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The Role of Visual Abilities and Cognitive Style in Artistic and Scientific Creativity of Singaporean Secondary School Students

ABSTRACT

The current research addresses the question of the multidimensional relationship between visual abilities, visual cognitive style, and creativity (artistic and scientific) in Singaporean students of 13–14 years old. Three hundred seventy students (100 students in Study 1 and 270 students in Study 2) from two typical secondary schools in Singapore were administered 10 tasks assessing their visual abilities, visual cognitive style and domain-specific, artistic, and scientific, creativities. Consistent with the results of recent research challenging the foundation of the current assessments of creativity as a general ability, the results of principal component analysis (PCA) (Study 1) and path analysis (Study 2) provided evidence that artistic and scientific types of creativities are clearly dissociable in students of 13–14 years old. Furthermore, the results of both studies demonstrated that although both visual abilities and corresponding cognitive style (object and spatial) reliably predicted artistic and scientific creativity respectively, cognitive style was a reliable predictor of corresponding creativity beyond visual ability. The findings suggest that domain-specific visual creativity begins developing concurrently with corresponding types of visual abilities and cognitive style, and that socio-cultural influences, as reflected by cognitive style, also affect the development of creative performance in a specific domain, beyond abilities.

Keywords: creativity, visual ability, visual cognitive style, art, science, secondary school.

The growth of the global economy in the 21st century has added urgency to calls to foster greater creativity in students. Currently, however, there is little understanding about the cognitive mechanisms underlying creativity and its relations to specific ways of information processing. The main goal of this study was to investigate the multidimensional relationship between visual abilities, visual cognitive style, and creativity (in visual arts and sciences) in students of 13–14 years old, the age when visualization abilities and cognitive styles start to develop (Blazhenkova, Becker, & Kozhevnikov, 2011; Vandenburg & Kuse, 1978).

Past psychological and educational research has often referred to creativity as a unitary construct, where creativity is defined as the general ability to produce ideas, work and behavior that is both novel and meaningful (Mumford, 2003; Plucker, Beghetto, & Dow, 2004; Runco, 2007). For example, one approach to creativity, as a general all or none ability, is to assess it by performance on tasks involving non-routine (insight) problems that require overcoming a familiar way of thinking, such as the Insight Problem Solving (IPS) questionnaire (Dow & Mayer, 2004). Another approach to creativity, one of the most widely used in the field of creative research (Hocevar, 1981; Silvia et al., 2008), has conceptualized it as a divergent thinking ability—the ability to generate multiple solutions to a problem that serves as an indicator of one's creative potential (Guilford, 1956; Runco & Acar, 2012). In this approach, creativity has been commonly measured by performance on divergent thinking tests such as Torrance Test of Creative Thinking (TTCT; Torrance, 1972) that remains to be one of the most widely used assessments of the divergent thinking ability (Dietrich & Kanso, 2010; Kim, 2006; Pidgeon et al., 2016). Since the 1990s, however, growing evidence for the existence of domain-specific creativity has accumulated (Baer, 1998; Kaufman & Baer, 2004), either through studies pointing to the different cognitive processes underlying creativity in different domains (Kaufman & Baer, 2005; Ward, Smith, & Finke, 1999), or through demonstrating that creativity in one domain does not necessarily extend to creativity in another (Ward et al., 1999). Yet, a number of recent studies on creativity, particularly in the domain of cognitive neuroscience (Baas, Nijstad, & de u, C., 2015; Beaty et al., 2018; Jung, Mead, Carrasco, & Flores, 2013; Park, Kim, & Hahm, 2016), continue to define the measured constructs as general creativity despite often constructing and utilizing assessments of domain-specific creativity (see Dietrich & Kanso, 2010 for a review). Hence, while research to some extent has recognized creativity as a complex construct consisting of multiple distinct cognitive and neural processes, the challenge remains in distinguishing different domains of creativity and ensuring the utilization of appropriate assessments (Dietrich & Kanso, 2010; Pidgeon et al., 2016).

Starting from 1990s, neuroscience research provided strong evidence for the distinction between object and spatial visual perception and imagery, by demonstrating that the visual areas of the brain are divided into two functionally and anatomically distinct pathways: the object (ventral) pathway that processes visual appearance of objects and the spatial relations (dorsal) pathway that processes spatial relations (e.g., Courtney, Ungerleider, Keil, & Haxby, 1996; Kosslyn & Koenig, 1992). Subsequent research has confirmed that similar dissociation exists in individual differences in visual imagery, and that there are two equally important and distinct components of visual imagery abilities, object and spatial abilities (Blazhenkova & Kozhevnikov, 2010; Kozhevnikov, Blazhenkova, & Becker, 2010; Kozhevnikov, Kosslyn, & Shephard, 2005). Object ability (i.e., the ability to imagine visual appearances of objects or scenes in terms of their shapes, color, and texture) is associated with more efficient use of object processing resources in the ventral pathway (Motes, Malach, & Kozhevnikov, 2008), whereas spatial ability (i.e., the ability to imagine spatial relations among, and movements of, objects and their parts, and complex spatial transformations) is associated with more efficient use of spatial processing resources in the dorsal pathway (Lamm, Bauer, Vitouch, & Gstattner, 1999; Vitouch, Bauer, Gittler, Leodolter, & Leodolter, 1997). While object ability predicts success in art, spatial ability predicts success in sciences and engineering (Blazhenkova & Kozhevnikov, 2010), suggesting a complex relationship between different types of visual imagery abilities and domain-specific visual creativity. In line with the above findings, several studies identified two distinct visual art and science creativity dimensions (Carson, Peterson, & Higgins, 2005; Kozhevnikov, Kozhevnikov, Yu, & Blazhenkova, 2013; Shi, Cao, Chen, Zhuang, & Qiu, 2017), providing evidence that visual creativity, similar to visual imagery, has a complex structure. Using self-report scales on creative achievements in visual arts and science (Creative Behavior Inventory, CBI; Hocevar, 1979), as indicators of the level of knowledge and mastery an individual has over the respective domains of creativity, Carson et al. (2005) has identified separate visual art and science factors, supporting the idea that individuals can differentially excel in different domains of visual creativity (artistic and scientific). A recent study by Kozhevnikov et al. (2013) also supported the domain-specific nature of creativity in a visual domain, by demonstrating that TTCT-picture completion assessments and IPS creativity were loaded on different factors. The TTCT-picture completion test, originally designed to measure general creativity, was positively related only to artistic creativity, whereas IPS tasks were related only to the scientific dimension of creativity. Furthermore, Kozhevnikov et al. (2013) demonstrated that different types of visual abilities contribute to different types of creativity. In particular, object ability was related to artistic creativity, whereas spatial ability was related to scientific creativity. Both artistic and scientific creativities were distinct from verbal creativity, which is rooted in brain areas related to verbal information processing (Kozhevnikov et al., 2010).

