



Research article

Individual differences in visualization and childhood play preferences

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ABSTRACT

Our research explored the structure of childhood visual play preferences, and examined different types of visual play in relation to individual differences in visualization and aptitudes in academic specializations requiring visualization skills. Principal component analysis dissociated visual-object play (e.g., exploring drawing media or decorative crafts) from visual-spatial play (e.g., assembling and disassembling mechanisms or playing with construction toys) preferences. Moreover, visual play preferences were dissociated from verbal play preferences (e.g., vocabulary games or making up stories). The structure of visual play preferences was consistent with object and spatial dimensions of individual differences in visualization. Visual-object and visual-spatial dimensions of play preferences were differentially related to measures of object visualization (processing pictorial appearances in terms of shape, texture, and color) versus spatial visualization (processing spatial relationships and spatial manipulations), as well as to aptitudes in artistic versus scientific domains. Furthermore, our research sheds new light on sex differences in play behavior: Previous studies commonly associated gender-specific play with visual versus verbal-social processing; our research demonstrated sex differences in play preferences across the two dimensions of visual play, where females preferred visual-object and males preferred visual-spatial play. Moreover, we found the object vs. spatial structure of visual play preferences was largely the same in both sexes, suggesting that differences in visual play preferences cannot be reduced to sex differences. Also, our questionnaire assessing visual-object, visual-spatial and verbal play preferences, developed for research purposes, demonstrated good reliability. Its two scales, assessing visual-object and visual-spatial play preferences, discriminatively correlated with assessments of individual differences in object and spatial visualization, respectively. This research creates a basis for further creation of comprehensive measures of visual play preferences, and should stimulate future studies examining visual play preferences and how they may create developmental opportunities for skills and preferences lasting into adulthood.

1. Introduction

Play is a fundamental childhood activity that is self-chosen and self-directed, intrinsically motivated, guided by mental rules, imaginative, and conducted in a relatively unstressed state (Gray, 2013; Vygotsky, 1978). A prevalent view in the psychological and educational literature suggests that childhood play experiences create developmental opportunities for differential shaping of social, emotional and cognitive abilities and constitute the basis for skills and preferences that last into adulthood (Larson and Verma, 1999; Piaget, 1932, 1963, 2013; Singer, 1977). The Vygotskian approach characterized play as a leading source of development in preschool years that enables young children to master necessary prerequisites of academic performance (Vygotsky, 1929, 1967). Our research explored diverse childhood visual play preferences in relation to individual differences in visualization

abilities as well as aptitudes in academic specializations requiring visualization skills.

The relationship between the engagement in social pretend play, play with imaginary companions, play with manipulative toys and positive developmental outcomes has been well researched (Bergen, 2002; Farran and Son-Yarbrough, 2001; Lillard et al., 2013). Engagement in social role-playing was related to advantages in affiliative and theory of mind abilities (Pellegrini and Smith, 1998), the incidence of childhood imaginary companions was related to adolescent creativity (Schaefer, 1969), and increased pretend play in childhood was related to enhanced performance on measures of creativity, social skills and cognitive skills (Fein, 1981). Previous literature also suggested that early development of visual-spatial skills is shaped through play activities that promote spatial awareness, spatial reasoning, and spatial imagery development (Kersh et al., 2008). There is substantial evidence for a relationship between

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childhood play and visualization abilities (Casey et al., 2008; Jirout and Newcombe, 2015). Positive associations have been found between preschoolers' spatial play, such as building blocks or puzzle play, and spatial visualization abilities, such as mental rotation or spatial transformation (Brosnan, 1998; Caldera et al., 1999; Levine et al., 2012). Moreover, experimental evidence demonstrated a causal relationship between play with construction toys and the development of spatial skills (Sprafkin et al., 1983). However, past research reported some puzzling findings and inconsistent correlations between play behavior and visualization abilities. For example, Jirout and Newcombe (2015) examined the relationship between spatial skills (assessed by a block design test) and play activities, including spatial (i.e., puzzles, blocks and board games) and non-spatial ones (e.g., drawing materials, sound-producing toys). They found a relationship between spatial ability and spatial play, but not between spatial ability and any of the other play types. In fact, previous research did not specifically focus on visual play, and within the visual domain it mainly focused on visual-spatial play behavior (e.g., construction from blocks) in relation to only one dimension of visualization abilities (i.e., visual-spatial abilities). However, literature considering non-spatial facets of visual ability in relation to diverse visual play preferences is limited. Robert and Heroux (2004) called for future research to aim at "augmenting both diversity in the visuo-spatial skills measured and sophistication in play behavior appraisal" (p.49).

The present research focuses on *visual* (i.e., involving visual processing) *childhood play*. It extends the existing literature and helps to explain previous inconsistencies by considering different dimensions of visual play. The main goal of our research was to examine the structure of childhood visual play preferences, which may include diverse visual spatial (e.g., playing with blocks and constructors, assembling mechanisms) and visual non-spatial (e.g., creative drawing with colors, making artistic and decorative crafts) kinds of play. Furthermore, the present research aims to improve our understanding of the relationships between different types of visual play and types of *visualization abilities* (i.e., abilities necessary to perform cognitive tasks that require visual imagery, visual perception, visual memory etc.). In particular, we intended to examine different types of visual play in relation to individual differences in spatial (processing spatial relationships and spatial manipulations) vs. object (processing pictorial appearances in terms of color, texture, and other object properties) visualization abilities, which have been established in previous research (Kozhevnikov and Blazhenkova, 2013). While the majority of the existing studies on visual play and visualization abilities were concerned with spatial visualization, the present study considers both spatial and object visualization abilities. In addition, our study intends to examine different types of visual play in relation to *aptitudes in different specialization* disciplines that require visualization, such as visual arts and natural sciences. Moreover, we aim to explore sex and age effects on play preferences.

Our examination of *different types of childhood visual play preferences in relation to individual differences in visualization abilities* was based on recent individual differences research (Kozhevnikov and Blazhenkova, 2013) that challenged the traditional view of *visualization ability* as a general undifferentiated skill (Richardson, 1977). For a long time, individuals were treated as having either high or low imagery capabilities. According to the popular 'Visual-Verbal' model of cognitive style, they were classified as either visualizers or verbalizers (Hollenberg, 1970; Paivio, 1983; Richardson, 1977). However, considerable neuroscience evidence supported the distinction between the neural pathways underpinning visual perception: a ventral or "what" pathway, processing appearances of objects in terms of their pictorial properties, and a dorsal or "where" pathway, processing spatial relations and transformations (Haxby et al., 1991; Kosslyn et al., 2001; Kosslyn and Koenig, 1992; Ungerleider and Mishkin, 1982). Neuroimaging and neuropsychological studies provided evidence that object-spatial distinction also exists in visual imagery (Farah et al., 1988; Kosslyn et al., 2001; Levine et al., 1985) and working memory (Baddeley, 1992; Darling et al., 2007; Logie et al., 2003). These studies demonstrated the dissociation between object visualization

