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Object–spatial imagery and verbal cognitive styles in children and adolescents: Developmental trajectories in relation to ability

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ABSTRACT

A new self-report instrument, the Children's Object–Spatial Imagery and Verbal Questionnaire (C-OSIVQ), was designed to assess cognitive styles in younger populations (8–17 years old). The questionnaire was based on the previously developed adult version of the Object–Spatial Imagery and Verbal Questionnaire (OSIVQ; Blazhenkova & Kozhevnikov, 2009), and includes three scales assessing object, spatial, and verbal cognitive styles. The C-OSIVQ was validated on a large sample consisting of 267 children and 83 college students. It demonstrated high internal reliability, predictive, and ecological validity in both children and adults. Following the design and validation of the C-OSIVQ, the development of object, spatial, and verbal cognitive styles and their corresponding abilities was examined across a wide range of ages (8–60 years old). The development of styles and abilities were strongly correlated across age groups, indicating that the trajectory of cognitive style development closely resembles the developmental trajectory of abilities; however, the development of cognitive style is more gradual and smooth.

1. Introduction

Cognitive styles traditionally refer to consistencies in an individual's manner of cognitive functioning, particularly in information processing and acquisition (e.g., Ausburn & Ausburn, 1978). It has been suggested that cognitive styles can be characterised as heuristics that individuals use to process information about their environments, which can be identified at multiple levels of information processing, from the perceptual to the metacognitive (Kozhevnikov, 2007). The construct of cognitive style continues to attract researchers due to it its predictive power of an individual's behaviour and success on complex tasks in real-life, academic, and educational settings (e.g., Bernardo, Zhang, & Callueng, 2002; Sadler-Smith & Badger, 1998; Sternberg & Zhang, 2001; Streufert & Nogami, 1989). The relative stability of cognitive style has been emphasised by many researchers (e.g., Messick, 1976) in the sense that it does not represent simple habits, but develops slowly and experientially. At the same time, there is evidence that cognitive style may be modified by life experiences (Hayes & Allinson, 1998; Leonard & Straus, 1997; Sternberg, 1997), and adaptively changed according to the demands of the external environment (Dunn, Dunn, & Price, 1989; Entwistle, 1981; Schmeck, 1988; Zhang & Sternberg, 2005). Therefore, since cognitive styles appear to be somewhat malleable, it is of particular interest to investigate the developmental changes that cognitive styles undergo from a life-span perspective and consider them in relation to the development of corresponding abilities.

Historically, the problem of reliably assessing cognitive style has been a challenge, due to theoretical and methodological difficulties (see Kozhevnikov, 2007, for a review). It has been even more challenging to conduct theoretically grounded and systematic studies attempting to measure cognitive styles in children and to investigate the development and formation of cognitive styles from childhood to adulthood. One of the limiting factors for conducting such research has been the lack of reliable and valid instruments for assessing cognitive style that are appropriate for children. The apparent problem with investigating and assessing cognitive styles in children is that children's level of knowledge, linguistic development, and overall cognitive ability are not fully mature, and many measures that are reliable and valid for adults, lack reliability and validity when applied to child populations.

The first goal of the current study was to design and validate an instrument for assessing visual–verbal cognitive style, targeted towards children and adolescents (8–17 years). We designed this questionnaire based on a previous instrument, the Object–Spatial Imagery and Verbal Questionnaire (OSIVQ; Blazhenkova & Kozhevnikov, 2009), which was developed to assess visual–verbal cognitive styles in adults. The approach taken in the design of the children's OSIVQ, as with the

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OSIVQ, is based on the revised model of Visual–Verbal cognitive style proposed by Kozhevnikov, Kosslyn, and Shephard (2005), which challenged the traditional Visual–Verbal model of cognitive style as a bipolar visual–verbal dimension (Paivio, 1971; Richardson, 1977). Instead, the researchers suggested the new Object–Spatial–Verbal (OSV) model of cognitive style, which distinguishes between three different types of individuals: *verbalisers*, who prefer to process information verbally, and two types of *visualisers*: *object visualisers*, who prefer to generate colourful, pictorial, high-resolution images of objects, and excel on visual–object tasks and in visual art, and *spatial visualisers*, who prefer to represent schematic images and spatial relationships, and excel on visual–spatial tasks and in natural science and engineering (Blazhenkova & Kozhevnikov, 2009; Hegarty & Kozhevnikov, 1999; Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov et al., 2005). The OSV cognitive style model is based on cognitive neuroscience evidence demonstrating the existence of two functionally and anatomically distinct visual processing systems: visual–spatial and visual–object (Courtney, Ungerleider, Keil, & Haxby, 1996; Ungerleider & Mishkin, 1982), and a separate verbal processing network (Cabeza & Nyberg, 2000; Gazzaniga, 2004). In contrast to Paivio's Individual Differences Questionnaire (IDQ; Paivio, 1971) and Richardson's Verbaliser–Visualiser Questionnaire (VVQ; Richardson, 1977), which demonstrated poor predictive validity, especially for visual dimensions, the OSIVQ demonstrated good predictive and ecological validity. Specifically, a close relationship was reported between the object, spatial and verbal scales, and successful learning and professional interests in the fields of visual art, science and humanities, respectively (Blazhenkova & Kozhevnikov, 2009).

