and flexibility in the use of multiple meanings of words' (Ekstrom et al., 1976). The AVT reliability reported by Ekstrom et al. (1976) is .83.

Arranging words (AW). The AW test (Ekstrom et al., 1976) requires the ability to formulate thoughts in a verbal format, and to produce new sentences according to certain rules. In this task, participants were asked to write as many sentences as they could by using four specified words (e.g. for the words 'take', 'few', 'land' and 'little', the appropriate sentences could be 'a few little boats take supplies to land' or 'few crops take little land'). All four words had to be used in each sentence in the same form as given, and sentences must differ from one another by more than merely one or two changed words. Participants had 3 minutes to complete the test. To assess the fluency of speech production, the scores were computed as the total number of the written words. The AW reliability reported by Ekstrom et al. (1976) is .68.

Results

The participants' OSIVQ object, spatial and verbal scale scores were created by averaging their ratings on object, spatial and verbal items, respectively, ($M = 3.65$, SD $= 0.62$ for the object scale, $M = 2.62$, SD $= 0.62$ for the spatial scale and $M = 3.07$, SD $= 0.53$ for the verbal scale).

Criterion validity of the OSIVQ

The correlations among the measures of verbal, spatial and object ability are presented in Table 3. The OSIVQ verbal scale scores were positively correlated with verbal measures: the AW scores ($p = .02$) and the SAT verbal scores ($p = .05$). The OSIVQ spatial scores were positively correlated with measures of spatial imagery: PFT ($p < .001$) and MRT ($p < .001$). Finally, the OSIVQ object scores were positively correlated with the VVIQ, an object imagery measure ($p < .001$). Thus, all three scales of the OSIVQ demonstrate acceptable predictive validity where the correlation coefficients were within McKelvie's

Table 3. The Pearson product-moment correlations among the OSIVQ spatial, object and verbal scores and the criterion measures

Measure		1	2	3	4	5	6	7	8	9
1	OSIVQ object	—	−.03	.12	.41**	−.27*	−.18*	−.04	−.02	−.12
2	OSIVQ spatial		—	−.18*	−.02	.47**	.31**	.07	−.05	−.12
3	OSIVQ verbal			—	.04	−.27*	−.10	.17	.20*	.10
4	VVIQ				—	−.12	−.03	−.01	.01	−.12
5	PFT					—	.55**	−.07	−.06	.06
6	MRT						—	−.01	−.10	.05
7	SAT verbal							—	.17	.27*
8	AW								—	.09
9	AV									—

$^{**}p < .01.$
$^{*}p < .05.$

(1994) very good ($r \geq .40$), acceptable ($.25 \leq r \leq .39$) and marginal ($.10 \leq r \leq .24$) convergent validity coefficient ranges.

The partial correlation analyses among the measures of verbal, spatial and object ability controlling for gender demonstrated that significant correlations between the scales and the corresponding criterion measures remain significant also after gender effect was partialled out. The OSIVQ verbal scale scores were positively correlated with the AW scores ($p = .025$) and the SAT verbal scores ($p = .05$). The OSIVQ spatial scores were positively correlated PFT ($p < .001$) and MRT ($p = .043$). Finally, the OSIVQ object scores were positively correlated with the VVIQ ($p < .001$). Thus, consistently with previous studies (e.g. Blajenkova et al., 2006; Kozhevnikov et al., 2005), the self-report cognitive style preferences cannot be reduced to gender differences.

As for the discriminant validity of the three scales, although none of the OSIVQ scales correlated positively with any criterion task corresponding to the other scales (all the positive correlation coefficients were within McKelvie's inconsequential $r \leq .15$ and acceptable $.16 \leq r \leq .25$ divergent validity range $r < .15$), there were several significant negative correlations. In particular, there were significant negative correlations between the OSIVQ object scale and both spatial imagery measures: PFT ($p = .001$) and MRT ($p = .001$); between the OSIVQ verbal scale and PFT ($p < .01$), as well as between the OSIVQ spatial scale and SAT verbal ($p < .001$). These negative correlations suggest that there might be some interference between spatial and object information processing as well as between spatial and verbal information processing.