Moreover, Kozhevnikov et al. (2013) indicated that visual cognitive styles, object style (preference to process information by using colorful and pictorial images) or spatial style (preference to process information using schematic images representing spatial relations), may be a better predictor of artistic versus scientific creativity than corresponding visual abilities. While object and spatial abilities refer to an individual's cognitive capacity to process information in terms of object and spatial images respectively, object versus spatial style refers to an individual's preferences or habits of processing information in terms of object versus spatial images. According to recent research (Kozhevnikov, Evans, & Kosslyn, 2014; Moskvina & Kozhevnikov, 2011), cognitive style can be viewed as environmentally sensitive individual differences in cognition that develop under a variety of environmental influences (ranging from the immediate environment such as family and schools, to institutional patterns of culture). Cognitive style takes abilities as constraints, but it is environmental influences that engender particular preferences or habits of information processing (Kozhevnikov, 2007; Kozhevnikov et al., 2014), such that cognitive style is likely to change only when the physical or socio-cultural environment itself changes in fundamental ways (Klein, 1951; Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). In the Kozhevnikov's et al.'s (2013) study, both visual style and corresponding visual ability reliably predicted corresponding creativity dimension. Object style, however, remained to be a reliable predictor of artistic creativity even after shared variance between object style and object ability was removed. Similarly, spatial style marginally predicted scientific creativity even after removing shared variance between spatial style and spatial ability.

The first objective of this research was to explore whether domain-specific creativities (artistic and scientific) could be clearly identified in children of 13–14 years old; that is, whether they develop concurrently with corresponding visual abilities (object and spatial) or during the later stages of life under the influence of professional exposure. Our second objective was to examine the relative contribution of visual cognitive styles (object and spatial) versus visual abilities to corresponding creativity dimensions (artistic and scientific). Although both object and spatial abilities tend to develop around the age of 13–14, they follow different developmental courses (e.g., Blazhenkova et al., 2011; Vandenberg & Kuse, 1978). Spatial ability exhibits a unique pattern of increase in adolescence (the age of 14–16), followed by gradual decline in adulthood (e.g., Vandenberg & Kuse, 1978). Object ability also tends to increase in adolescence but does not show the same age-related decline in adults as spatial ability measures and may even increase in adulthood (Campos & Sueiro, 1993; Van Leijenhorst, Crone, & Van der Molen, 2007; White, Ashton, & Brown, 1977). While object and spatial styles begin developing at the same time as corresponding object and spatial abilities, their development, however, is more gradual and in some cases may deviate from the development of corresponding abilities (Blazhenkova et al., 2011), suggesting that visual cognitive styles continue to change within individuals as a result of experience and socio-cultural influences. Thus, while object and spatial cognitive styles have been shown to be better predictors of artistic and scientific creativity than the corresponding visual abilities in adults (Kozhevnikov et al., 2013), whether they are sufficiently robust to reliably predict corresponding creativity dimension in adolescents of 13–14 years remains a question for further investigation.

For the current study, we chose a participant pool of Singaporean secondary school students. Singapore's education system has the highest performance in international education and tops global rankings (Coughlan, 2016). Its unique features, such as placing a strong emphasis on learning sciences and mathematics, as well as Singaporean cultural norms that value engineering, scientific, and technical professions over those related to arts, might shape a unique cognitive style in Singaporean students, which would differ significantly from the cognitive style of students from other countries[1]. This holds especially true for students in Express streams,[2] in which they receive similar combinations of subjects as students in the Normal stream but have even more advanced syllabus in terms of science subjects (i.e., Mathematics and Sciences). Such over-emphasis on science compared to art may not only lead to a possible lapse in the education system in terms of developing multi-faceted creativity, but instead promote the development of strong preferences to process information spatially (i.e., spatial style), as usually exhibited by scientists and engineers (Chong, 2017; Kehk, 2019). In the current study, we were interested in examining how Singapore's school streaming system may affect students' visual abilities, styles, and creativity, by comparing the cognitive style of Singaporean students with the cognitive style of their counterparts from USA and Russia (as reported in ref. Kozhevnikov et al., 2010). Finally, significant gender differences were identified and reported in both object and spatial visual abilities and styles in previous research (see Blazhenkova & Kozhevnikov, 2009 for a review), with male overperforming females on spatial tasks and preferring to process information spatially, and females overperforming males on object tasks and reporting higher object visual style. As such, we were also interested in exploring gender differences in visual ability and style in our Singaporean sample and examining possible ways in which these differences could relate to their artistic and scientific creativity.

STUDY 1

METHOD

Participants

One hundred students (48 males) were recruited from one of the typical secondary schools in Singapore, consisting of students with average academic abilities (relative to Singapore's national average). All

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[1] Singapore students have mathematics and sciences as compulsory and examinable parts of the school syllabus up to Secondary 2 (grade 8; Tan et al., 2016), while art is a non-examinable subject (Cheng, 2008).

[2] The streaming scheme is a unique practice adopted by the Singapore education system: students are assigned to these two streams based on their PSLE scores (Primary School Leaving Exam), given to the student after Primary 6 (grade equivalent to 6th grade in the US system), composed of the scores on Math, Science, English, and Mother Tongue Language subjects (see https//beta.moe.gov.sg/secondary/courses/ for more detail). In the context of Singapore's education system, Express stream consists of about 50% of students, while Normal stream consists of about 25% of students (Liu et al., 2005; Ng & Choo, 2020).

participants, aged 13–14 years old, were selected from Secondary 2 (equivalent to the Grade 8 of the US system), with 68 students (36 males) from Express stream and 32 students (12 males) from Normal stream.

Materials

All students were administered the following assessments, grouped into creativity, and visual ability and style assessments.

Creativity assessments

We used three creativity measurement instruments—TTCT-picture completion task, TTCT, IPS Task (Spatial Subscale), IPS, and CBI (artistic and scientific scales).

Torrance Test of Creative Thinking-picture completion task

The TTCT is one of the most widely used assessment of divergent thinking (Dietrich & Kanso, 2010; Torrance, 1972), which has been shown to measure domain-specific artistic creativity (Kozhevnikov et al., 2013). For this study, only the picture completion task was used, where participants were instructed to finish 10 incomplete drawings and make up an interesting title for each within 10 minutes. Their drawings were scored according to "Torrance Test of Creativity Thinking Streamlined Scoring Guide for Figural Forms A and B" (Torrance, 1972). Each TTCT subscale: fluency, originality, elaboration, abstractness of titles, and resistance to premature closure was assessed by two separate judges, with inter-judge reliability .80. Torrance (1998) has provided the internal consistency reliability from the Kuder-Richardson 21 (KR–21) estimates, which ranged from .89 to .94.

Insight Problem Solving Task (Spatial Subscale)

All insight problems require overcoming the constraints of routine ways of thinking, and solutions to spatial insight problems particularly lie in removing a self-imposed spatial constraint (Dow & Mayer, 2004). For the current study, 10 out of 17 insight problems, appropriate for secondary school level, were selected from the spatial subscale of the insight problem packet provided by Dow and Mayer (2004; see Figure 1 for an example). Participants had 15 minutes to solve 10 problems. The creativity score was calculated as a sum of the correct items. The internal reliability (Cronbach's alpha) of IPS, computed on the current sample is .60.