However, the OSIVQ was developed and validated using samples of college students and adult professionals, and the complexity and content of some of the items are inappropriate for younger populations. Thus, in the current work (Study 1), based on the original version of the OSIVQ, designed for adults, we designed and validated the new *Object–Spatial Imagery and Verbal Questionnaire for Children* (C-OSIVQ), geared towards children between 8 and 17 years of age.

The second goal of our study was to conduct theoretically grounded and systematic studies attempting to measure cognitive styles in children, and to investigate the development and formation of cognitive styles from childhood to adulthood. In Study 2, we examined the developmental trajectories of visual–object, visual–spatial, and verbal styles from childhood to adulthood (from 8 to 60 years old), using the C-OSIVQ and OSIVQ, and compared these trajectories with those of visual–object, visual–spatial, and verbal abilities, as measured by objective performance tests, in order to track similarities and differences in the development of object–spatial–verbal styles and their corresponding abilities.

2. Study 1

The goal of Study 1 (A, B, and C), was to design and validate the C-OSIVQ. Prior to conducting Study 1, we designed pilot items of the C-OSIVQ (described below in Section 2.1). Then, Study 1A consisted of the final item selection and validation of the C-OSIVQ on a large sample of children and adolescents (ages 9–17). Study 1A also included the ecological validation of the C-OSIVQ, based on children's ratings of their learning interests. In Studies 1B and 1C, the finalised C-OSIVQ was revalidated on two independent samples of participants: a sample of children (8–17 years old) in Study 1B and a sample of college students (18–42 years old) in Study 1C, who also received the OSIVQ developed for adults, thus allowing examination of the applicability of this assessment instrument to adult populations, as well as using it for investigation of developmental patterns in Study 2.

2.1. Initial design of items for the C-OSIVQ object and spatial scales

Prior to Study 1, the original adult OSIVQ (Blazhenkova & Kozhevnikov, 2009) was individually administered to 13 children from the School-Plus, weekend enrichment programme in Teaneck, NJ. Children were interviewed about how well they understood the items from all three scales (object, spatial, and verbal), and were asked to explain what aspects of the questions were unclear and confusing. Based on these interviews, a prototype C-OSIVQ questionnaire was developed. It included the original OSIVQ items that were found appropriate for children as well as new, redesigned items that were modified versions of those OSIVQ items that were difficult for children to understand. Furthermore, additional prototype C-OSIVQ items were developed to assess visual–object, visual–spatial, and verbal preferences. The prototype C-OSIVQ items designed to assess visual–object cognitive style included questions about vividness of mental imagery, photographic memory, preferences for painting with colours, ease of image maintenance, and elicited imagery. Items designed to assess visual–spatial cognitive style included questions about 3D geometry, schematic mental imagery, mechanical inclination, and spatially intensive games. Verbal cognitive style was assessed using items that asked about speed of reading, ease of writing, fluency in expressing thoughts and ideas verbally, and storytelling.

Compared to the adult version of the questionnaire, the prototype C-OSIVQ included more concrete examples, and eliminated complicated or negatively formulated items (for example, “I have difficulty expressing myself in writing” was changed to “I am good at expressing myself in writing”), as well as those irrelevant to children's experiences (for example, “I was very good in 3D geometry as a student” was changed to “I am good at solving geometry problems with 3D figures,” and “When reading fiction, I usually form a clear and detailed mental picture of a scene or a room that has been described “ was changed to “When reading a book, I can usually imagine clear, colourful pictures of the people and places”). Furthermore, questions containing a choice between options were split into separate questions, and questions related to children's everyday activities (e.g., playing games, drawing, and learning in school) were included (for example, “I am good at playing 3D action video games (for example shooter, flight/car simulation, or maze games)” and “I enjoy language games (games with words, sentences and letters)”.

In the final version of the C-OSIVQ, six items were the same as in the OSIVQ (4 object, 1 spatial, and 1 verbal). Four items were reversed to be formulated positively (1 object, 1 spatial, and 2 verbal). Thirteen items were modified to use simpler language and refer to activities relevant to children's experiences, rather than professional and past scholastic experience (6 object, 3 spatial, and 4 verbal). Twenty-two items on the C-OSIVQ were brand new (4 object, 9 spatial, and 9 verbal), however, they tapped the same constructs as the adult OSIVQ scales. Overall, 91 questions (including both old and new prototypes) adjusted for children/adolescents' level of comprehension (33 object, 31 spatial, and 27 verbal items) were included in the prototype C-OSIVQ.