(perceptual, memory and imagery processing of the literal appearances of objects in terms of their pictorial properties, such as shape, color, brightness, and texture) and spatial visualization (perceptual, memory and imagery processing of spatial relations and locations, as well as performing spatial transformations). Experimental evidence further supported the distinction between visual-object and visual-spatial processing at the individual differences level (Blazhenkova and Kozhevnikov, 2010; Kozhevnikov and Blazhenkova, 2013; Kozhevnikov et al., 2002; Kozhevnikov et al., 2005). In contrast to the traditional two-dimensional Visual-Verbal model of cognitive style (Paivio, 1983; Richardson, 1977), the new Object-Spatial-Verbal model that distinguished between different types of individuals (object visualizers, spatial visualizers, and verbalizers) was proposed by Kozhevnikov et al. (2005) and further validated by Blazhenkova and Kozhevnikov (2009). *Object visualizers* were found to excel in object performance visualization tasks and tended to use their imagery to construct vivid images of pictorial properties of objects and scenes. *Spatial visualizers* excelled in spatial performance visualization tasks and tended to use their imagery to represent spatial relations and transformations. *Verbalizers* excelled in verbal processing and tended to process information in verbal form.

The above-discussed research on individual differences in object vs. spatial visualization abilities provided a robust basis for considering different dimensions of visual play behavior. Also, based on substantial evidence of a close association between play behavior and the development of specific abilities (e.g., Casey et al., 2008; Kersh et al., 2008; Pellegrini and Smith, 1998), the current research hypothesized that the object vs. spatial dissociation, previously found for visualization abilities (Kozhevnikov and Blazhenkova, 2013), may also exist in play behavior. As illustrated in Figure 1A, previous literature mostly discussed visual-spatial (or general undifferentiated visual) abilities in relation to spatial play preferences (Brosnan, 1998; Caldera et al., 1999; Sprafkin et al., 1983). The correlations between play behavior and visualization abilities were inconsistent when visual-spatial play behavior was linked with visual-spatial or visual non-spatial play activities (Jirout and Newcombe, 2015). This lack of a relationship between non-spatial visual play and spatial ability is not surprising, since spatial and non-spatial visual measures are likely to tap different cognitive constructs. Possibly, non-spatial visual play behavior is positively associated with some non-spatial (i.e., visual-object) abilities. No studies explicitly linked visual non-spatial play activities to object visualization skills. Thus, in the present research, we made the following predictions (Figure 1B):

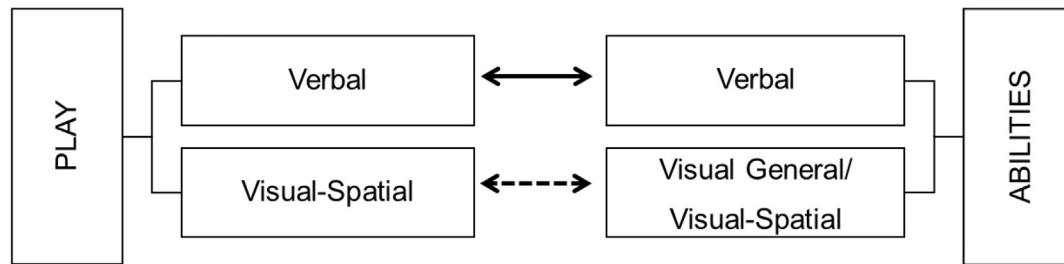
Hypothesis 1. Visual childhood play preferences are dissociable into visual-object and visual-spatial dimensions, which are also separate from the verbal dimension.

Hypothesis 2. Visual-object and visual-spatial dimensions of play preferences are associated with individual differences in object and spatial visualization, respectively.

An additional aim of the present research was to explore *childhood visual play preferences in relation to different specialization aptitudes*. Several studies showed positive associations between early childhood play behavior and future engagement and accomplishments in different specializations and disciplines. For example, children's advancement in spatial play activities such as block building related to later success in mathematical learning (Assel et al., 2003; Kersh et al., 2008; Verdine et al., 2014). Schlewitt-Haynes et al. (2002) found that professional visual artists, during their childhood, engaged in a variety of fantasy-based visual games (e.g., searching for meaningful objects in clouds and rocks, imagining beyond the picture borders, mentally blurring the edges of objects etc.) more frequently than did non-artists.

Furthermore, prior research has established that there are relationships between visualization abilities and professional/educational performance. Spatial visualization was shown to be crucial for success in the scientific, technical, and mathematical fields (Ferguson, 1977; Hegarty and Kozhevnikov, 1999; Holliday, 1943; Kozhevnikov et al., 2007;

A) Traditional view



B) Proposed view

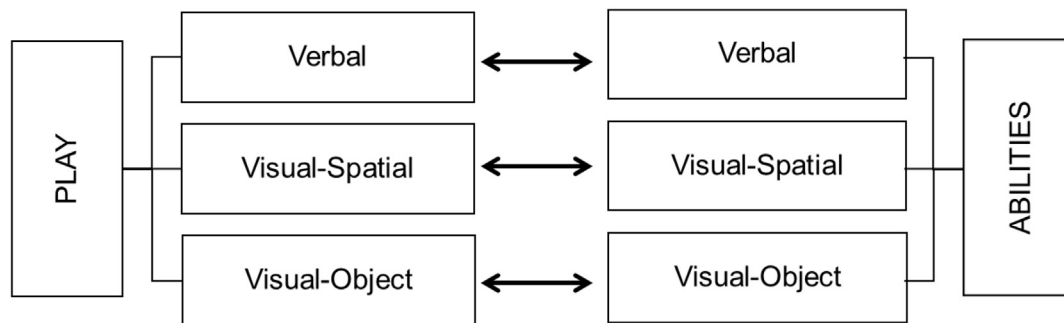


Figure 1. Play behavior in relation to individual differences in abilities.

Kozhevnikov and Thornton, 2006; Smith, 1964; see McGee, 1979, for a review). More recent research demonstrated that not only does spatial visualization specifically relate to specialization in natural sciences, but also object visualization uniquely relates to specialization in visual arts (Blazhenkova and Kozhevnikov, 2010). There is also evidence that visual artists show superior performance in non-spatial visual tasks that require pictorial imagery, perception, and visual memory (Chamberlain et al., 2011; Kassels, 1991; Kozhevnikov et al., 2005; Miller, 1996; Ostrofsky et al., 2012; Roe, 1975; Rosenberg, 1987; Rosenblatt and Winner, 1988; Winner and Pariser, 1985). Individual differences in object imagery vs. spatial imagery measures were correlated with self-reported aptitudes in arts vs. science as well as artistic creativity vs. scientific creativity (Kozhevnikov et al., 2013). Moreover, object imagery and spatial imagery assessed in schoolchildren were found to differentially relate to their talents in science and visual arts, as well as to learning interests and future professional intents in these domains (Blazhenkova et al., 2011; Kozhevnikov et al., 2010). Longitudinal research reported that extraordinary spatial abilities detected in adolescents were predictive of subsequent educational and vocational achievements in STEM domains (Humphreys et al., 1993; Rieser et al., 1994; Wai et al., 2009). Moreover, research showed that individual visual strengths may manifest even before school age, prior to any formal training in a particular specialization, and still be predictive of future specialization preferences and performance (Assel et al., 2003; Clements, 2004; Verdine et al., 2014; Winner and Martino, 2003).