Confirmatory factor analysis

According to the traditional model of Visual–Verbal style, Verbal and Visual styles constitute two opposite dimensions, whereas according to our new revised model of cognitive style, there should be three separate dimensions (object, spatial and verbal). In this section, we will test both models against each other using confirmatory factor analysis.

The traditional two-factor model of Visual–Verbal cognitive styles assumes all visual measures (OSIVQ spatial, OSIVQ object, PFT, MRT and VVIQ) to load on the visual factor, and all verbal measures (OSIVQ verbal, AV, AW and verbal SAT) to load on the verbal factor. Since verbal and visual dimensions in such a model are considered to be bipolar, the model also assumes a significant negative correlation between visual and verbal factors. Figure 2 shows the results of the estimated two-factor model, and the values of fit are reported in Table 4. As seen in Figure 2, verbal measures according to the model are in fact loaded on the verbal factor and spatial imagery measures loaded on the visual factor, and the correlation between these two factors are negative ($p = -.31$). However, the object imagery assessments (OSIVQ-object and VVIQ) loaded negatively on the visual factor. The chi-square for the two-factor model is significant [$\chi^2 (26) = 49.322, p = .004$] suggesting that the model is significantly deviated from the data. Moreover, the values of CFI (.813) and RMRSEA (.084) indicate that this model does not have a good fit, and therefore does not describe the data.

The three-factor model, based on the new theoretical approach that distinguishes between two types of imagery, assumes that all spatial imagery measures (OSIVQ-spatial, PFT and MRT) load on one factor, all object imagery measures (OSIVQ-object and VVIQ) load on a second factor and all verbal measures (OSIVQ-verbal, AW, AV and SAT verbal) load on a third factor. Figure 3 shows the estimated three-factor model, and values of fit are reported in Table 3. The indices suggest that the three-factor model fits the data well. The
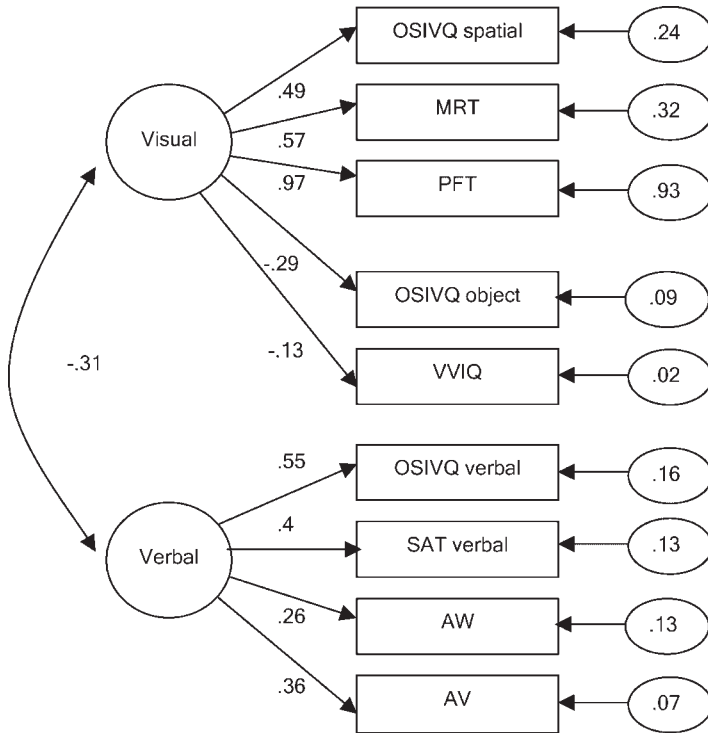
Figure 2. The estimated two-factor model of cognitive style. The numbers above the arrows indicate the standardized factor loadings, the numbers above the shorter arrows on the right indicate the error terms

Table 4. The values of fit for the two-factor and three-factor models

Model	χ^2	df	*p*-value	χ^2/df	χ^2_{diff}	df$_{diff}$	CFI	PCFI	PNFI	RMSEA
Three-factor	27.61	24.00	.28	1.15	—	—	.97	.65	.55	.03
Two-factor	49.32	26.00	.00	1.90	21.72	2.00	.81	.59	.50	.08