2.2. Method

2.2.1. Study 1A

Two-hundred and twenty-two children from elementary to high school in Moscow, Russia participated in Study 1A (138 males, 9–17 years old, *M* age = 14.23; SD = 1.89. All participants in Study 1A were administered the object and spatial scales of the pilot version of the C-OSIVQ. Since the verbal scale was developed later than the object and spatial scales, only a sub-sample of the original sample, consisting of 117 children (82 males) received the verbal scale. Participants had to indicate the degree to which they agreed with the statements on a scale of 1–5. They were also asked to provide feedback on any difficult questions by writing their comments next to the questions.

All participants were also administered two assessments of visual–spatial ability: the *Paper Folding Test* (PFT) and the *Mental Rotation Test* (MRT). The PFT consists of ten items showing successive drawings of several folds made in a square sheet of paper and a hole punched through the folded paper (Ekstrom, French, & Harman, 1976). Participants responded by indicating what the sheet would look like if it were fully opened. In the MRT, participants were shown four three-dimensional forms, two of which were rotated relative to the target (Shepard & Metzler, 1971). Participants determined which two were identical to the target.

Two assessments of visual–object ability: the *Degraded Pictures Test* (DPT) and the *Vividness of Visual Imagery Questionnaire* (VVIQ) were also administered to all participants. In the DPT, participants viewed degraded line drawings of common objects (e.g., umbrella and scissors) embedded in backgrounds of visual noise and were asked to identify the degraded objects (Kozhevnikov et al., 2005). In the VVIQ, participants created mental images from verbal descriptions of scenes and objects, and rated the images' vividness (Marks, 1973).

In addition, to examine the predictive validity of the verbal scale, the subsample of 117 children who completed the verbal scale of the questionnaire also completed a verbal task, the *Arranging Words Test* (AW). Participants were given four specific words, and asked to write as many sentences as they could including these words (Ekstrom et al., 1976). To assess the fluency of speech production, scores were computed based on the total number of written words.

Finally, all participants were asked to rate on a scale of 1 (low interest) to 5 (high interest) their learning interests in visual art, design, math, physics, chemistry, technical drawing, algebra, geometry, biology, computer science, history, and literature, as well as their intention to become a visual artist, designer, scientist, computer scientist, literature professional, or history specialist.

2.2.2. Study 1B

Forty-seven additional children from elementary, middle, and high schools in Moscow, Russia (24 males, 8–17 years old, *M* age = 12.07, SD = 2.22[1]) participated in Study 1B. Children completed the C-OSIVQ along with measures of visual–spatial ability (PFT and MRT), visual–object ability (DPT and VVIQ), and verbal ability (AW).

2.2.3. Study 1C

Eighty-three college students from George Mason University, VA, USA (27 males, 18–42, *M* age = 21.77; SD = 5.04) participated in the study. The students were administered the C-OSIVQ in order to examine whether this questionnaire can be used for an adult sample. In addition, to examine test–retest reliability, a subsample of 22 students completed the C-OSIVQ a second time (separated by a 2-week interval). All students completed measures of visual–spatial ability (PFT and MRT) and visual–object ability (DPT and VVIQ), as well as the OSIVQ. The assessments of verbal ability included the AW, completed by 43 students, and SAT verbal scores, reported by 36 students.

2.3. Results

2.3.1. Study 1A

2.3.1.1. Selection of items. First, we conducted Principal Component Factor analysis on the 33 object and 31 spatial items only. The first factor identified was the *object factor*, since all of the items designed to assess object imagery experiences positively loaded onto this factor (loadings from .44 to .75, *M* = .59), and the second factor was identified as the *spatial factor*, since all of the items designed to assess spatial imagery preferences loaded positively on the second factor (loadings from .41 to .72, *M* = .59). These two factors explained 36.7% of variance. The 15 items with the highest factor loadings were selected for each of the final C-OSIVQ object and spatial scales.

Since the verbal scale was developed later, Principal Component Analysis was performed again on the 15 object and 15 spatial items as well as the additional 27 verbal items. Analysis revealed two major object and spatial factors, and a third verbal factor. The items designed to assess object cognitive style loaded positively onto the first factor (loadings from .34 to .76, *M* = .58), but spatial and verbal items did not (spatial: loadings from −.39 to .18, *M* = −.07; verbal: loadings from −.06 to .31, *M* = .10). Items assessing spatial cognitive style loaded positively onto the second factor (loadings from .48 to .73, *M* = .61), while object and verbal items either did not load or loaded negatively on this factor (object: loadings from −.21 to .11, *M* = −.05; verbal: loadings from −.14 to .22, *M* = .01). The items designed to assess verbal cognitive style loaded positively on the third factor (loadings from .40 to .74, *M* = .51), whereas most of the items designed to assess object or spatial imagery preferences either did not load or loaded negatively on this factor (spatial: loadings from −.24 to .32, *M* = .02; object: loadings from −.01 to .29, *M* = .13). Consistently with object and spatial items-per-scale quota, the 15 items with the highest factor loadings were selected for the final C-OSIVQ verbal scale.