Based on this literature, we expected to find relationships between different types of childhood visual play preferences and different specialization aptitudes. In addition, we expected to replicate the findings of positive associations between visualization abilities and different specialization aptitudes.

Hypothesis 3. Visual-object and visual-spatial play preferences will be associated with aptitudes for different academic specializations (i.e., visual arts vs. sciences), respectively.

Hypothesis 4. Visual-object and visual-spatial abilities will be associated with aptitudes for different academic specializations (i.e., visual arts vs. sciences), respectively.

Finally, the present research examined *sex differences in childhood play preferences*. A large number of studies, using a variety of measures and a broad range of toys and play activities, have consistently found differences in boys' and girls' play preferences in preschool age, and across childhood (Berenbaum and Hines, 1992; Etaugh and Liss, 1992; Grellert et al., 1982; also see reviews by Collaer & Hines, 1995; Todd et al., 2018; Zosuls and Ruble, 2018). The common finding was that girls tend to prefer dolls, dolls' accessories, and stuffed animals, whereas boys tend to prefer games that involve spatial manipulation and construction such as tools, blocks, and transportation toys (Bradbard and Parkman, 1984; Emmott, 1985; Erikson, 1951; Kersh et al., 2008; Serbin and Connor, 1979). According to Collaer and Hines' review, the effect size for sex differences in childhood play is moderate to large, making play preference one of the largest behavioral sex differences (Hines, 2010). Sex differences in the interest in gender-typed toys was detected in infants at 5–6 months of age (Alexander et al., 2009). These robust sex differences in play behavior were explained by both environmental (e.g., gender-typing, Sherman, 1967, Zosuls et al., 2009; parents' behavior, Pruden and Levine, 2017) and biological factors (e.g., hormonal influences, Collaer and Hines, 1995; Hines, 2010). Additional support for the role of biological factors in sex differences in play preferences comes from studies with nonhuman primates, who exhibited sex differences in toy preferences similar to those found in human children, but apparently

did not experience human social stereotypical pressure (Alexander and Hines, 2002; Hassett et al., 2008).

The majority of studies on play preferences in relation to visualization abilities considered sex to be a crucial factor (Carter and Levy, 1988; Cherney and London, 2006; Newcombe et al., 1983; Robert and Heroux, 2004). The common conclusion of these studies was that gender-specific play encourages the improvement of visual-spatial abilities in boys and verbal/social abilities in girls (Serbin and Connor, 1979). Consequently, play preferences that involve considerable visual processing (e.g., playing with dolls and stuffed animals) were essentially linked to females' advantage in the verbal but not visual domain. At the same time, imagery research demonstrated that females were not generally worse than males in visual abilities, but they excelled in visual-object abilities, whereas males excelled in visual-spatial abilities (Blajenkova et al., 2006; Blazhenkova and Kozhevnikov, 2009; Linn and Petersen, 1985; Voyer et al., 1995). Since females outperform males in some aspects of visualization, sex differences should not be viewed from the perspective of a bipolar visual-verbal distinction. Consistent with these previous studies, we expected to find sex differences in play preferences. However, in contrast to previous approaches that considered individual differences in play preferences primarily in the light of sex differences along the visual-verbal distinction, the current study aimed to examine differences in play preferences in consideration of the visual-object and visual-spatial distinction.

Hypothesis 5. Males have more pronounced visual-spatial play preferences, while females have more pronounced visual-object play preferences.

Hypothesis 6. Individual differences in visual-spatial and visual-object play preferences exist in both males and females, and thus are not reducible to sex differences.

Additionally, the present research examined *sex differences in childhood play preferences in participants with a wide range of ages*. Particularly, we examined sex differences in object vs. spatial play preferences in the light of possible historical changes. Previous research suggested that cognitive gender differences could be disappearing due to societal changes in attitudes towards women, fostering gender equality (Feingold, 1988). Rosenberg and Sutton-Smith (1960) reported that play preferences of girls had become substantially more similar to those of boys than they had been in 1921. Sutton-Smith (1979) reported that since the beginning of 20th century, there was a stable increase in girls' interest for boy-typed games. Sutton-Smith and Rosenberg's (1961) historical review of children's game preferences from the end of the 19th century to the second half of the 20th century also reported a growing similarity between the sexes. This similarity was attributed to changes in girls' play preferences (i.e., increasing incorporation of traditionally masculine preferences). Moreover, Sutton-Smith and Rosenberg suggested that the increasing similarity between sexes can be at the expense of boys' variety of play preferences. For example, they found that boys' rankings of play with dolls dropped from 51st place in 1886 to 171st in 1959. In other words, boys may lower their preferences for games that became more preferred by girls and that are not obviously 'masculine', which results in increasingly circumscribed play in boys. A recent review and meta-analysis (Todd et al., 2018) found an effect of publication year: girls played more with female-typed toys and boys played more with male-typed toys in earlier studies than in more recent studies, which suggested a possible effect of historical time on toy preference. Nevertheless, it should be noted that despite the fact that girls and boys may have become more similar in their play preferences, there are still robust and significant sex differences in play behavior. Similarly, in the present research we expected to find sex differences in visual-object and visual-spatial play preferences in different age cohorts. Additionally, we explored possible historical changes in sex differences in visual-spatial and visual-object play preferences.

Hypothesis 7. Sex differences in visual-spatial and visual-object play preferences increase as the age of the participants increase.

To summarize, previous research provided evidence of relationships among play behavior, visualization abilities, and specialization. However, it often considered visualization as a single, general visual dimension (and in practice, often focused primarily on spatial visualization) which is opposite to the verbal/social dimension. Consequently, previous literature largely ignored non-spatial visualization abilities, and did not explicitly examine visual-object abilities in relation to non-spatial visual play behavior. The current research incorporated a novel approach based on recent cognitive neuroscience and individual differences findings dissociating object and spatial visualization. It integrated cognitive research on individual differences in imagery with developmental research on play preferences. Eventually, our research aimed to improve the understanding of individual differences in visualization in relation to complex and naturally occurring behaviors such as childhood play. This knowledge could have multiple applications in educational, developmental, occupational, and clinical fields.