Note: CFI, comparative fit index; PNFI, parsimony normed fit index; PCFI, parsimony comparative fit index; RMSEA, root mean square error of approximation.

chi-square for this model was not significant ($\chi^2(24) = 27.607$, $p = .27$). Moreover, the values of CFI (.97) are above the criterion of .90 for a good fit, RMRSEA (.034) which is below .05 that indicate a close fit of the model in relation to the degrees of freedom, which indicate that this model does explains the data. Interestingly, consistent with the correlational patterns reported in the previous section, the results of the confirmatory factor analysis indicated a negative correlation between spatial and object constructs ($r = -.30$) as well as between spatial and verbal constructs ($r = -.23$), however, they indicated no relation between object and verbal scales ($r = -.02$).

Furthermore, the traditional two-factor model was compared with the three-factor model. The chi-square difference comparing the fit of two models indicates that the overall
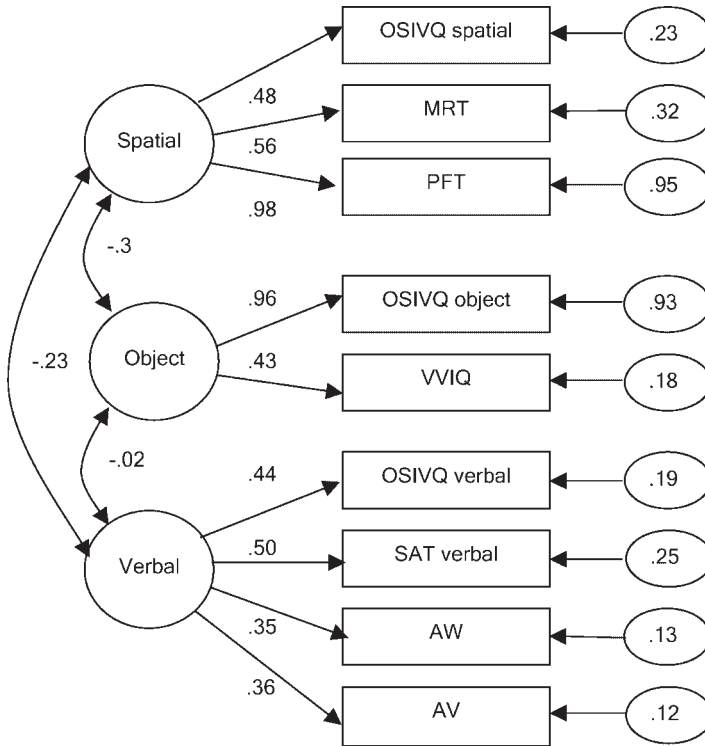
Figure 3. The estimated three-factor model of cognitive style. The numbers above the arrows indicate the standardized factor loadings, the numbers above the shorter arrows on the right indicate the error terms

fit of the three-factor model is significantly greater than that of the two-factor model (χ^2 (2) = 21.72, $p < .001$).

Test–retest reliability

To assess test–retest reliability, the OSIVQ was administered to the subsample of the participants who completed the measures for Study 2 ($N = 41$), on a second occasion, separated from the first occasion by 3 weeks. The scores were computed by averaging across the 15 items for each scale, and correlations between the testing sessions were computed. For the verbal scale, $r = .73, p < .001$, for the object scale, $r = .75, p < .001$ and for the spatial scale, $r = .84, p < .001$. The object and spatial correlation coefficients were above McKelvie's (1994) recommended minimum for delayed test–retest reliability coefficients ($r = .75$), but the verbal correlation coefficient was slightly below McKelvie's recommended minimum.