2.3.1.2. Finalisation of scales. The object, spatial, and verbal ratings were averaged to create object, spatial, and verbal scale scores (*M* = 3.99, SD = .65 for the object scale, *M* = 3.11, SD = .80 for the spatial scale, *M* = 3.35, SD = .66 for the verbal scale). The Cronbach Alpha's were .87 for the object scale, .87 for the spatial scale, and .81 for the verbal scale, confirming the high internal reliability of the scales. In addition, for convenience of interpretation and comparisons of scores between the scales, raw scores were standardised, and plotted against percentiles (see Fig. 1). Overall, the distribution of C-OSIVQ scores, and the relationships between the scales were nearly identical to the distribution of OSIVQ scores described for adults (Blazhenkova & Kozhevnikov, 2009). Consistent with previous results (Blajenkova, Kozhevnikov, & Motes, 2006; Blazhenkova & Kozhevnikov, 2009; Chabris et al., 2006), the ratings for the object scale tended to be higher than those for the spatial and verbal scales. However, all children's ratings on each scale tended to be higher than those given by adults (children reported an average of .28 points higher for spatial. .36 higher for object, and .36 higher for verbal scales than adults did).

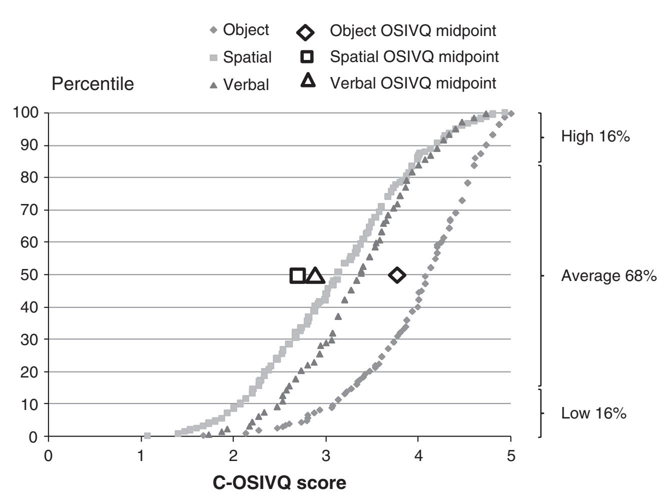

Fig. 1. The distribution of the raw scores on the three scales of C-OSIVQ in terms of percentiles. Midpoint scores from the OSIVQ (Blazhenkova & Kozhevnikov, 2009) are included for comparison.

[1] Two 8-year old children did not finish the study, since they experienced difficulties with timed measures.

2.3.1.3. Predictive validity. Furthermore, the predictive validity of the new questionnaire was tested by correlating scores on the object, spatial, and verbal scales with performance on visual–object (DPT and VVIQ), visual–spatial (PFT and MRT), and verbal assessments (AW). The obtained results were consistent with those obtained for the OSIVQ developed for adults (Blajenkova et al., 2006, Blazhenkova & Kozhevnikov, 2009). Overall, children's self-assessments of object, spatial, or verbal preferences and abilities predicted performance on measures of object and spatial imagery and verbal abilities. The results of the correlation analysis (see Table 1) showed that scores on the object scale correlated with performance on visual–object tasks, scores on the spatial scale correlated with performance on visual–spatial tasks, and scores on the verbal scale correlated with performance on verbal tasks, thus supporting the predictive validity of the C-OSIVQ. In addition, the object scale tended to be negatively correlated with the spatial scale, but positively correlated with the verbal scale as well as verbal tasks. This is consistent with previous results (Blazhenkova & Kozhevnikov, 2009) that showed negative correlations between the object and spatial, as well as the verbal and spatial dimensions, suggesting that there might be some negative interference between object and spatial information processing and between verbal and spatial processing, but not between object and verbal processing.

2.3.1.4. Ecological validity. Next, the object, spatial, and verbal scales were correlated with the ratings of learning preferences for various school subjects and future professional intent. Scores on the object scale were correlated with learning preferences in visual art ($r=.27$, $p<.01$, $N=196$), and the degree of intention to become a visual artist ($r=.20$, $p<.01$, $N=190$) or a designer ($r=.27$, $p<.01$, $N=196$). Scores on the spatial scale were correlated with learning preferences in physics ($r=.40$, $p<.01$, $N=195$), chemistry ($r=.32$, $p<.01$, $N=179$), technical drawing ($r=.31$, $p<.01$, $N=139$), math ($r=.36$, $p<.01$, $N=211$), algebra ($r=.37$, $p<.01$, $N=197$), geometry ($r=.42$, $p<.01$, $N=195$), and the degree of intention to become a scientist ($r=.15$, $p<.01$, $N=194$) or a computer scientist ($r=.33$, $p<.01$, $N=189$). Scores on the verbal scale were correlated with learning preferences in literature ($r=.25$, $p<.01$, $N=116$) and history ($r=.32$, $p<.01$, $N=117$), and professional intent towards literature ($r=.43$, $p<.01$, $N=104$) or history ($r=.33$, $p<.01$, $N=104$). Interestingly, scores on the object scale correlated positively with learning preferences in literature ($r=.14$, $p<.05$, $N=218$), and negatively with professional intent towards computer science ($r=-.21$, $p<.05$, $N=189$), but were not correlated with learning preferences in biology. Scores on the spatial scale correlated negatively with professional intent towards design ($r=-.21$, $p<.05$, $N=189$). Scores on the verbal scale correlated negatively with learning preferences in algebra ($r=-.19$, $p<.05$, $N=113$). Thus, overall, the scales scores predicted, ranging from weak to moderate correlations (Cohen, 1992), interests in the fields that require visual–object, visual–spatial, or verbal skills. This correlation pattern indicates that the questionnaire cognitive style scales (object, spatial, and verbal) discriminatively relate to different learning and professional interests, thus further supporting the ecological validity of the C-OSIVQ. These results are also consistent with previous studies that ecologically validated the OSIVQ scales on members of different professions known to predominantly rely on visual–object (visual artists), visual–spatial (scientists), or verbal (humanities professionals) skills in their training and work (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009).