Creative Behavior Inventory

The CBI is a self-report instrument assessing individuals' creative behavior and achievements in art, science, and literature domains (Hocevar, 1979). For the purpose of this study, we used only assessments of creative behavior in art and science. Participants reported the frequency of their creative behavior and achievements in visual art and science on a 6-point scale with "1" denoting never and "6" denoting more than six times. Typical items were as follows: "Drew a picture for aesthetic reasons" or "Entered a project

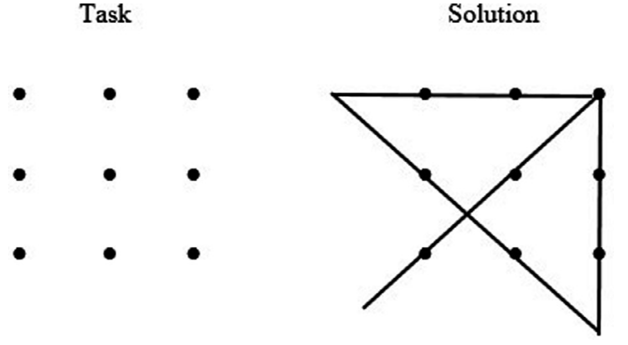

FIGURE 1. An item from Insight Problem Solving.
Note. The task is to draw four continuous straight lines, connecting all the nine dots without lifting pencil from the paper.

into a science contest." Some questions were adapted to suit the common experience of secondary school students in Singapore and others found inapplicable were removed. In total, we kept 17 items, out of which nine items from the art scale, and eight from the science scale. Scores for domain-specific creative behavior were calculated by averaging the ratings of respective items separately for each scale. The internal reliability (Cronbach's alpha) of CBI in art and science domains, computed on the current sample, are .78 and .75, respectively.

Visual ability assessments

These included assessments of object and spatial abilities. The spatial assessments included Paper Folding Task (PFT) and Mental Rotation Task (MRT). The object assessments included Degraded Picture Task (DPT), Camouflage Task (CT).

Paper Folding Test

The PFT measures spatial visualization ability, which reflects the ability to apprehend, encode, and mentally manipulate abstract spatial forms (Ekstrom, French, & Harman, 1976). The paper-and-pencil test consists of 10 items representing successive drawings of two- or three-folds made to a square sheet of paper and a final drawing showing the folded paper with a hole punched through it (see Figure 2). The participants were to select one correct drawing among five drawings depicting how the paper would look when fully unfolded. Participants have 3 minutes to complete the test. The score was calculated as the number of correct answers minus the quotient of the number of incorrect answers divided by four (total score = correct – incorrect/4) (Ekstrom et al., 1976). The internal reliability (Cronbach's alpha) of the test is .84 (Ekstrom et al., 1976).

Mental Rotation Test

The MRT measures abilities to rotate mentally spatial forms (Shepard & Metzler, 1971). For the current study, we used the paper-and-pencil version of the test (Vandenburg & Kuse, 1978), in which the participants were asked to identify the correct drawings of the rotated images of a target object. Each test item was designed to contain a drawing of the target object on the left and four drawings either identical or as mirror-images to the target object on the right (see Figure 3). Out of the four options, only two are identical to the target object. We adopted the strict marking criteria of the test—participants were given a score of "1" only when they correctly identified both drawings that are identical to the target object to avoid guessing (Vandenburg & Kuse, 1978). Participants were given 3 minutes to complete the test consisting of 12 items. The internal reliability (Cronbach's alpha) of the test is .88 (Vandenburg & Kuse, 1978).

Degraded Picture Test, DPT

DPT involves top-down holistic processing to fill in the obscured portions of the degraded object, which relates to object visual ability (Kosslyn, 1994; Kozhevnikov et al., 2005). We used a paper-and-pencil version of the DPT, adapted from the Object Imagery Ability Test (MM Virtual Design, 2004). The DPT included 10 degraded line-drawings of common objects embedded in visual noise. Participants had 2 minutes to complete the test. The total score was calculated as the number of correct answers. Participants scored 1 mark for each correctly identified object, and 0.5 mark if the identified object had a similar shape to the correct one (see Figure 4 for an example item with its scoring). The internal reliability (Cronbach's alpha) of the test, computed on the current sample, is .84.

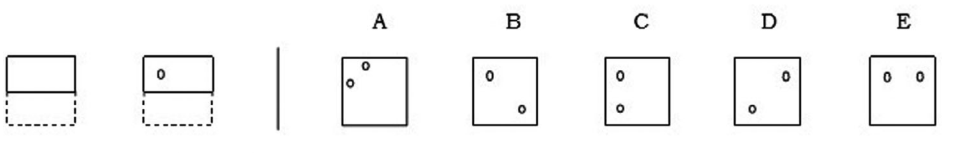

FIGURE 2. An example item from Paper Folding Test.
Note. The third option on the right is the correct answer. Reproduced from Kit of factor-referenced cognitive tests with the permission of the Educational Testing Service.

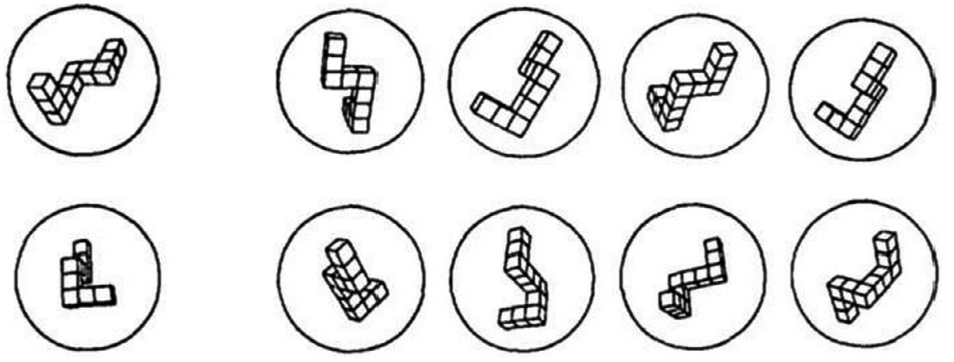

FIGURE 3. Sample items from Mental Rotation Test.
Note. The correct answer is the first and the third figures on the right. Republished with the permission of SAGE Publishing from Perceptual and Motor Skills, Mental Rotations, A group Test of Three-Dimensional Spatial Visualization (Vandenberg & Kuse, 1978).

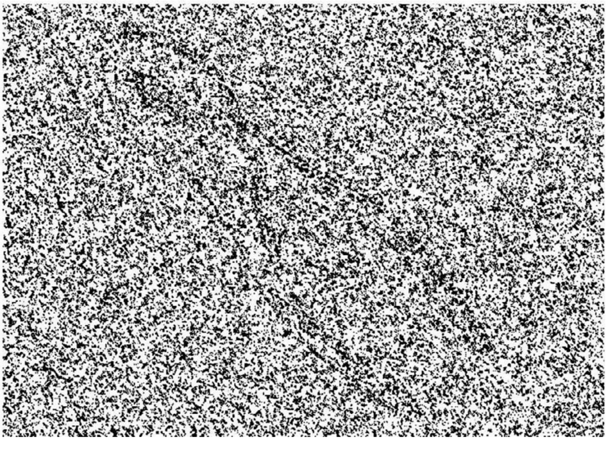

FIGURE 4. An example item from Degraded Picture Test.
Note. Participants will get a score of "1" for correctly identifying the object as "pliers," and "0.5" for "tweezers." Reproduced with the permission of MM Virtual Design, LLC.