Thus, the data from Study 2 provide further validation of the OSIVQ. First, the OSIVQ demonstrated acceptable test–retest reliability. Second, unlike many previous self-report questionnaires, all three scales of the OSIVQ demonstrated acceptable criterion validity: the participant's ratings on the object, spatial verbal correlated positively with only the corresponding criterion tasks. Third, the traditional two-factor model that describes Visual–Verbal cognitive style as a bipolar dimension was compared to the three-factor model that comprises three independent dimensions, verbal, object and spatial. The results

of the confirmatory factor analysis indicated that the overall fit of the three-factor model was significantly greater than that of the two-factor model and that only the three-factor model can provide a fit to the empirical data. Finally, the negative correlations found between spatial and object factors as well as between spatial and verbal factors obtained from the confirmatory factor analysis suggest that spatial imagery style might not be entirely independent, but exhibits some degree of interference with both object and verbal cognitive styles. Overall, the findings of Study 2 provide support for the three-dimensional model of cognitive style and help to explain inconsistencies in previous findings regarding the relations between visual and verbal measures as well as help to explain problems with establishing the predictive validity of previous cognitive style instruments.

STUDIES 3A AND 3B

Studies 3a and 3b were designed to examine the ecological validity of the OSIVQ by examining the relationship between the OSIVQ scales and *peoples preferences regarding their real-world* activities (beyond the laboratory testing settings) that require object imagery, spatial imagery or verbal abilities. Spatial imagery skills, such as spatial visualization of abstract schematic representations and spatial transformation of complex three-dimensional forms are important in physics, chemistry, engineering and other fields of natural sciences (e.g. Casey et al., 1990; Ferguson, 1977; Kozhevnikov et al., 2002; Pellegrino, Mumaw, & Shute, 1985). On the other hand, such object imagery skills as the construction of clear and bright visual images, and depicting real objects and scenes in detail and colour, have been shown to be crucial for creative processes in visual arts (e.g. Lindauer, 1983; Roe, 1975; Rosenberg, 1987). Indeed, our previous studies (e.g. Blajenkova et al., 2006; Kozhevnikov et al., 2005) demonstrated that visual artists scored higher on object imagery tasks and rated themselves as having higher object imagery than scientists, whereas scientists scored higher on spatial imagery tasks and rated themselves as having higher object imagery than visual artists. The work of humanities professionals, in contrast, requires more extensive reading, comprehension and production of verbal materials rather than the use of either object or spatial imagery. Indeed, the examination of GRE scores for different majors indicates that Philosophy majors had the highest Verbal scores and Analytical writing scores of students in all majors (Graduate Record Examinations Board by Educational Testing Service, 2006–2007).

In Study 3a, we examined the correlations between each of the OSIVQ scales and the number of college-level courses taken in visual arts and physics and writing. In Study 3b, the OSIVQ was administered to visual arts, science and humanities professionals. We expected that both professional membership and educational choices are related to the participants' cognitive style.

Method

Participants
For Study 3a, we recruited 186 participants (130 females) enrolled in undergraduate and graduate courses at Rutgers University, New Jersey Institute of Technology, George Mason University, New York Institute of Fashion and Design and Stevens University.

In Study 3b, based on the convenience sample, we recruited 192 professionals with majors in visual arts, sciences or humanities, and with at least 2 years working experience

Table 5. The Pearson product-moment correlations among the OSIVQ spatial, object and verbal scores and the number of classes taken in visual art, physics and writing

Measure		1	2	3	4	5	6
1	OSIVQ object	—	−.08	.05	.22*	−.12	−.07
2	OSIVQ spatial		—	−.19**	−.09	.34**	−.23**
3	OSIVQ verbal			—	−.11	−.19*	.28**
4	Visual art classes				—	−.01	.34*
5	Physics classes					—	.80
6	Writing classes						—

**p < .01.
*p < .05.

in their respective professions. The group of visual artists consisted of 79 (44 females) designers and visual artists. The group of scientists consisted of 64 (18 females) computer scientists, physicists, biologists, engineers, biochemists, chemists and mathematicians. Finally, the group of humanities professionals consisted of 49 (14 females) historians, philosophers, English teachers, literature professors and journalists.

Procedure

All of the participants in Studies 3a and 3b were administered the OSIVQ. The participants from Study 3a were asked about the number of classes taken in visual arts, physics or writing.