2.3.1.5. Gender differences. Finally, we examined gender differences on the object, spatial, and verbal scales of the C-OSIVQ. Although examination of gender differences was not the primary goal of the current research, gender differences in visual ability are consistently reported in the literature (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995) as well as in previous research (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009), with males typically scoring higher on visual–spatial assessments and females typically scoring higher on visual–object assessments. Consistent with these reports, males had significantly higher C-OSIVQ spatial scores than females [$F(1,221)=52.96$, $p<.001$, M males $=3.57$, SD $=.73$; M females $=2.84$, SD $=.72$], and females had significantly higher C-OSIVQ object scores than males [$F(1,221)=14.41$, $p<.001$, M males $=3.78$, SD $=.67$; M females $=4.12$, SD $=.61$], and no gender differences were found on C-OSIVQ verbal scores.

2.3.2. Study 1B

The results of the correlation analysis between C-OSIVQ and visual–object, visual–spatial, and verbal criterion measures in the independent sample of children (see Table 2) were consistent with those of Study 1A, and supported the predictive validity of C-OSIVQ. In particular, scores on the object scale tended to correlate with performance on visual–object tasks, scores on the spatial scale correlated with performance on visual–spatial tasks, and scores on the verbal scale correlated with performance on verbal tasks. In addition, similar to Study 1A and previously reported results (Blazhenkova & Kozhevnikov, 2009), the verbal scale was correlated with object measures.

2.3.3. Study 1C

The results of the correlation analysis in college students showed that the OSIVQ scales designed for adult populations were significantly correlated with the corresponding scales of the C-OSIVQ ($r=.67$, $p<.001$ between object scales; $r=.75$, $p<.001$ between spatial scales; $r=.57$, $p<.001$ between verbal scales).

Furthermore, the results of the correlation analysis (see Table 3) between C-OSIVQ scales and corresponding visual–object, visual–spatial, and verbal criterion measures in the sample of college students were consistent with the results of both children's samples (Study 1A and Study 1B). Scores on the object scale of the C-OSIVQ correlated with performance on VVIQ (but not significantly for DPT), scores on the spatial scale of the C-OSIVQ correlated with performance on visual–spatial tasks, and scores on the verbal scale of the C-OSIVQ correlated with performance on verbal tasks. Thus, the questionnaire proved to be a valid instrument for extended ages (18 to 42 years old),

Table 1
The Pearson product–moment correlations among spatial, object, and verbal scores and the criterion measures in Study 1A[a].

	1	2	3	VVIQ	DPT	MRT	PFT	AW
1. C-OSIVQ object	–	−.12†	.38**	.42**	.18**	−.01	−.03	.10
2. C-OSIVQ spatial		–	.07	.13†	.11	.42**	.34**	.18†
3. C-OSIVQ verbal			–	.10	.06	.03	−.06	.31**

Note. [a] $N=117$ for C-OSIVQ verbal and AW, $N=222$ for all other assessments. † $p<.1$, ** $p<.01$.
The underlined entries identify correlations between object C-OSIVQ scale and corresponding measures of object ability, spatial C-OSIVQ scale and corresponding measures of spatial ability, and verbal C-OSIVQ scale and corresponding measure of verbal ability.

Table 2
The Pearson product–moment correlations among spatial, object, and verbal scores and the criterion measures in Study 1B.

	1	2	3	VVIQ	DPT	MRT	PFT	AW
1. C-OSIVQ object	–	.11	.56**	.54**	.26†	.07	.05	.17
2. C-OSIVQ spatial		–	.06	−.00	−.05	.49**	.31*	.17
3. C-OSIVQ verbal			–	.55**	.39**	.22	.29†	.37*

† $p<.1$, * $p<.05$, ** $p<.01$.
The underlined entries identify correlations between object C-OSIVQ scale and corresponding measures of object ability, spatial C-OSIVQ scale and corresponding measures of spatial ability, and verbal C-OSIVQ scale and corresponding measure of verbal ability.

Table 3
The Pearson product–moment correlations among spatial, object, and verbal scores and the criterion measures in Study 1C[a].