Camouflage Test

The CT is designed to assess' object ability. The task requires participants to recognize and name an animal or object that is hidden and difficult to discriminate from its background.[3] The CT is a computerized test, which consists of 54 trials, at the beginning of which participants are presented with an image of an animal in camouflage and asked to identify the hidden animals (see Figure 5). No time limit was allocated for the test and once participants had identified the object, they were to click "OK," with a text box subsequently popping up for them to key in their answers. If participants were not able to recognize the object,

[3] In the camouflage test, it would be more effective to engage in conjunction search, using knowledge of object properties such as color, shape, texture and brightness, and engaging in feature binding (Treisman, 1988), in order to locate and identify the hidden objects embedded within the noise of the physical environment. Thus, the test should tap on more than just simple object recognition, but also on higher level processes of the integration of object properties to achieve figure-ground segregation (Rubin, 2001).

FIGURE 5. An example item of Camouflage Test.
Note. The correct answer is 'frog'.

they were asked to click "I am not able to recognize." The internal reliability (Cronbach's alpha) of the test, computed on the current sample, is .88.

Cognitive style assessments

These included self-assessments of object and spatial style, as measured by the object and spatial scales of the Object-Spatial Imagery Questionnaire (OSIQ, Blajenkova, Kozhevnikov, & Motes, 2006; Blazhenkova & Kozhevnikov, 2009). The OSIQ questionnaire consists of 15 items assessing object cognitive style (e.g., "My mental pictures are very detailed precise representations of the real things"), while the spatial scale consists of 15 items assessing spatial cognitive style (e.g., "My images are more like schematic representations of things and events"). Participants were asked to read each statement and rate on a 5-point scale with "5" indicating absolute agreement with the statement and "1" indicating total disagreement. Scores for object and spatial styles were calculated by averaging the 15 ratings. The internal reliability (Cronbach's alpha) of the object and spatial scales are .83 and .79, respectively (Blazhenkova & Kozhevnikov, 2009).

Procedure

The current study was a part of a larger project, in which participants' visual abilities were assessed through paper-and-pencil tests spread into a 4-month period during a school term and later through computerized tests at the end of the term. Specifically, during the school term, the students were given a combination of paper-and-pencil object and spatial visual ability tests during the last 10 minutes of selected art classes in the classrooms, including PFT for 3 minutes, DPT for 2 minutes, and MRT for 3 minutes. At the end of the term, students were brought to the school's computer lab in groups of their respective classes to complete computerized CT, OSIQ, and paper-and-pencil creativity assessments: TTCT, IPS, and CBI. On average, it took to complete 20 minutes for CT, 5 minutes for both object and spatial style scales of OSIQ, 10 minutes for TTCT, 15 minutes for IPS and 5 minutes for CBI, with 2 minutes of resting time in-between each test.

RESULTS

Due to the absence of the students on different testing days as well as technical issues when recording the students' entries, 37% of all the data-points were randomly missing, with some students not completing some of the computerized tests. The data of those students with missing scores on more than one assessment were deleted from the analyses, leaving a final dataset of 73 students (30 males; 47 students from Express stream and 26 students from Normal stream) with 4.93% missing data for this set replaced by mean of the corresponding student's class. Their descriptive data can be found in Table 1.

TABLE 1. Mean and Standard Deviation for Study 1 Assessments

	Mean	*SD*
CBI-art	1.32	0.85
CBI-science	0.98	1.06
TTCT	43.88	13.04
IPS	0.95	0.93
PFT	4.43	3.23
OSIQ-object	3.30	0.62
OSIQ-spatial	2.95	0.53
CT	32.91	12.36
DPT	2.16	1.21
MRT	2.69	2.36

CBI, Creative Behavior Inventory; CT, Camouflage Task; DPT, Degraded Picture Task; IPS, Insight Problem Solving; MRT, Mental Rotation Task; OSIQ, Object-Spatial Imagery Questionnaire; PFT, Paper Folding Task; TTCT, Torrance Test of Creative Thinking.

Relationship between visual abilities, cognitive styles, and creativity measures

Considering the unique features of the Singaporean sample, with no previous data on the visual creativity structure of children and adolescents available for reference, in order to explore the structure of relationships between the different dimensions of visual abilities, cognitive styles, and creativity in Singaporean students, we conducted a PCA using a Varimax rotation on 10 assessments (TTCT, IPS, CBI-art, CBI-science, PFT, MRT, DPT, CT, OSIQ-object, and OSIQ-spatial).[4] Correlations between the measures are presented in Table S1. To normalize the data and minimize differences between the different, non-homogenous assessments (e.g., self-assessment scales, paper-and-pencil, and computerized assessments), we used standardized Z-scores of each of the 10 assessments. Based on the scree plot criterion (Cattell, 1966), two factors (out of 10) were identified and retained (these two factors explained 49.31% of variance. Principal component loadings for all the assessments are presented in Table 2. Object ability (DPT), object styles (OSIQ-object), and artistic creativity (CBI-art and TTCT) measures were loaded on the first factor; while spatial ability (PFT and MRT), spatial style (OSIQ-spatial), and scientific creativity (CBI-science and IPS) measures were loaded on the second factor (although OSIQ-object was also significantly loaded on the second factor). Thus, we identified the first factor as *art*, and the second one as *science*, where the first factor consists largely of artistic creativity measures and object ability measures closely associated with success in art, while the second factor consists largely of scientific creativity measures and spatial ability measures closely associated with success in science (Blazhenkova & Kozhevnikov, 2010). The factor structure supports our hypothesis that even in students aged 13–14 years, artistic and scientific creativity could be clearly separated, with object ability and object cognitive style related to artistic creativity, and spatial ability and spatial cognitive style related to scientific creativity.

Visual abilities and cognitive styles as predictors of creativity

Factor analyses have shown that spatial and object visual abilities and cognitive styles load significantly on scientific and artistic creativity respectively. However, to further investigate the separate effects of visual ability and cognitive style, and the relative contribution they may have in predicting the respective domains of creativity, regression analyses, with visual abilities and cognitive styles as predictors and domain-specific creativity as a regressor, were also conducted. Firstly, for each participant, we computed Composite Spatial Ability and Composite Object Ability values by averaging the standardized Z-scores of spatial assessments (PFT and MRT) and object assessments (DPT and CT), respectively. This procedure is often used in psychology research to derive a more reliable measure of interest, in particular, when a number of tests

[4] Our sample size of 73 students corresponded to the recommendations for the sample size to be larger than 5 times the number of assessments (Bryant and Yarnold, 1995; Hatcher, 1994). Furthermore, The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .62 and that showed the total sample size of 73 participants was adequate.