Study 1 explored the factor structure of visual play preferences; specifically, it investigated whether spatial and object play preferences are dissociable into two separate factors (Hypothesis 1). Study 2 further examined the dissociation between different dimensions of visual as well as verbal play preferences. Furthermore, Study 1 examined the relationships among the visual play dimensions and object vs. spatial visualization self-report measures (Hypothesis 2), as well as self-efficacy in different academic specializations that require visualization, such as arts and sciences (Hypotheses 3 and 4). Study 2 further examined these relationships by adding verbal play preferences and self-efficacy in humanities, as well as behavioral measures of visualization abilities. In addition, both Studies 1 and 2 examined sex differences in visual play preferences (Hypothesis 5). Furthermore, Study 1 tested whether individual differences in play preferences exist in both sexes (Hypothesis 6) by examining the factor structure of visual play preferences separately for each sex. Finally, to explore whether sex differences in childhood visual play preferences vary across different generations of participants, Study 1 tested for possible interactions between sex and age of participants (Hypothesis 7).

2. Study 1

Study 1 examined the structure (i.e., different types) of play preferences for different childhood visual games. Self-report assessment of play preferences was used since this approach has been popular in the literature (Robert and Heroux, 2004), and such self-reports have been found to be consistent with observable play behavior (Sallis, 1991). Previous research demonstrated that retrospective self-reports of play preferences are reliable and largely overlap with objective measures (Brewin et al., 1993; Yarrow et al., 1970; see also Robert and Heroux, 2004). The preference ratings were obtained from a large sample of participants, with a broad age range. A subsample of adults was additionally assessed on their object and spatial visualization, as well as specialization aptitudes. This sample allowed us to examine the relationships among object-spatial visualization, play preferences and specialization aptitudes. Notably, questions about play preferences referred to the period of childhood (even in adult participants), thus any variations in different age groups' ratings refer to cohort differences (i.e., historical changes) rather than developmental differences in play preferences at different ages.

2.1. Method

2.1.1. Participants

Overall, 546 participants (2–93 years old; 383 females) were recruited based on convenience sampling through various methods. These data were collected alongside data for an unrelated study. The first

147 participants were tested in live sessions, individually or in small groups of up to five participants: 54 children were recruited in a summer camp (Turkey), 20 elderly participants were recruited in a retirement home (Russia), and other participants from all age groups were recruited via convenience sampling in Turkey and Russia. All these participants received a gift (stationery or sweets). Subsequent participants were surveyed online using Qualtrics (Qualtrics, Provo, UT); among them, a subsample of 60 participants (19–24 years old; 36 females) were university students, who received course credits for their participation. The study was approved by Sabanci University Research Ethics Council (SUREC). Informed consent was obtained from all the participants. Younger participants were assisted by their parents. Parental assessment of children's play preferences and activities is a commonly used measure (Jirout and Newcombe, 2015; Robert and Heroux, 2004). In the current study, results from younger children, assisted by their parents, were consistent with results obtained from older children and adults (in terms of the structure of play preferences, and sex differences).

2.1.2. Materials and procedure

All 546 participants completed the first version of the *Play Preferences Questionnaire* and indicated their Age and Sex. In addition, a subsample of participants ($N = 400$) rated their *Aptitudes in Different Academic Specializations*. Among them, university students ($N = 60$) also completed the *Object-Spatial Imagery and Verbal Questionnaire*. Data files have been deposited in Mendeley Data and are available at <https://doi.org/10.17632/jxbg69v778.1>.

Play Preferences Questionnaire (version 1). This questionnaire was prepared specifically for this study since there are no currently available instruments that deliberately measure different kinds of visual games. It did not attempt to exhaustively embrace all play activities but aimed to include a variety of children's play activities with a significant visual component. The selection of play activities was based on literature review (Bradbard and Parkman, 1984; Emmott, 1985; Robert and Heroux, 2004; Serbin and Connor, 1979) and informal conversations with parents and colleagues. Participants rated on a scale from 1 (don't like at all) to 5 (like very much) the degree to which they like (or liked in their childhood) each of the following 14 play activities: Drawing with Paints, Drawing with Pencil, Constructing from Paper (e.g., origami), Playing with Blocks, Playing with Construction Toy Play Sets, Playing with Dolls, Colored Paper Applique, Mathematical and Geometrical Games, Clay or Play-Dough Modeling, Handiwork (e.g., needlework), Disassembling and Assembling Mechanisms, Artistic Crafts, Plastic Modeling, and Puzzles (jigsaws).

Aptitudes in Different Academic Specializations. Participants separately rated on a scale from 1 (lowest) to 7 (highest) their abilities in the three specializations: Visual Arts (visual art, design, realistic drawing with color), Natural Sciences (physics, math, computer programming, engineering), and Humanities (writing, history, philosophy, literature). This is a self-efficacy measure (Bandura, 1982) assessing a belief in one's capability or performance. The predictive value of self-efficacy judgments has been established for a variety of activities, including academic performance (Wood and Locke, 1987). In the current study, aptitudes in art, sciences and humanities were assessed with one question per specialization (thus reliability was not computed).

Object-Spatial Imagery and Verbal Questionnaire (OSIVQ). This self-report measure is based on the Object-Spatial-Verbal model of cognitive style (Kozhevnikov et al., 2005) and assesses individual differences in object visualization, spatial visualization, and verbal processing (Blazhenkova and Kozhevnikov, 2009). The OSIVQ consists of 15 items assessing object visualization (e.g., 'My mental pictures are very detailed precise representations of the real things'), 15 items assessing spatial visualization (e.g., 'My images are more like schematic representations of things and events'), and 15 items assessing verbal processing (e.g., 'I would rather have a verbal description of an object or person than a picture'). Participants rated each statement on a 5-point scale from '1' (total disagreement) to '5' (absolute agreement).

Separate scores for each scale were calculated by averaging the corresponding 15 ratings. The internal reliabilities (Cronbach's alpha) of the Object, Spatial, and Verbal scales are .83, .79, and .74, respectively (Blazhenkova and Kozhevnikov, 2009).

3. Results and discussion

3.1. Factor structure of play preferences

To examine play preference structure, the ratings of all play preferences obtained from the full sample ($N = 546$) were analyzed using Principal Component analysis with a Varimax rotation. Missing values were replaced by the series mean. The results of Parallel Analysis (also known as Eigenvalue Monte Carlo Simulation; O'Connor, 2000) identified two statistically significant Eigenvalues or components that accounted for more variance than the components derived from randomly generated data on 1000 parallel data sets (the 3rd raw data Eigenvalue of 1.17 was exceeded by the value of 1.20 from the 95th percentile of the random data Eigenvalues). Thus, an additional Principal Component analysis restricted to a 2-factor solution was conducted, and it cumulatively explained 44% of the variance. The first factor grouped *visual-object play preferences* for games involving processing pictorial appearances in terms of shape, texture, and color. The second factor grouped *visual-spatial play preferences* for games involving processing spatial relationships and transformations (Table 1). Notably, 'Puzzles' and 'Constructing from Paper' preferences had comparable moderate loadings on Visual-Object and Visual-Spatial Play Preferences factors.