	1	2	3	OSIVQ object	OSIVQ spatial	OSIVQ verbal	VVIQ	DPT	MRT	PFT	AW	SAT
1. C-OSIVQ object	–	.11	.20†	.67**	.03	−.16	.44**	.04	−.01	.21†	.23	.31†
2. C-OSIVQ spatial		–	−.12	.08	.75**	.10	.01	−.06	.23*	.41**	−.07	.02
3. C-OSIVQ verbal			–	.13	−.21†	.57**	.11	−.05	−.08	−.14	.34*	55**

Note. [a] $N=36$ for SAT verbal, $N=43$ for AW, $N=83$ for all other assessments. † $p<.1$, * $p<.05$, ** $p<.01$.
The underlined entries identify correlations between object C-OSIVQ scale and corresponding measures of object ability, spatial C-OSIVQ scale and corresponding measures of spatial ability, and verbal C-OSIVQ scale and corresponding measure of verbal ability.

demonstrating that it can be used reliably not only for children, but also for adolescents and adults.

2.3.3.1. Test–retest reliability. Additionally, 22 students from this sample also received the C-OSIVQ in a second testing session (separated by a 2-week interval). Test–retest analysis was conducted by correlating scores on the object, spatial, and verbal scales between the testing sessions. The analysis showed that all the C-OSIVQ scales were significantly correlated between the two testing sessions ($r=.71$, $p<.001$ between spatial scales; $r=.65$, $p<.01$ between object scales; $r=.79$, $p<.001$ between verbal scales).

3. Study 2

The goal of this study was to investigate the developmental trajectories of visual–spatial, visual–object, and verbal cognitive styles and their corresponding abilities. The data from Study 1 and Study 2 were merged with additional data from an adult sample.

3.1. Participants

The data from Study 1A (222 school children), Study 1B (45 school children), Study 1C (83 college students), as well as data from 296 new participants (college students and adults with college degrees) were used in this study (total = 646, 237 males, 8–60 years old). For the analyses, participants were divided into groups according to age: 8 years old ($N=2$), 9 years old ($N=6$), 10 years old ($N=6$), 11 years old ($N=27$), 12 years old ($N=33$), 13 years old ($N=37$), 14 years old ($N=41$), 15 years old ($N=42$), 16 years old ($N=48$), 17 years old ($N=25$), 18 years old ($N=27$), 19 years old ($N=51$), 20 years old ($N=56$), 21 years old ($N=62$), 22 years old ($N=42$), 23 years old ($N=37$), 24 years old ($N=18$), 25 to 29 years old ($N=47$, M age = 26.47), and 30 years or older ($N=39$, $M=36.33$).

All participants were recruited from schools and universities from countries with developed educational systems (Russia, USA, and Singapore); all have education indices in top 15% according to a report by the United Nations Development Programme. The additional sample of 296 participants consisted of college students and adults that had college degrees (USA and Singapore). Despite the cultural differences between participants, all participants held comparable levels of education and socioeconomic status within each age group (all participants were students or degree-holding professionals from nations with high education indices).

3.2. Materials

Participants' scores on the following visual cognitive style and ability assessments were used for analyses: C-OSIVQ (or OSIVQ) spatial scale, PFT and MRT as visual–spatial assessments, and C-OSIVQ (or OSIVQ) object scale, DPT and VVIQ as visual–object assessments, C-OSIVQ (or OSIVQ) verbal scale, and AW[2] ($N=131$) for verbal assessments. For those 296 participants who did not receive C-OSIVQ, the OSIVQ scores were used (additional sample of adults 18–60).

3.3. Results

To allow comparison across ages, z-scores for all assessments were calculated.[3] Composite scores for object assessments, spatial assessments, and verbal ability assessments were created for each participant by averaging the normalised z-scores on object, spatial and verbal ability assessments, respectively, across all age groups. Fig. 2 shows the developmental trajectories for object, spatial, and verbal cognitive styles, along with averaged ability scores, separately for object (Fig. 2A), spatial (Fig. 2B), and verbal (Fig. 2C) dimensions.

The 95% confidence intervals, which are recommended as the most appropriate technique estimating the magnitude and direction of each group's difference from an estimated population average (Denis, 2003), demonstrate that the developmental trajectories of the cognitive style scales of the C-OSIVQ approximated those of the corresponding ability measures. Examining the confidence intervals reveals that cognitive styles generally did not differ from corresponding abilities within each age group, suggesting that object–spatial–verbal cognitive styles develop in correspondence with abilities.

However, separate analyses of developmental trends across different age groups for cognitive styles and their corresponding abilities demonstrated that while abilities tend to undergo significant age-related changes, cognitive styles do not change significantly with age. In particular, spatial ability measures tended to peak between the ages of 14 and 16, and slowly decline after that, consistently with the results of other studies (e.g., Vandenberg & Kuse, 1978). In addition, our results show another peak in spatial ability measures around 20 years of age, which may reflect sampling bias (while studies on children usually involve the general population, studies on young adults usually involve college students, who tend to have higher abilities than the general population). Overall, the development of spatial ability exhibits a unique pattern of increase in adolescence, followed by gradual decline. However, while the decline was significant for spatial ability ($F(18, 645)=5.88$, $p<.001$), it was nonsignificant ($F(18, 645)=1.25$, $p=.22$) for spatial cognitive style.