TABLE 2. Principal Component Loadings for Study 1 Assessments (after Varimax Rotation)

	Factor 1	Factor 2
CBI-art	**.774**	.152
CBI-science	.020	**.629**
TTCT	**.750**	.040
IPS	.203	**.464**
OSIQ-object	**552**	.498
OSIQ-spatial	.270	**.751**
CT	**.524**	.260
DPT	**.830**	.039
PFT	.054	**.685**
MRT	.084	**.626**

Note. Bold indicates the highest loadings within a factor. CBI, Creative Behavior Inventory; CT, Camouflage Task; DPT, Degraded Picture Task; IPS, Insight Problem Solving; MRT, Mental Rotation Task; OSIQ, Object-Spatial Imagery Questionnaire; PFT, Paper Folding Task; TTCT, Torrance Test of Creative Thinking.

purporting to measure the same construct have low reliability and validity (e.g., Evans, 1996).[5] Similarly, Grand-Scientific Creativity (GSC) and Grand-Artistic Creativity (GAC) scores were created for each participant by averaging their standardized Z-scores of all scientific (CBI-science and IPS) and all artistic creativity measures (CBI-art and TTCT), respectively.

A linear regression[6] with Composite Object Ability, Composite Spatial Ability, Object Style, and Spatial Style as predictors and GAC as the criterion variable was significant, $R^2 = .39$, $F(4, 68) = 10.71$, $p < .001$. Neither the Composite Spatial Ability nor Spatial Style scores predicted GAC, $ß = 0.08$, $t(72) = 0.74$, $p = .46$ and $ß = -0.13$, $t(72) = -1.10$, $p = .28$, respectively, while both Composite Object Ability and Object Style significantly predicted GAC, $ß = 0.31$, $t(72) = 3.12$, $p < .01$ and $ß = 0.51$, $t(72) = 4.67$, $p < .001$, respectively. The stepwise regression method revealed that Object Ability alone predicted 16.6% of variance in GAC, $F(1, 71) = 14.11$, $p < .001$, while the model with Object Ability and Object Style as independent variables predicted 37.5% of variance, $F(2, 70) = 20.97$, $p < .001$]; thus Object Style explained 20.9% of unique variance in GAC beyond Object Ability.

Next, a linear regression with Composite Object Ability, Composite Spatial Ability, Object Style, and Spatial Style as predictors and GSC as the criterion variable was also significant, $R^2 = .26$, $F(4, 68) = 6.01$, $p < .001$. Neither Composite Object Ability nor Object Style scores predicted GSC, $ß = 0.18$, $t(72) = 1.70$, $p = .09$ and $ß = -0.08$, $t(72) = -0.67$, $p = .50$, respectively. Surprisingly, Composite Spatial Ability only marginally predicted GSC, $ß = 0.23$, $t(72) = 1.96$, $p = .05$, while Spatial Style predicted GSC significantly $ß = 0.32$, $t(72) = 2.45$, $p = .01$. Further regression analyses showed that Spatial Ability alone predicted only 15.1% of variance in GSC, $F(1, 71) = 12.60$, $p = .001$, while the model with Spatial Ability and Spatial Style as independent variables predicted 22.8% of variance, $F(1, 70) = 10.32$, $p < .001$]; thus Spatial Style explained 7.7% of unique variance in GSC beyond Spatial Ability.

Further simple bivariate correlation and semipartial correlations between visual abilities, styles, and corresponding creativity dimensions are presented in Table 3. Although visual ability and corresponding style correlate significantly with each other ($r = .24$ for object and $r = .44$ for spatial dimensions) and with corresponding creativity dimension, consistently with the results of the regression analyses, style predicts corresponding creativity dimensions even after the shared variance between ability and style are removed.

[5] In the field of visual cognition, this procedure is commonly used to derive more meaningful measures of visual (object or spatial) abilities and reduce possibility of receiving high scores by applying alternative non-visual strategies to the tasks (Blazhenkova & Kozhevnikov, 2009; Kozhevnikov et al., 2010). For example, both PFT and MRT are often solved by using analytical strategies, but it is unlikely that an individual will figure out successful analytical solutions for both tasks.

[6] A-priori sample size analysis for multiple regression (Cohen, 1988), where we used a power of .80 and alpha .05 for the probability level, and anticipated effect size of .2 indicated that our sample size of 73 participants was adequate (a minimum sample size for this type of analysis is 65).

TABLE 3. Simple Correlations and Semipartial Correlations between Object Ability/Style (OA/OS) and Artistic Creativity and between Spatial Ability/Style (SA/SS) and Scientific Creativity

	Artistic-Grand		**Scientific-Grand**
Object Ability	.41*	Spatial-Ability	.39**
Object-Style	.53**	Spatial-Style	.44*
Residual: OA-OS	.35**	Residual: SA-SS	.30**
Residual: OS-OA	.50**	Residual: SS-SA	.24*

Note. Residual: OA-OS = Object-Ability minus the shared variance with Object-Style; Residual: OS-OA = Object-Style minus the shared variance with Object-Ability; Residual: SA-SS = Spatial-Ability minus the shared variance with Spatial-Style; Residual: SS-SA = Spatial-Style minus the shared variance with Spatial-Ability.
** $p < .01$(two-tailed). * $p < .05$ (two-tailed).

In summary, the two-factor structure revealed in Study 1 suggests that dissociation between artistic and scientific dimensions of creativity exists in students of ages 13–14 years old. Furthermore, consistent with the results of Kozhevnikov et al. (2013), the results of this study demonstrate that TTCT and IPS assessments are loaded on different factors, suggesting that they assess different types of domain-specific creativity (in art and science respectively). Finally, while both visual abilities and styles significantly predict corresponding creativity dimensions, visual cognitive style (object and spatial) predict unique variance in corresponding creativity dimensions beyond visual ability (object and spatial, respectively).

STUDY 2

METHODS

Participants

Two hundred seventy participants (113 males) were recruited from a different typical secondary school in Singapore. All participants 13 and 14 years of age were recruited from three grades (Secondary 1–3; Grades 7–9 equivalents of the US system), comprising of 20 classes. Out of the 270 participants, 16 participants were randomly missing stream information, with the remaining 174 participants (72 males) in Express stream and 80 participants (32 males) in Normal stream.

Materials

All students were administered the following assessments, grouped into creativity, and visual ability and style assessments. Similar to Study 1, we employed TTCT, IPS, and a modified version of art and science CBI scales as creativity measurement instruments. Due to overall low self-assessments on the CBI art and science scales in Study 1, in the modified version of CBI we retained only four items per scale, while other items, related to students' participation in exhibition and contests (e.g., "Received an award for artistic accomplishment" and "Entered a mathematical paper into a contest") were removed, as they were consistently rated as "1" (never) by most of the students.