The two separate scale scores of Play Preferences were computed by averaging the corresponding items per scale. 'Puzzles' and 'Constructing from Paper' were not included in the scale scores because they did not clearly differentiate between the two types of Play Preferences. The internal reliability (Cronbach's alpha) of the final ratings for Visual-Object Play Preferences scale was .77 (7 items), for Visual-Spatial Play Preferences scale was .73 (5 items).

3.2. Visualization, specialization, and play preferences

To examine the relationships among individual differences in visualization, specialization, and play preferences, the OSIVQ scales' scores ($N = 60$) were correlated with aptitude ratings in different specializations as well as with the play preferences' factor scores (see Table 2). Kolmogorov-Smirnov tests of normality showed that OSIVQ scores were normally distributed, but play preferences and aptitudes were not. Thus, Spearman correlation was used. The results indicated that Visual-Object Play Preferences positively correlated with Object Visualization and Art

Table 1. Principal Component Analysis of Play Preferences.

Play preferences	Visual-Object	Visual-Spatial
Drawing with Paints	.749	-.004
Drawing with Pencil	.654	.047
Colored Applique	.646	.179
Clay or Play-dough Modeling	.639	.218
Playing with Dolls	.613	-.217
Artistic Crafts	.586	.257
Handiwork	.543	.218
Playing with Constructors	.095	.732
Disassembling & Assembling Mechanisms	-.087	.789
Plastic Modeling	.196	.677
Mathematical & Geometrical Games	.010	.611
Playing with Blocks	.284	.511
Puzzles	.330	.379
Constructing from Paper	.488	.429

Note: Loadings in bold $\geq .500$; $.500 >$ Underscored Loadings $> .300$; $N = 546$.

Table 2. Correlations among the measures of Visualization, Specialization, and Play Preferences.

	1.	2.	3.	4.	5.	6.	7.	8.
1. Visual-Object Play Preferences	1	.157	<u>.426**</u>	-.134	-.058	<u>.356**</u>	-.129	.071
2. Visual-Spatial Play Preferences		1	-.052	<u>.523**</u>	-.024	-.070	<u>.435**</u>	.038
3. OSIVQ-Object			1	-.112	-.206	<u>.330**</u>	-.198	-.061
4. OSIVQ-Spatial				1	-.221 ⁺	-.034	<u>.503**</u>	-.233 ⁺
5. OSIVQ-Verbal					1	-.169	-.060	<u>.621**</u>
6. Visual Art Aptitude						1	-.222 ⁺	.081
7. Science Aptitude							1	-.254 [*]
8. Humanities Aptitude								1

Note: ⁺ $p < .1$; ^{*} $p < .05$; ^{**} $p < .001$; correlations between related constructs are underscored. $N=60$.

Aptitude ratings, whereas Visual-Spatial Play Preferences positively correlated with Spatial Visualization and Science Aptitude ratings. Neither Visual-Object nor Visual-Spatial Play Preferences were positively correlated with the Verbal scale of the OSIVQ or Humanities Aptitude. Additionally, consistent with previous research (Blazhenkova and Kozhevnikov, 2010), there were positive associations between Object Visualization and Visual Art Aptitude, between Spatial Visualization and Science Aptitude, and between Verbal ability/style and Humanities Aptitude.

Next, the relationships between play preferences and individuals' OSIVQ Object and Spatial Visualization scores were examined separately for each particular game (Figure 2). The coordinates of each point on the graph are defined by the magnitude of the correlation between Play Preference towards that particular game and Spatial Visualization score (Y-axis), and between Play Preference towards that game and Object Visualization score (X-axis). The trendline indicates that Play Preferences' relationships with Spatial versus Object Visualization tend to be inverse ($R^2 = .508$).

Play Preferences for games that were more associated with Object Visualization tended to be less associated with Spatial Visualization, and vice versa. Visual-Spatial Play Preferences (those with high loadings on the Visual-Spatial Play Preferences factor), tended to group in the positive-spatial and negative-object visualization quadrant, whereas Visual-Object Play Preferences (those with high loadings on the Visual-Object Play Preferences factor) grouped in the positive Object and both negative and positive Spatial Visualization coordinate space. Visual-Spatial Play Preferences clustered together more distinctly than Visual-Object Play Preferences.

Similarly, the relationships between each play preference towards a particular game and aptitudes in different specializations were examined ($N = 400$, Figure 3). Consistent with the Play Preferences and

Visualization analysis described above, the identified linear trend ($R^2 = .478$) suggests that Play Preferences' relationships with Scientific versus Artistic Aptitudes tended to be inverse. Notably, virtually all Play Preferences were distributed in the positive Visual Art Aptitude coordinate space; whereas only playing with dolls and drawing preferences were clearly positioned in the negative Science Aptitude coordinate space.

3.3. Age and Sex differences in visual Play preferences

To examine sex differences in visual Play Preferences, independent samples *t*-tests were conducted using the data from all participants ($N = 546$). These analyses revealed significant sex differences, favoring females, in Visual-Object Play Preferences [$t(544) = -7.539, p < .001$; males: $M = 2.72, SD = 0.74$, females: $M = 3.20, SD = 0.65$] and, favoring males, in Visual-Spatial Play Preferences [$t(544) = 6.782, p < .001$; males: $M = 3.37, SD = 0.76$, females: $M = 2.91, SD = 0.70$].

To further examine sex differences in Play Preferences, Principal Component Analysis of play preferences (2-factor solution) was conducted separately for males and females to examine the structure of their play preferences. It revealed the same two (Visual-Object and Visual-Spatial Play Preferences) factors, and similar loadings (for details see Supplementary Tables 1 and 2). However, some notable differences appeared. In females, the first factor loaded Visual-Object Play Preferences and the second loaded Visual-Spatial Play Preferences, whereas in males, the Visual-Spatial factor appeared first. Furthermore, for males, preference for 'Puzzles' loaded more on the visual-spatial factor (.593) than it did on the visual-object factor (.128), whereas for females it moderately loaded on both (.325 and .350). For females, the 'Constructing from Paper' preference loaded more on the visual-object factor (.513) than it did on the visual-spatial factor (.385), whereas for males it similarly loaded on both (.480 and .466). Moreover, in females, visual

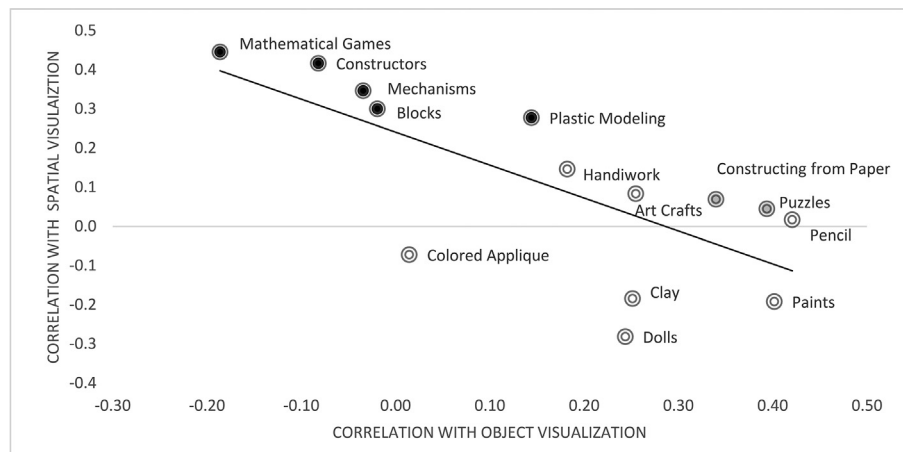


Figure 2. Play Preferences in relation to visual-object and visual-spatial OSIVQ scales' scores. ● Visual-Spatial Play Preferences ○ Visual-Object Play Preferences ● Undifferentiated Play Preferences; $N=60$.