Object ability measures also tended to increase in children but did not show the same age-related decline in adults as spatial ability measures did, and even tended to increase with age ($F(18, 645)=1.56$, $p=.066$). This is consistent with previous research that indicated that certain aspects of visual–object processing tend not to decay with age, and moreover, may even increase in older individuals (Campos & Sueiro, 1993; Van Leijenhorst, Crone, & Van der Molen, 2007; White, Ashton, & Brown, 1977). However,

[2] SAT verbal scores were not included in the combined verbal score, since participants who reported this measure all took it between ages 16 and 18, which gives no indication of development of ability.

[3] Since Study 1C demonstrated that children ratings on the C-OSIVQ tend to be heightened, a correction was performed on their data in order to allow comparison between their preferences and those of adults.

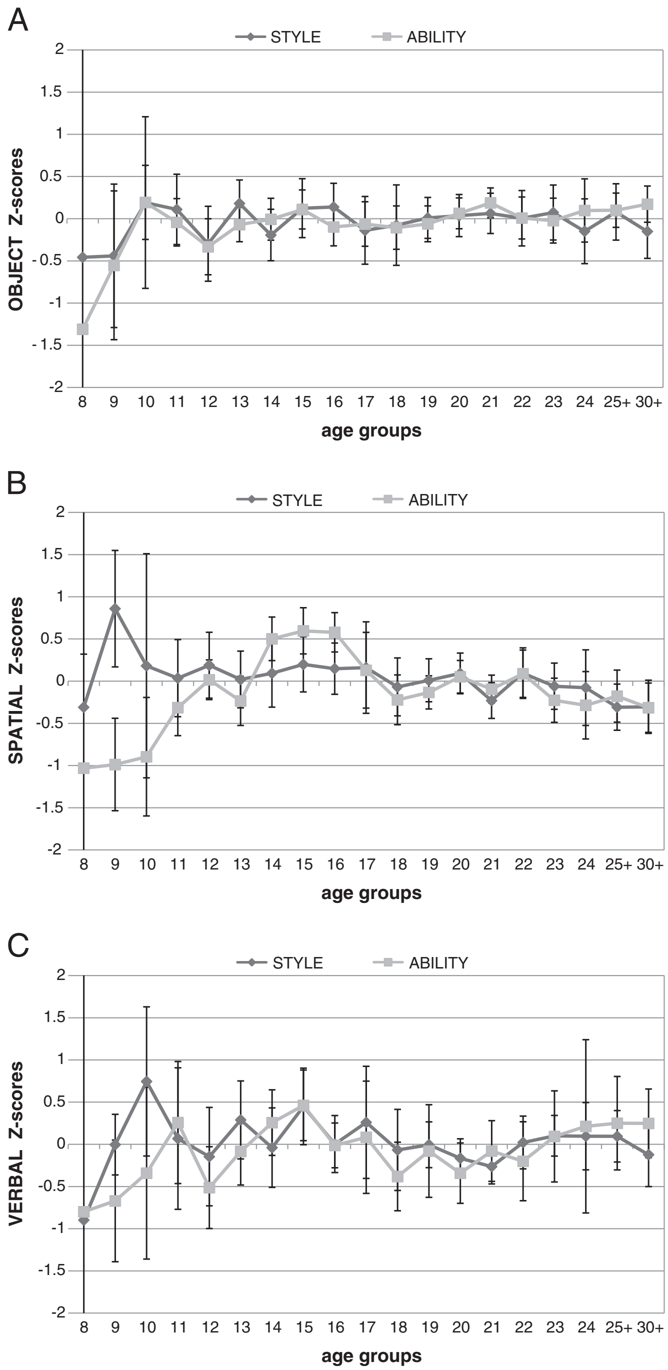

Fig. 2. The developmental trajectories for cognitive styles and abilities: A) object, B) spatial, C) verbal. The bars represent 95% confidence intervals.

object cognitive style does not change significantly with age ($F(18, 645) < 1$).

Our findings on the development of verbal ability are consistent with other studies, generally showing that many aspects of the verbal dimension, such as vocabulary, tend to increase with age and not decline until approximately 80 years of age (Giambria, Arenberg, Zonderman, Kawas, & Costa, 1995). Verbal ability tended to increase with age only in younger children ($F(18, 335) = 1.53$, $p = .075$), but verbal cognitive style did not show any significant increase ($F(18, 540) = 1.20$, $p = .25$). However, verbal cognitive style also does not undergo any age-related significant changes.