The spatial assessments included PFT and MRT, and the spatial scale of the OSIQ. The object assessments included DPT and Vividness of Visual Imagery Questionnaire (VVIQ), and the object scale of the OSIQ. The VVIQ, a frequently utilized measure for assessing the vividness of an individual's visual imagery (Marks, 1973), was used to measure object ability instead of CT, due to the time constraints during Study 2 (out of all the visual ability assessments, CT required the longest time).[7] The VVIQ consists of 16 items where participants rated on a 5-point scale the vividness of mental imagery of scenarios they were instructed to create. There were four scenarios and a total of 16 items (e.g., "The sun is rising above the horizon into a hazy sky"). No specific instructions were given to participants to keep their eyes opened or closed while completing the assessment. The internal reliability (Cronbach's alpha) of the test is .88 (McKelvie, 1995).

7 Averaged Z-score of DPT and VVIQ tasks have been used in previous studies to reliably assess object ability (Blazhenkova et al., 2011; Kozhevnikov et al., 2010; Kozhevnikov et al., 2013). In a similar study by Kozhevnikov et al. (2013) with Singaporean adults, VVIQ loaded higher on artistic creativity factor (.77) than CT in Study 1 (.52). Support for VVIQ as a reliable measure of object imagery ability comes from neuroimaging studies showing that the questionnaire taps the ventral brain areas underlying object imagery (Amedi et al., 2005).

TABLE 4. Mean and Standard Deviation for All Study 2 Measures

	Mean	*SD*
CBI-art	3.03	0.97
CBI-science	3.07	0.96
TTCT	40.62	12.73
IPS	1.02	1.25
PFT	4.59	2.81
OSIQ-object	3.39	0.66
OSIQ-spatial	3.06	0.58
VVIQ	3.47	0.86
DPT	0.24	0.13
MRT	0.64	0.13

CBI, Creative Behavior Inventory; DPT, Degraded Picture Task; IPS, Insight Problem Solving; MRT, Mental Rotation Task; OSIQ, Object-Spatial Imagery Questionnaire; PFT, Paper Folding Task; TTCT, Torrance Test of Creative Thinking; VVIQ, Vividness of Visual Imagery Questionnaire.

Procedure

Study 2 was conducted using online methods via Qualtrics, where students completed the tests in two parts. The first part consisted of DPT, PFT, and MRT, while the second part consisted of TTCT, IPS, OSIQ, CBI, and VVIQ, which were also completed in the order mentioned above. Both parts of the study were completed 4–5 weeks apart depending on the students' schedule, with 1 hour allocated for students to complete each part of the study. Part 1 was completed in class using students' personal learning device,[8] while Part 2 was completed either via their personal learning devices in class or at home due to timetable and scheduling differences. For all computerized tests, the test format and instructions given to the students in Study 2 were identical to those given to them in Study 1. Accuracy and response time for MRT, Camo, and DPT were recorded online, similar to how it was done in Study 1. For time-limited paper and pencil tests (Torrance, IPS, and PFT), students were given a copy of the original test before the start, with a specific time countdown timer that automatically skipped to the next page requesting for students to stop and upload their answers once the time was up, via either photographed or scanned versions of their answers. Students were given multiple choice attention checks at the end of each part of Study 2.

RESULTS

Due to technical issues during online data collection, 3.45% of data points were found to be randomly missing. One student with missing data on both spatial ability assessments (PFT and MRT), as well as stream information, was removed from the study. The remaining missing data were replaced with values obtained from the mean of the student's corresponding stream and secondary level. The final analysis was conducted with a total of 269 students with 173 participants (72 males) in Express stream and 80 participants (32 males) in Normal stream. The data of 15 students who were missing information on their streams were omitted from the analysis comparing students from different streaming scheme. Descriptive statistics is presented in Table 4.

Path analysis

The goal of Study 2 was to confirm dissociation between artistic and scientific creativity as well as multidimensional relations between visual ability, visual style, and corresponding creativity dimensions reported in Study 1. Considering previous research on artistic and scientific creativity in adults (Kozhevnikov et al., 2013) as well as the results of Study 1 with students 13–14 years old, the following hypotheses were tested using path analysis (as shown in Figure 6): (a) artistic and scientific types of creativity are unrelated constructs, and thus will not share significant variance; (b) visual ability (object and spatial) will significantly

[8] All students at this secondary school own a tablet, referred to as a personal learning device (PLD). Under the MOE's National Digital Literacy Programme (NDLP), all secondary school students will own a PLD by end of 2021. PLDs consists of either tablets or laptops, as per each school's choice.

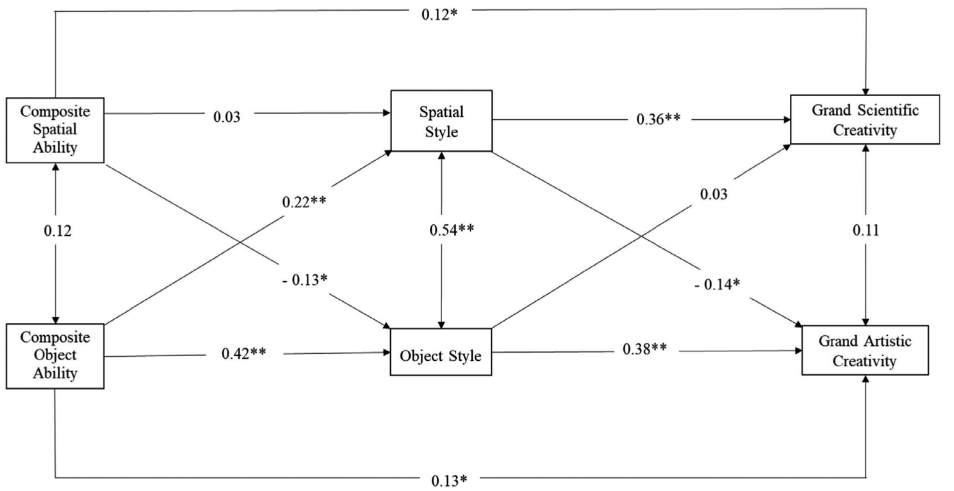

FIGURE 6. Path analysis model of effects of visualization ability and style on domain-specific creativity. $*p < .05$. $**p < .01$

contribute to the corresponding (but not opposing) visual style (object and spatial); (c) visual style (object and spatial) will explain a larger proportion of variance in the corresponding creativity dimension (artistic and scientific) as compared to the corresponding visual ability (object or spatial); and (d) since object and spatial visual processing resources are distinct, there will be no significant relation between object and spatial abilities, as well as between object and spatial style.

As in Study 1, GSC and GAC scores were created for each participant by averaging the standardized Z-scores of two scientific (CBI-science and IPS) and two artistic creativity measures (CBI-art and TTCT), respectively. Similarly, for each participant, we computed Composite Spatial Ability and Composite Object Ability measures by averaging the standardized Z-scores of spatial assessments (PFT and MRT) and object assessments (DPT and VVIQ), respectively Standardized Z-scores were also computed for OSIQ-spatial (Spatial Style) and OSIQ-object (Object Style). The correlations between all assessments are presented in Table S2.

Path analysis was conducted using lavaan in R, with Maximum Likelihood as the estimator used. Model fit was evaluated through model Chi-square (χ^2), Steiger–Lind.