Results and discussion

Study 3a
We examined the correlations between the OSIVQ scales and the number of classes in visual art, physics or writing that our participants took in college (see Table 5). The analyses revealed that the OSIVQ verbal scores were positively correlated with the number of writing classes ($p < .001$), but negatively correlated with the number of physics classes ($p = .008$). The OSIVQ spatial scores were positively correlated with the number of physics classes ($p < .001$), but negatively correlated with the amount of writing classes ($p = .002$). Finally, the OSIVQ object scores were positively correlated with the amount of visual art classes ($p = .003$). Furthermore, the number of writing classes taken in college correlated positively with the amount of visual art classes ($p < .001$).

The above results support the ecological validity of the three OSIVQ scales, and suggest that cognitive styles might be an important predictor in course choices, and thus, could be also helpful for vocational guidance. In addition, the above results support the findings from Study 2 that spatial cognitive style might not be entirely independent, but exhibit some degree of interference with both object and verbal cognitive styles.

Study 3b
Figure 4 illustrates the distribution of the raw OSVIQ scores on the three scales for visual artists, scientists and humanities professionals. As can be seen from the figure, three groups of the professionals form three separate clusters, and in fact, all three professional groups differ significantly on their OSIVQ scores. A MANOVA (Pillai's Trace) with professional
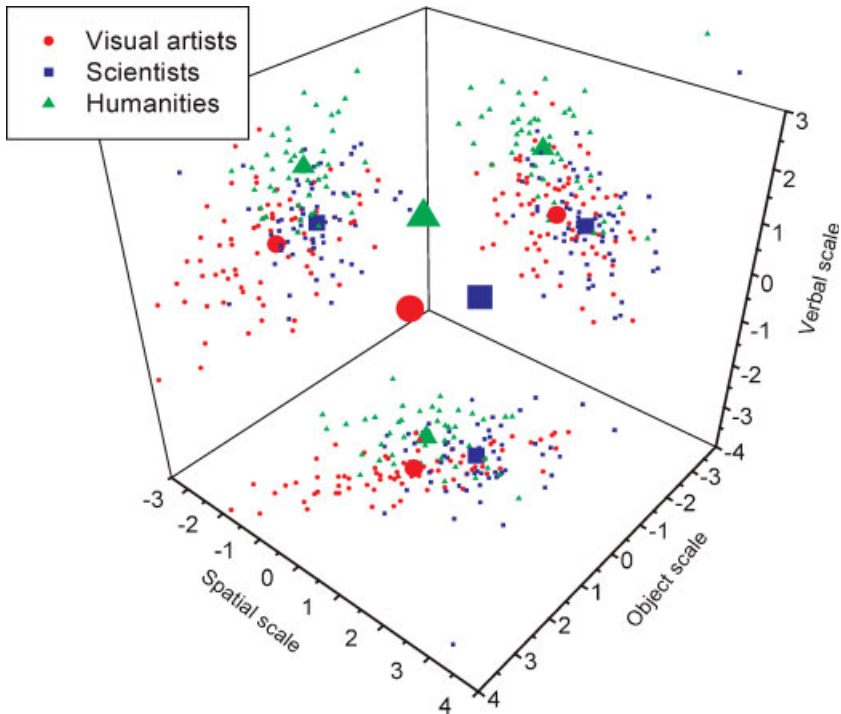
Figure 4. The OSVIQ scores of visual artists, scientists and humanities professionals. The large filled points represent the group mean scores for visual artists, scientists and humanities professionals