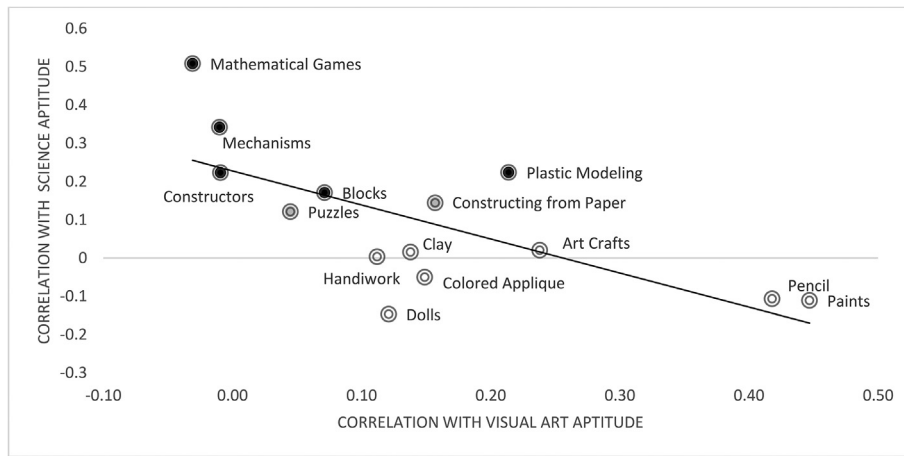


Figure 3. Play preferences in relation to visual arts and Science Aptitudes. ● Visual-Spatial Play Preferences ○ Visual-Object Play Preferences ● Undifferentiated Play

play preferences involving an aesthetic component clearly loaded on the visual-object factor, whereas in males, they loaded on both visual-object and visual-spatial factors ('Artistic Crafts': .487 & .415; 'Handiwork': .373 & .449). In addition, the same analysis, conducted separately for children (age ≤18), adults (19–49 years old) and older adults (age ≥50) revealed very similar object-spatial factor structure of visual play preferences (see Supplementary Tables 3,4, 5 and 6).

Nonlinear regressions were used to assess the relationships between age and play preferences, which scatterplots suggested were curvilinear (see Figure 4). Age did indeed have a curvilinear relationship with both visual-object [linear effect significant, unstandardised $B = -0.004$, $R^2 = .009$, $F(1, 544) = 5.11$, $p = .024$; quadratic effect significant, $B = 0.0003$, $\Delta R^2 = .034$, $F(1, 543) = 19.38$, $p < .001$; cubic effect nonsignificant, $B = 2.77 \times 10^{-6}$, $\Delta R^2 = .001$, $F(1, 542) = 0.79$, $p = .375$] and visual-spatial play preferences [linear effect significant, $B = -0.008$, $R^2 = .030$, $F(1, 544) = 16.65$, $p < .001$; quadratic effect significant, $B = 0.0002$, $\Delta R^2 = .018$, $F(1, 543) = 10.41$, $p = .001$; cubic effect nonsignificant, $B = -3.39 \times 10^{-6}$, $\Delta R^2 = .002$, $F(1, 542) = 1.09$, $p = .296$], indicating that age's relationships with play preferences have both a linear and a quadratic component.

We wished to check whether these curvilinear relationships were equivalent for the two sexes, so we conducted moderated nonlinear regression analyses, following the guidance of Hayes (2017). First, visual-object play preferences were regressed on sex, age's linear effect, age's quadratic effect, sex's interaction with age's linear effect, and sex's interaction with age's quadratic effect; then, visual-spatial play preferences were regressed on the same model. None of the interaction terms were significant (all $|B|s < 0.004$, $ps > .460$), indicating that the relationships between age and play preferences are approximately equivalent for the two sexes.

4. Study 2

Study 2 aimed to corroborate the results of the first study by using more advanced measures of Play Preferences and Visualization. These new measures assessed Verbal Play Preferences, self-efficacy in humanities, as well as Visualization abilities that included performance tests in addition to self-reports. We further examined how the two dimensions of visual play are dissociable from each other, and also from verbal play. Based on the results of our factor analysis of play preferences from Study

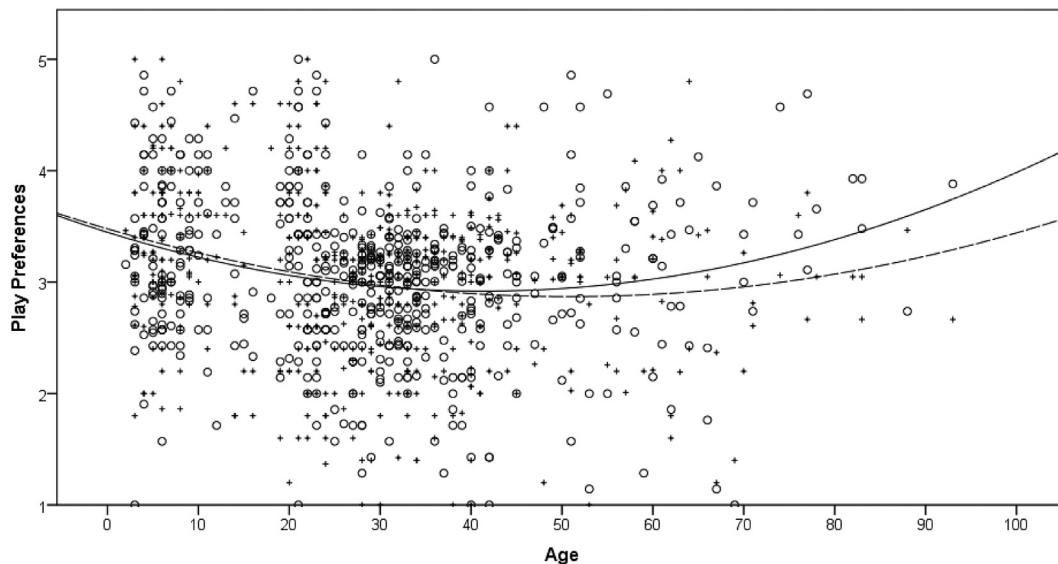


Figure 4. Relationships between age and visual-object play preferences (circles and solid fit line) and between age and visual-spatial play preferences (crosses and broken fit line).