Root Mean Square Error of Approximation (RMSEA), comparative fit index (CFI) and Standardized Root Mean Square Residual (SRMR; Kline, 2016). The good model fit cut-off for χ^2 is where $p > .05$, RMSEA < .07, CFI ≥ .96 and SRMR < .06 (Hu & Bentler., 1999). χ^2 p-value and RMSEA did not indicate good model fit (χ^2: $p = .03$, RMSEA = .10). However, based on CFI and SRMR values, the overall fit for the model was acceptable, with CFI = .98 and SRMR = .03 deemed as sufficient to indicate good model fit (Hu & Bentler, 1999). Consistent with Study 1, the results of path analysis (see Figure 6) show that visual cognitive styles can predict corresponding creativity dimensions beyond visual ability. As shown in Figure 6, according to our hypotheses, both Spatial Style and Composite Spatial Ability significantly predicted GSC ($\beta = .36$, $p < .001$ and $\beta = .12$, $p < .05$ respectively). Similarly, both Object Style and Composite Object Ability significantly predicted GAC ($\beta = .38$, $p < .001$ and $\beta = .13$, $p < .05$ respectively). Furthermore, Spatial Style negatively predicted GAC ($\beta = -0.14$, $p < .05$), while Object Style did not significantly predict GSC ($\beta = .03$, $p > .05$). Importantly, GSC and GAC ($\beta = .11$, $p > .05$) did not share significant variance, supporting our hypothesis that they are present as two distinct constructs in 13- to14-year-old students.

As predicted, Composite Object Ability was shown to significantly predict Object Style ($\beta = 0.42$, $p < .001$), however, in contrast to our predictions, Composite Spatial Ability did not significantly predict Spatial Style ($\beta = .03$, $p > .05$). While Composite Spatial Ability was showed a significant negative effect on Object Style ($\beta = -0.13$, $p < .05$), surprisingly, Composite Object Ability significantly predicted Spatial Style

($\beta = 0.22$, $p < .001$). There was also significant covariance between Spatial and Object Styles ($\beta = 0.54$, $p < .001$), while Composite Spatial and Object Ability ($\beta = 0.12$, $p > .05$) did not share significant variance.

Overall, the results of path analysis support our model that (a) artistic and scientific creativities are distinct constructs in students of 13–14 years old and (b) visual cognitive style (object and spatial) significantly predict corresponding creativity dimensions beyond visual ability (object and spatial, respectively). In contrast to our predictions, however, there was a significant effect of Composite Object Ability on Spatial Style as well as significant covariance between Spatial and Object Styles (which will be discussed below).

COMPARISONS BETWEEN EXPRESS AND NORMAL STREAM CLASSES

There was a significant difference between Express and Normal classes in their GSC, for both schools, $F(1, 72) = 10.09$, $p < .01$ (Study 1), and $F(1, 243) = 14.71$, $p < .001$ (Study 2) in the favor of the Express classes. The Express classes also had significantly higher scores on Spatial Ability, $F(1, 72) = 16.25$, $p < .001$ (Study 1), and $F(1, 243) = 40.86$, $p < .001$ (Study 2), and displayed either marginally significant difference, $F(1, 72) = 3.04$, $p = .09$ (Study 1) or significant difference, $F(1, 244) = 6.15$, $p = .01$ (Study 2) in their Spatial Style.

There were no significant differences between the streams in their GAC, $F(1, 72) = 1.96$, $p = .16$ (Study 1) and $F(3, 243) = 1.59$, $p = .21$ (Study 2), and no significant differences in Object Style, $F(1, 72) = 0.23$, $p = .63$ (Study 1) and $F < 1$, $p = .36$ (Study 2). The difference in Object Ability between streams was significant, also in favor of the Express classes, $F(1, 72) = 4.59$, $p = .04$ (Study 1) and $F(1, 243) = 5.83$, $p = .02$. While it is not surprising that students in the Express stream, who receive a more advanced syllabus in terms of science subjects, had significantly higher Spatial Ability scores than students in the Normal stream, it is surprising that students from the Express stream from both schools also displayed higher Object Ability. It was also surprising that the students from the Express stream were not different from those from the Normal stream in neither Object Style nor Spatial Style.

OBJECT AND SPATIAL COGNITIVE STYLE COMPARISONS

Table 5 presents the means and SDs of Object and Spatial Styles for samples chosen for comparisons with Object and Spatial Styles of Singaporean students from Express and Normal streams. Specifically, the additional samples chosen for comparisons were: (a) a sample of 13–14 years old Russian and US adolescents from typical secondary schools in Russia or US (the datasets are taken from Blazhenkova et al., 2011 and Kozhevnikov et al., 2010); (b) two samples of US undergraduate and graduate college students (the datasets are taken from Kozhevnikov et al., 2010), with students majoring in arts (painters, designers) in the first sample, and students majoring in science (physics, mathematics, and computer science) in the second sample.

For Object Style, one-way ANOVA revealed a significant difference between the groups, $F(6, 594) = 13.96$, $p < .001$. Tukey's HSD tests revealed that Singaporean students from both Express and

TABLE 5. Comparison of Mean and Standard Deviation of OSIQ Object and Spatial Scores across Samples

	Singaporean students Express Stream		**Singaporean students Normal Stream**		**Russia/US students**	**US College Students**	
	Study 1	**Study 2**	**Study 1**	**Study 2**		**Art major**	**Science major**
N	**51**	**174**	**22**	**80**	**123**	**71**	**74**
	Mean (*SD*)	**Mean (*SD*)**	**Mean (*SD*)**	**Mean (*SD*)**	**Mean (*SD*)**	**Mean (*SD*)**	**Mean (*SD*)**
Object Style	3.39 (0.59)	3.45 (0.63)	3.31 (0.77)	3.29 (0.66)	3.65 (0.62)	4.01 (0.52)	3.22 (0.68)
Spatial Style	3.07 (0.51)	3.13 (0.60)	2.92 (0.58)	2.93 (0.48)	2.62 (0.62)	2.69 (0.60)	3.17 (0.58)

Note. Singaporean, Russian and US students were 13–14 years old, while US college students had a mean age of 22 years old.

Normal classes had significantly lower Object Style scores than their Russian and US counterparts (all *ps* $< .05$) as well as US students majoring in arts (all *ps* $< .001$). Among all Singaporean students, other than Express stream students (Study 2) who had higher Object Style scores than US college students majoring in science ($p = .01$), the scores of all other Singaporean groups on the OSIQ object scale were no different from those of US college students majoring in science (all *ps* $> .15$). For Spatial Style, one-way ANOVA also revealed significant difference between the groups, $F(6, 594) = 13.65$, $p < .001$. Tukey's HSD tests revealed that Singaporean students from both Express and Normal classes had no significant differences in their Spatial Style from US College Students majoring in sciences (all *ps* $> .14$) but had significantly higher Spatial Style than their Russian and US counterparts (all *ps* $< .05$). Therefore, independently of their streams as well as object and spatial abilities, visual style profile of Singaporean students is biased towards Spatial Style, in comparison with Russian and US students of similar age and is rather similar to that of US college students majoring in science.