group as a predictor and OSIVQ scales as criterion variables revealed a significant multivariate effect, $F(4, 188) = 4.255$, $p < .001$, partial $\eta^2 = .315$. The follow-up univariate ANOVAs were performed on the individual OSIVQ scales to investigate differences between the professional groups. The analysis of the verbal scores revealed significant and large differences between the professional groups, $F(2, 197) = 39.462$, $p < .001$, partial $\eta^2 = .914$. Tukey's HSD revealed that the humanities professionals' OSIVQ verbal scores ($M = 3.51$; SD $= .50$) were significantly higher than the scientists' ($M = 2.71$; SD $= 0.52$) and visual artists' ($M = 2.72$; SD $= 0.58$) scores ($p < .001$). However, OSIVQ verbal scores did not significantly differ between the scientists and visual artists. Thus, the results showed that humanities professionals scored the highest on the verbal imagery scale. Given that professionals known to be experts in the use of verbal skills also highly rate their verbal abilities and preferences on OSIVQ, these findings further confirm the validity of the OSIVQ verbal scale as an instrument assessing verbal cognitive style. Furthermore, a one-way ANOVA revealed significant and large differences in object ($F(2, 197) = 39.443$, $p < .001$, partial $\eta^2 = .890$) and spatial ($F(2, 197) = 22.309$, $p < .001$, partial $\eta^2 = .816$) OSIVQ scales among members of different professions. Tukey's HSD demonstrated that visual artists had significantly higher object imagery scores ($M = 4.01$; SD $= 0.52$) than scientists ($M = 3.23$; SD $= 0.68$, $p < .001$) and humanities professionals ($M = 3.39$; SD $= 0.57$, $p < .001$), but scientists had significantly higher spatial imagery scores ($M = 3.41$; SD $= .55$) than visual artists ($M = 2.92$; SD $= 0.65$, $p < .001$) and humanities professionals ($M = 2.63$; SD $= 0.66$, $p < .001$).

Thus, the findings of Study 3b demonstrated that professionals known to use either object imagery or spatial imagery, or verbal skills assess themselves differently on the three scales. Therefore, the OSIVQ three dimensions are related to the educational activities and professional interests. Furthermore, these findings support the idea that there is a close relation between an individual cognitive style and the area of specialization. Previous studies have shown the relation between such styles as holistic-analytical, divergent–convergent, concrete-abstract and professional specialization (e.g. Hayes & Allinson, 1993; Kolb, 1984). Our results extend previous findings to the object-spatial-verbal cognitive style.

GENERAL DISCUSSION

The current research proposed and examined a new theoretical model of Visual–Verbal cognitive style that distinguishes between three separate dimensions: object imagery, spatial imagery and verbal as opposed to the traditional bipolar Visual–Verbal cognitive style model that distinguishes between two opposing dimensions: Visual and Verbal. Furthermore, based on the above three-dimensional model, we designed a new self-report instrument, the OSIVQ, that was validated across the three studies.

Overall, the results of the three studies supported the construct validity of the OSIVQ demonstrating that the new instrument measures the object, spatial and verbal theoretical constructs that it purports to measure. According to the findings of Study 1, all three scales of the OSIVQ showed acceptable internal reliability, and principal component analysis performed on the OSIVQ items demonstrated that items which were constructed to measure object, spatial or verbal constructs, indeed, loaded on the distinct and coherent factors, supporting the legitimacy of operationalization of our theoretical constructs. The results from Study 2 showed that the patterns of correlations between the measures known to be related or unrelated to object, spatial and verbal constructs were consistent with the theoretical expectations, thus, supporting convergent and discriminant validity of OSIVQ. Thus, the OSIVQ reliably assesses three different dimensions of cognitive style, unlike most of the previous instruments such as IDQ or VVQ, which failed to significantly predict the scores on the criterion tasks, particularly on visual imagery measures. Overall, these findings demonstrate that the problem of predictive validity of self-report cognitive style instruments can be resolved when imagery is considered as a multidimensional rather than unitary construct, and when imagery self-report measures and the corresponding criterion tasks assess the same type of imagery (see also Blajenkova et al., 2006; Dean & Morris, 2003; McAvinue & Robertson, 2007). Furthermore, the results from Studies 3a and 3b provided ecological validation of the OSIVQ. In Study 3a, we found significant correlations between object, spatial and verbal scales of the OSIVQ and the number of college courses taken by the participants in visual arts, physics and writing, respectively. In Study 3b, we showed a significant relationship between an individual cognitive style and the area of specialization. These findings demonstrate the generalizability of the new cognitive style model to real-life activities that extend beyond the laboratory testing settings. In addition, consistent with the previous studies on gender differences (e.g. Blajenkova et al., 2006; Linn & Petersen, 1985; McKelvie, 1995), we found that while there was no significant gender differences on verbal scale of the OSIVQ, males reported higher spatial imagery ratings than females, and females reported higher object imagery ratings than males. The results of Studies 1 and 2, however, demonstrated that relationships

between object, spatial and verbal cognitive style dimensions cannot be explained by gender differences alone. All the significant correlation between different object, spatial and verbal scales of cognitive style and corresponding objective measures of object, spatial and verbal ability remained significant after the effect of gender was partialled out.