4. General discussion

The new self-report instrument, the Children's Object–Spatial Imagery and Verbal Questionnaire (C-OSIVQ), measuring children and adolescents' (9–17) preferences for object, spatial or verbal processing, was designed and validated. Furthermore, using this new instrument, the current study was the first to compare children's and adolescents' cognitive styles to those of adults, and to trace the separate developmental courses of visual–object, visual–spatial, and verbal styles. Overall, the results demonstrate the high internal reliability and predictive validity of the C-OSIVQ. Consistent with previous studies, which found that cognitive style is a significant predictor of area of specialisation, vocational intent, educational activities, and learning styles (Billington, Baron-Cohen, & Wheelwright, 2007; Blazhenkova & Kozhevnikov, 2009; Kolb, 1984; Kozhevnikov, Blazhenkova, & Becker, 2010), our results on the correlation between C-OSIVQ scales and learning and professional interests suggest that cognitive style is an important factor for predicting learning interests and future professional intent. Therefore, the C-OSIVQ seems to be a promising instrument for understanding and detecting children's and adolescents' object, spatial, and verbal cognitive styles, which underlie successful learning processes and future performance in different professional domains. From a theoretical perspective, the development of a reliable and valid instrument for measuring object–spatial–verbal cognitive style in children opens a great deal of possibilities for future investigations into how cognitive style develops and relates to other psychological constructs in children and adolescents. From an applied perspective, such an instrument may be a useful tool for developing efficient theoretically-based and practically valid teaching and training methods and vocational guidance. In addition, advisory institutions that aid in students' selection of classes, colleges/universities, major and preprofessional advising might also wish to assess students' cognitive styles in order to provide more complete feedback as to what might fit a particular student best. Future research is needed to more specifically characterise which cognitive styles facilitate learning in specific domains, and how students of different styles can be taught strategies for translating material to representations that are compatible with their own preferred cognitive style (see also Kozhevnikov et al., 2002).

In addition, our results demonstrate that the newly developed C-OSIVQ is also suitable for adult populations. However, the questions' content suggests that the C-OSIVQ is more suitable for children and adolescent populations (9–17), while the OSIVQ is better suited for adults. In Study 2, we traced the developmental courses of visual–object, visual–spatial, and verbal cognitive styles in relation to their corresponding abilities. Previous research indicated a close relationship between cognitive style and associated abilities (e.g., field independence is closely related to high spatial ability, Goodenough & Karp, 1961; MacLeod, Jackson, & Palmer, 1986; Vaidya & Chansky, 1980), to the extent that ability and cognitive style are sometimes confused (see Kozhevnikov, 2007 for review). The alternative view is that cognitive style and cognitive ability are separate constructs; Köstlin-Gloger (1978) has suggested that cognitive abilities should be regarded as developmental presuppositions for cognitive styles, and other researchers (Kozhevnikov, 2007; Moskvina & Kozhevnikov, 2011) have added to this by suggesting that cognitive styles may develop as an interaction between innate cognitive abilities and external physical and socio-cultural environments. Supporting the latter view, our results demonstrate that, although the development of cognitive style and that of corresponding ability are closely linked, their developmental trajectories are somewhat different. Overall, the development of cognitive style, though closely related to the corresponding ability, is more gradual and smooth. It is possible that cognitive style develops on the basis of innate predispositions, in reciprocal interaction with the corresponding ability, and may develop even before the full development of the corresponding ability. Later, this preference may become habitual, and it does not undergo such dramatic increases related to ability. Overall, our findings suggest that cognitive style and cognitive ability are separate constructs, and they are consistent with other developmental studies on cognitive style (e.g., Globerson, Weinstein, & Sharabany, 1985), which have shown that cognitive style's development is separate from cognitive development, although they are highly interlinked. However, a limitation of the current study is the cross-sectional nature of our sample, and future longitudinal studies on the development of cognitive style and corresponding ability are required to fully understand the relationship between cognitive style and ability, and the differences in the developmental courses that these constructs follow.

Interestingly, as it was shown in Study 1A, children's ratings on the C-OSIVQ tended to be higher than those of adults on OSIVQ, while there were no differences in C-OSIVQ and OSIVQ ratings in the adult sample. These heightened scores in children may be related to the development of metacognition (one's awareness of one's own abilities and mental states). Indeed, research demonstrated that individuals' knowledge about their own minds and cognitive preferences only becomes fully developed in young adulthood (Schneider, 1998). Schneider also reports that younger children, while they do have some metacognitive ability, tend to overestimate their performance on ease-of-learning self-monitoring judgments, which are similar to some of the C-OSIVQ questions. This tendency of children to exaggerate could also be related to the fact that children's perceptual systems are more sensitive to those of adults (e.g., kids can hear higher pitched sounds than adults, Robinson & Sutton, 1979). This could also be related to the model of learning as a process of successive approximation, in which initially grossly exaggerated responses are fine-tuned into more precise abilities with time and experience. Further studies are needed to investigate the development of styles in correspondence to abilities in younger ages, and their relation to the development of metacognitive skills.

In summary, the newly developed C-OSIVQ provides researchers with an instrument that can be used to identify children's and adolescents' cognitive styles, which in turn may aid the development of methods by which students of different styles can transfer problematic material into representations that are compatible with their own preferred cognitive style. Overall, this questionnaire may be applied as a unique tool for research, assessment and applied fields, such as education and academic counselling.

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