GENDER DIFFERENCES

As for gender differences, consistent with Blazhenkova and Kozhevnikov (2009), the results of one-way ANOVA revealed that females scored significantly higher on Object Ability than males, $F(1, 71) = 4.09$, $p < .05$ in Study 1 and marginally higher than males, $F(1, 268) = 3.09$, $p = .08$ in Study 2. Surprisingly, we did not find significant differences between males and females in their Spatial Ability, $F < 1$, $p = .56$, although previous research reported consistent differences in Spatial Ability in favor of males (see Blazhenkova & Kozhevnikov, 2009). However, there was a significant difference in Spatial Style, with males reporting higher Spatial Style than females, $F\ (1,71) = 4.60$, $p < .05$ (Study 1) and $F\ (1,268) = 23.70$, $p < .001$ but no differences were found in Object Style, $F < 1$, $p = .30$ (Study 1) and $F < 1$, $p = .66$ Study 2). With regard to gender differences in creativity, previous literature has reported inconsistent results that may differ due to differences in tests used in the studies (Baer & Kaufman, 2008; Forisha & Goldman, 1981; Voyer, Voyer, & Bryden, 1995). For artistic creativity, there were no significant differences between males and females, $F(1, 71) = 1.11$, $p = .29$ (Study 1) and $F(1, 268) = 2.67$, $p = .10$ (Study 2). As for scientific creativity, there were no significant differences between males and females, $F < 1$, $p = .50$ in Study 1, but there was a significant difference in favor of males, $F(1, 268) = 14.79$, $p < .001$ in Study 2.

DISCUSSION

Our first research question was to examine whether artistic and scientific creativity can be clearly dissociated in 13–14 years old secondary school students. Indeed, the results of both Studies 1 and 2 not only challenge the notion of visual creativity as a general ability and foundation of current creativity assessments, but also demonstrates that dissociation between artistic and scientific dimensions of creativity already exists in 13–14 years old students. Moreover, the results of Study 1 suggest that visual creativity relies on separate, distinct information processing resources. While artistic creativity relies on the visual-object processing resources (underpinned by the ventral pathway in the brain), spatial creativity is associated with visual-spatial processing resources (underpinned by the dorsal pathway), as the former was loaded on the same factor as all object ability assessments, while the latter was loaded on the same factor as all assessments of spatial ability. While neuroscience research on visual creativity continues to utilize divergent thinking tests in measuring visual creativity (Aziz-Zadeh, Liew, & Dandekar, 2013; Zhu et al., 2017) or assess neural processes of creativity through visual art assessments alone (Ellamil, Dobson, Beeman, & Christoff, 2012), our findings propose specific cognitive and neural processes underlying artistic and scientific creativity, thus paving the way for future neuroscience studies to look for specific neural circuits underlying different domains of visual creativity.

Our second research question was to examine the relative contribution of visual style versus visual ability (object or spatial) to the corresponding type of creativity (artistic or scientific). Our findings from both Studies 1 and 2 showed that although both visual abilities and corresponding cognitive style (object and spatial) reliably predicted artistic and scientific creativity, object and spatial styles explained significantly larger proportion of variance in corresponding creativity dimensions than corresponding visual ability. Thus, cognitive style seems to be the most reliable predictor of creativity, not only in adults but also in secondary school students. Overall, considering that object and spatial cognitive styles are reliable predictors of learning preferences and career choices in arts and sciences, respectively (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009), and rely on unique processing resources developed under socio-cultural influences beyond corresponding abilities (Kozhevnikov et al., 2014), our findings suggest that educational experiences and socio-cultural forms of support are extremely important for the development of domain-specific creativity. Indeed, recent research highlights the importance of different experiences and environments on the development of creativity in children and adolescents (Barbot, Lubart, & Besançon, 2016), consistent with our results that having high object or spatial ability alone is insufficient to become a creative artist or scientist, respectively. Corresponding educational experiences, such as presenting art or science topics in depth, and learning environments that places importance on building educational curricula based on the amount and types of support needed to provide optimal resources for creative development are also critically important at this age.

The most unexpected results of both studies were that the OSIQ object scale was significantly loaded not only on artistic creativity but also on scientific creativity (Study 1), there was significant correlation between object ability and the OSIQ spatial scale, as well as significant covariance between OSIQ spatial and object scales (Study 2). Similarly, the lack of significant relation between spatial ability and spatial style in Study 2 seems puzzling. These findings are highly unusual and indicate the distinctiveness of Singaporean students' visual style, as the results of all the previous studies conducted with US or Russian samples with both adults and children consistently demonstrated (a) a trend for negative correlation between OSIQ object and spatial scales, and (b) significant correlations between visual ability and corresponding visual style, as well as the loading of the OSIQ object scale on the same factors as both object ability and spatial ability in PCA analyses (Blajenkova et al., 2006; Blazhenkova et al., 2011; Blazhenkova & Kozhevnikov, 2009, 2010; Kozhevnikov et al., 2013). Similarly, although Singaporean females scored significantly higher than males on object ability, we did not find significant gender differences in their object style, in contrast to the Russian and US samples, where females had both higher object ability and style, consistently reporting higher preferences for visual-object processing than males (Blajenkova et al., 2006; Blazhenkova & Kozhevnikov, 2009).

A possible explanation for these results is that Singaporean students, independent of their gender, stream, or visual abilities, prefer to pursue a future career in science-related industries (with males having even stronger preference for a scientific career than females). Indeed, Singaporean students' spatial style from both Express and Normal streams were comparatively higher than spatial styles of Russian and US students of the same age, and not significantly different from the spatial style of US college students majoring in science. At the same time, their object style was significantly lower than the object style of secondary school students from Russia and US, indicating that Singaporean students have rather mixed feelings about their preferences for object visual processing as well as for the choice of a career path related to artistic fields, preferences that are independent of their visual ability. While the emphasis on science education may provide more resources for Singaporean students in developing scientific knowledge and a variety of problem-solving strategies that can contribute to scientific creativity, it leads to a possible oversight of the development of artistic skills and creativity, which may negatively affect students with high object ability. Considering that cognitive style is a more adaptive and flexible construct than ability, in order to boost the development of a particular type of creativity that builds on an individual's talent and strengths, it is important to understand how different educational systems and cultural norms may shape a particular cognitive style, which in turn affects the development of a particular type of creativity. It should be noted that Singapore recognizes the need to improve their students' creativity (Kehk, 2019). On the curricular front, several major curriculum changes have been introduced to schools as part of efforts to foster greater creativity and innovation in Singaporean students (e.g., Thinking Schools, Learning Nation and Project Work; Kehk, 2019). Our results further emphasize potential benefits of how synergy between art and science education can encourage creativity.

Furthermore, while we used a cross-sectional design in our study, future longitudinal research is critically important to better address how students' abilities and their interaction with educational opportunities may impact the development of domain-specific creativity. We believe that the results of this study present important initial steps to help educators design learning curricula and assessments to enhance artistic and scientific creativity for achievement of higher performance in visual arts and sciences, respectively.

CONFLICT OF INTEREST

Maria Kozhevnikov, Ho Shuen, and Elizabeth Koh declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Study 1 assessments correlation matrix.
Table S2. Study 2 assessments correlation matrix.