1, the best items tapping different dimensions of play preferences were selected for the Play Preferences Questionnaire. Study 2 further examined the relationships among the visual play dimensions and object vs. spatial visualization as well as self-efficacy in arts, sciences, and humanities. Participants received an extended Play Preferences questionnaire assessing a variety of visual and verbal play preferences along with a number of visual-spatial, visual-object, and verbal measures. The Play Preferences Questionnaire's reliability was examined by calculating Cronbach's alpha for each scale. Its validity was examined by correlating the scale scores with the criterion visual-spatial, visual-object, and verbal measures. In addition, Study 2 examined sex differences in visual play preferences.

5. Method

5.1. Participants

University students (95 males, 110 females), 18–26 years old ($M = 21$; $SD = 1.67$) participated in the study. These data were collected alongside data for an unrelated study.

Informed consent was obtained for experimentation with human subjects. They were reimbursed with course credits. The study was approved by Sabanci University Research Ethics Council (SUREC). Informed consent was obtained from all the participants.

5.2. Materials and procedure

Participants completed the updated version of *Play Preferences Questionnaire*, as well as *Aptitudes in Different Specialization Areas* and *OSIVQ*, which were the same as those used in Study 1. In addition, participants completed the tests of object visualization (*VVIQ*, *Fragmented Pictures*, and *Camouflage task*) and spatial visualization (*Mental Rotation Task* and *Paper Folding Task*). Participants completed the study via online Qualtrics software (Qualtrics, Provo, UT). Data file have been deposited to Mendeley Data and are available at <https://doi.org/10.17632/jxbg69v778.1>.

Play Preferences Questionnaire (version 2). Based on the results of the first study and feedback from participants, the items of the play preferences questionnaire were modified. This updated version of the questionnaire included more comprehensive questions assessing various visual and verbal play preferences. Overall, 15 items assessing visual-object, 15 items assessing visual-spatial, and 10 items assessing verbal play preferences were created (see the final list of items in Table 3). The instructions were the same as in the Study 1, but the ratings were given on a 7-point scale.

Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). This is the most popular assessment of imagery vividness, tapping object imagery (Blazhenkova, 2016; Blazhenkova and Kozhevnikov, 2009). Participants rated the subjective vividness of the evoked visual images from 16 verbal descriptions of scenes (e.g., ‘The sun is rising above the

Table 3. Principal Component Analysis of the final items of the Play Preferences Questionnaire.

Play preferences	Visual-Object	Visual-Spatial	Verbal
S1. Assembling Mechanisms	.825	.011	-.057
S2. Creating motion machineries	.819	-.064	-.127
S3. Disassembling mechanisms	.799	.066	.022
S4. Devices according to technical manuals	.782	.194	-.124
S5. Planning future constructions	.763	.038	.145
S6. Observing how real-life mechanisms work	.748	-.029	.056
S7. Scientific play sets	.741	.093	-.027
S8. Mathematical and geometrical games	.649	-.097	.042
S9. Remote machine control games	.637	.028	-.016
S10. Moving balls and estimating their trajectories	.582	-.035	.067
S11. Assembling from toy construction sets	.550	.336	-.001
O1. Exploring drawing media	.050	.752	.116
O2. Drawing shapes	.118	.647	.037
O3. Mixing colors	-.202	.638	.091
O4. Shading while drawing	.168	.636	.104
O5. Matching colors	-.183	.621	.134
O6. Colored Paper Applique	.018	.617	-.014
O7. Clay, or Playdough Craft	.070	.615	.169
O8. Artistic & decorative crafts	-.245	.588	.228
O9. Crafts from nature objects	.162	.568	.122
O10. Drawing visual appearance of textures	.084	.530	.176
O11. Drawing lines	.084	.529	.048
V1. Word games	.049	.045	.689
V2. Writing poems	-.010	-.180	.684
V3. Writing stories	-.005	.154	.665
V4. Making up stories	.067	.178	.652
V5. Rhyming games	.006	.085	.624
V6. Vocabulary and spelling games	.056	.082	.590
V7. Vocalizing a doll or toy's speech	-.030	.149	.507
V8. Role playing using dolls	-.152	.177	.488
V9. Talking to dolls	-.199	.199	.461
V10. Crosswords, word puzzle	.141	.096	.399

Note: The highest loadings are highlighted in **bold**. S refers to spatial, O refers to object, and V refers to verbal items.

horizon into a hazy sky”) on a 5-point scale from ‘1’ (no image at all, you only “know” that you are thinking of the object) to ‘5’ (perfectly clear and as vivid as normal vision). VVIQ scores were created by averaging all the ratings. Internal reliability (Cronbach's alpha) for this questionnaire is .88 (McKelvie, 1995).

Fragmented Pictures task. This task requires shape recognition ability, related to object visualization. Thirty-four pictures were taken from the stimulus set created by De Winter and Wagemans (2004). Participants had 5 min to recognize meaningful objects from their fragmented outlines, and to write down the names of the recognized objects. The final score was computed as the number of correctly identified objects. In the current study, Cronbach's alpha for this task was .77.

Camouflage Pictures task. This task requires object recognition ability. Thirty-six pictures of various nature scenes were presented; half included a hidden living object, e.g., an insect in grass. Participants had 5 min to identify living objects in these scenes, and either write down the name of the recognized object or indicate that there was no living object in the scene. The final score was computed as the sum of correct answers. In the current study, Cronbach's alpha for this task was .80.

Paper Folding test (Part 2, Ekstrom et al., 1976). This test measures spatial visualization ability. Participants had 3 min to identify how 10 folded and punched papers would look like when fully opened. Test scores were computed as the number of correct answers, minus one quarter of a point for each incorrect answer. The split-half reliability for this test is .75 (Miyake et al., 2001).

Mental Rotation test (Part B; Vandenberg and Kuse, 1978; redrawn by Peters et al., 1995). This test measures spatial transformation ability. Participants had 3.5 min to mentally rotate 12 three-dimensional geometric figures and to indicate which two of four provided figures were rotated versions of the criterion figure. The scores were calculated as the number of items in which both rotated images of the criterion figure were correctly identified. Internal reliability was shown to be good (Kuder-Richardson (KR20) internal consistency for the full test is .88, Vandenberg and Kuse, 1978; Cronbach's inter-item reliability for the 12-item test is .79, Casey et al., 2017).