The main theoretical goal of the current research was to evaluate a new theoretical model of object-spatial-verbal cognitive style, and to further examine the interrelationships between the three dimensions. The results of the confirmatory factor analysis demonstrated that the overall fit of the new three-factor model is significantly greater than that of the traditional Visual–Verbal two-factor model. An additional important finding from our confirmatory factor analysis was the negative correlations between object and spatial factors as well as between verbal and spatial factors. Although relatively independent on structural and functional levels, in many real-life tasks these three systems collaborate (e.g. Mazoyer, Tzourio-Mazoyer, Mazard, Denis, & Mellet, 2002; Paivio, 1991), and also, there is evidence of interferences and trade-offs between them (e.g. Kirby, 1993; Morey and Cowan, 2004). Kirby (1993), for instance, argued that the arising interference between the processing systems in complex tasks is due to competition for limited executive resources. In fact, our previous research (Kozhevnikov et al., 2005) provides evidence regarding the trade-off between object and spatial imagery abilities. It is possible that in a complex spatial task, keeping all the pictorial details of an image while manipulating the image spatially may overload visual working memory. Thus, possibly, spatial visualizers might tend not to maintain a lot of pictorial details in their images in order to develop efficient spatial transformation abilities. Object visualizers, in contrast, might tend to develop an ability to maintain a large amount of pictorial details in their images which hampers effective spatial transformations. Similarly, there might be cases when spatial and verbal processing interfere. In natural science fields such as physics or mathematics, spatial and verbal processing modes might serve as alternative strategies to approach the same problem. Thus, in order to not overload limited cognitive resources, if one is effective in spatial imagery, one may use this skill more frequently than verbal-analytical strategies in one's work and vice versa. Indeed, the accounts of many scientific discoveries contrasted scientists who developed only one prevalent mode of thinking, either spatial or verbal-analytical, in the expense of the other (see, Miller, 1996). For example, the workbooks of the famous mathematician Poincare demonstrated an abundance of clearly written sequential text and formulas, without any lines being crossed out or any diagrams drawn. In contrast, Einstein was known for his difficulties in learning language, but in his creative thinking he primarily relied on spatial visualization. As for the relation between object imagery and verbal systems, overall, they do not seem to compete for shared cognitive resources (Paivio, 1971, 1991), but rather support each other to permit dual coding of information. There is evidence showing that concrete nouns are better recalled due to dual information coding than less imaginable abstract concepts (Paivio & Yuille, 1969), and that verbal information automatically activates visual-object imagery (Sadoski, 1985; Wharton, 1980). Moreover, recent neuroimaging studies suggest that mental images generated from verbal description elicit activations in both visual and language areas of the brain, and share common structural properties (Mazoyer et al., 2002), and that retrieval of visual features is associated with neural activity in processing natural semantic categories (Sim & Kiefer, 2005).

Although we did find negative correlations between the object and spatial scales as well as between verbal and spatial scales, however, there was a notable proportion of the participants (for example, about 11% of all the participants from Study 1) who scored

above average on all three OSIVQ scales as well as a notable proportion of the participants (e.g. 10% of all the participants from Study 1) who scored below average on all three OSIVQ scales. This indicates that although there may be some tendencies in the development of different dimensions of cognitive style (i.e. a person who is especially good in spatial processing might tend not to develop object imagery or verbal cognitive style), an individual's scores on these three dimensions should not be combined (e.g. as ratio or subtraction), but assessed independently, since a given person could score high or low on all three scales. One interesting direction for future research could be the investigation of factors (e.g. age, gender, differences in experience and training, inborn abilities and cultural differences) that affect the development of a preferred style of information processing (object, spatial or verbal), and the relationship between these styles.

Another important direction for future research is further investigation of individual differences in information processing related to each of the three dimensions of object-spatial-verbal cognitive style (such as holistic vs. analytical, dynamic vs. static processing, emotionality vs. rationalism, field dependent vs. field independent etc.). The previous conceptualizations of the traditional Visual–Verbal cognitive style dimension tended to describe visualizers as individuals inclined to think concretely, holistically and subjectively. In contrast, verbalizers have been characterized as individuals inclined to think abstractly, successively and objectively (see Jonassen & Grabowski, 1993 for review; Kirby et al., 1988). However, the results of the present research suggest that the preceding description might not be accurate. All three models of processing might support abstract representations. According to the results of Study 3, most scientists (who are known to think in an abstract way) reported themselves as spatial visualizers. Indeed, spatial imagery system could rely on schematic representations such as graphs or diagrams depicting abstract structural relations. Furthermore, the object imagery system could also rely on abstract object images that are not based on previously seen real objects but represent an abstract mixture of feelings and emotions (e.g. Miller, 1996). Similarly, verbal systems might support abstract verbal-analytical thinking. Thus, the differences and similarities between the processing of information by the three systems cannot be simply explained by the differences in abstract-concrete dimensions. Furthermore, the previous description of visualizers as holistic thinkers and verbalizers as sequential-analytical thinkers might need further revision. Recent evidence (Kozhevnikov et al., 2005) suggests that spatial visualizers tend to encode and process images analytically, part by part, using spatial relations to arrange and analyse the components. Object visualizers, in contrast, tend to encode visual images globally as a single perceptual unit, which they process holistically. Nevertheless, they can successfully apply sequential/analytical reasoning in verbal domains (e.g. Kozhevnikov et al., 2002) and therefore cannot be considered as holistic thinkers overall.

Furthermore, the OSIVQ might be a valuable tool not only for psychological research but also in applied settings; in particular, it can serve as a useful tool for vocational guidance and career selection. Our recent study (Blazhenkova & Kozhevnikov, 2007) demonstrated that children as of 10 years old, who are gifted in visual art and science (but not yet extensively trained in these fields) already exhibit the similar cognitive style as adult professions, suggesting that cognitive styles might start to develop prior to formal training and career selection. Future studies are needed to investigate the development of object, spatial and verbal cognitive styles in relation to the development of imagery and verbal abilities. In addition to being a useful instrument in providing vocational guidance, the OSIVQ could be a useful tool for educators in the development of efficiently targeted

teaching methods and a choice of instructional materials. Recent studies demonstrated that object visualizers, for instance, have serious difficulties in interpreting science graphs as abstract schematic representations and instead interpret them literally, as a picture (e.g. Hegarty & Kozhevnikov, 1999; Kozhevnikov et al., 2002). It is important to identify such object visualizers and expose them to the instructional materials and technologies that pair physical events with their graphical representation in real time and thus provide students with the possibility of exploring connections between object and spatial representations (e.g. Kozhevnikov & Thornton, 2006). Furthermore, determining cognitive style and matching it to the appropriate role assignment in team performance appeared to be critical to team effectiveness. For instance, the recent study of Woolley, Hackman, Jerde, Chabris, Bennett, and Kosslyn (2007) showed that composing teams according to their object or spatial imagery skills can provide insights into how teams can best perform. Thus, the OSIVQ seems to be a valuable tool for both psychological research as well as applied settings. As a research tool, this instrument should be useful for studying object, spatial and verbal cognitive style, their relations between each other, and their development. In applied settings, an understanding of particular combinations of imagery and verbal skills that underlie successful performance in different professional domain should lead to efficiently conceptualized teaching and training methods, vocational guidance and effective team composition.

In summary, as we pointed out, one of the main problems in the previous research on cognitive styles was a lack of theory and incongruity between theory and measurement. The current research supported the validity of the cognitive style model, developed on the basis of modern cognitive science theories, that distinguishes between object, spatial and verbal modes of processing.

ACKNOWLEDGEMENTS

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