6. Results and discussion

6.1. Principal Component Analysis

First, all the visual items of the Play Preferences Questionnaire (30) were analyzed using Principal Component analysis with a Varimax rotation. The results of Parallel Analysis (O'Connor, 2000) identified three statistically significant Eigenvalues or components that accounted for more variance than the components derived from randomly generated data on 1000 parallel data sets (4th raw data Eigenvalue of 1.48 was exceeded by the value of 1.58 from the 95th percentile of the random data Eigenvalues). Thus, the PCA was restricted to a 3-factor solution. In this solution, all Visual-Spatial Play Preferences loaded on the first factor, whereas all Visual-Object Play Preferences loaded on the second or the third factor. Thus, consistent with Study 1, the revealed factor structure supported separating object and spatial visual games into different dimensions. Notably, the third factor was highly loaded upon by items that were intended to assess visual aspects of doll play (e.g., ‘Dolls’ accessories’, ‘Dressing dolls’, ‘Expressions on dolls’ faces’, ‘Taking care of doll’s appearance’). When verbal items were added to the PCA, these visual doll play items appeared to load on both the Visual-Object and the Verbal Play Preferences factors. Since these ‘doll’ items did not discriminatively measure either Visual-Object or Verbal Play preferences, they were not kept for the final version of the Play Preferences Questionnaire (however, other items related to play with dolls were clearly tapping the verbal dimension, and these were retained; V7–V9, Table 3). Similarly, four visual-spatial items with lower loadings on the Spatial Play Preferences factor were removed (i.e., ‘Building 3D structures from blocks’, ‘Plastic Modeling’, ‘Chess’, and ‘Tying rope’). Eventually, 11 Visual-Object Play Preferences items, 11 Visual-Spatial Play Preferences items, and 10

Verbal Play Preferences items were retained for the final version of the Play Preferences Questionnaire.

The results of parallel analysis (O'Connor, 2000) on all these final 32 visual and verbal items identified five statistically significant Eigenvalues (the 6th raw data Eigenvalue value of 1.25 was exceeded by the value of 1.48 from the 95th percentile of the random data Eigenvalues). Therefore, the PCA was forced to produce a 5-factor solution, which revealed that all Visual-Spatial Play Preferences loaded on the first factor, all Visual-Object Play Preferences loaded on the second (related to crafts and colors) or the fourth (related to shapes and lines) factor, whereas all Verbal Play Preferences loaded on the third (related to storytelling) or the fifth (related to word games) factor. Since these results further supported the dissociation between Visual-Object, Visual-Spatial and Verbal Play Preferences, the PCA was finally forced to produce a 3-factor solution, cumulatively explaining 45% of the variance. In this solution, Visual-Object, Visual-Spatial and Verbal Play Preferences were clearly dissociated in separate factors (Table 3).

6.2. Play preferences questionnaire reliability and validity

The two separate scale scores of the Play Preferences Questionnaire were computed by averaging the corresponding items per scale. The internal reliability (Cronbach's alpha) of the final ratings for Visual-Object Play Preferences was .85 (11 items), for Visual-Spatial Play Preferences was .91 (11 items), and for Verbal Play Preferences was .79 (10 items), which meets McKelvie (1994) recommendations for psychometric properties of imagery questionnaires. The Play Preferences Questionnaire's construct validity was examined by correlating the scale scores with the criterion measures. Since tests of normality showed that data does not come from a normal distribution for many measures, Spearman correlation was used. Overall, the results supported the convergent and discriminative validity of the Play Preferences Questionnaire (Table 4).

In particular, the Visual-Object Play Preferences scale was positively associated with measures of Object Visualization (significantly with the OSIQ object scale, VVIQ, Camouflage Pictures task, and marginally with the Fragmented Pictures task, $p = .055$) and Visual Art Aptitude ratings. At the same time, it did not correlate with Spatial Visualization measures and even negatively correlated with Science Aptitude. In contrast, the Visual-Spatial Play Preferences scale positively correlated with measures of Spatial Visualization (spatial OSIQ scale, Mental Rotation test, and

Table 4. Correlations between the scales of Play Preferences Questionnaire and criterion measures.

	Visual-Object Play Preferences	Visual-Spatial Play Preferences	Verbal Play Preferences
Visual-Object Play Preferences	1		
Visual-Spatial Play Preferences	.059	1	
Verbal Play Preferences	.370**	-.003	1
OSIVQ-object	.518**	-.150*	.226**
OSIVQ-spatial	.005	.536**	-.184**
OSIVQ-verbal	-.062	-.203**	.360**
Visual Art Aptitude	.451**	-.193**	.137 ⁺
Science Aptitude	-.157*	.492**	-.161*
Humanities Aptitude	.059	-.222**	.287**
VVIQ	.379**	.076	.236**
Camouflage Pictures	.182**	.118 ⁺	-.015
Fragmented Pictures	.134 ⁺	.116 ⁺	.028
Paper Folding	.107	.345**	-.011
Mental Rotation	.011	.264**	-.101

Note: ⁺ $p < .1$; * $p < .05$; ** $p < .001$; correlations with criterion constructs are underscored. $N=205$.

Paper Folding test) and Science Aptitude. At the same time, it negatively correlated with the Object and Verbal scales of the OSIVQ as well as with Visual Art and Humanities Aptitudes. The Visual-Spatial Play Preferences scale did not significantly correlate with the Object Visualization measure (VVIQ), however, it marginally correlated with the Camouflage Pictures task ($p = .091$) and the Fragmented Pictures task ($p = .099$). Finally, the Verbal Play Preferences scale positively related to criterion verbal measures (OSIVQ-verbal and Humanities Aptitude) and was unrelated (Paper Folding and Mental Rotation) or even negatively related (OSIVQ-spatial and Science Aptitude) to spatial measures. However, while it was unrelated to Object Visualization performance measures (Camouflage Pictures and Fragmented Pictures), it was positively related to Object Visualization self-reports (OSIVQ-object and VVIQ) and marginally correlated with self-rated Visual Art Aptitude. Moreover, while the two visual Play Preferences scales appeared to be independent, there was a moderate positive association between the Visual-Object and Verbal Play Preferences scales.

6.3. Sex differences in visual and verbal Play preferences

Males and females were compared on each of the scales of the Play Preferences Questionnaire, using t -tests. The analysis revealed significant sex differences, favoring females, in Visual-Object Play Preferences [$t(203) = -6.037, p < .001$; males: $M = .61, SD = .86$, females: $M = 1.34, SD = .87$] and in Verbal Play Preferences [$t(203) = 5.139, p < .001$; males: $M = .33, SD = .94$, females: $M = 1.02, SD = .98$], and favoring males in Visual-Spatial Play Preferences [$t(203) = 6.310, p < .001$; males: $M = .88, SD = 1.10$, females: $M = -.22, SD = 1.35$].

7. General discussion

The current research explored the structure of visual play preferences and examined the relationships between different visual play preferences, object and spatial visualization abilities, as well as different academic specializations that require visualization, i.e. arts and natural sciences. In contrast to previous studies on play preferences, which mainly focused on spatial visualization (or visualization in general) and largely ignored the visual-object dimension, the current study is the first to examine diverse, spatial and non-spatial visual play preferences in relation to different types of visualization. Study 1 explored the structure of visual play preferences and revealed two major factors aggregating visual play preferences along the visual-object (involving processing of pictorial properties) and visual-spatial (involving spatial processing of relationships and transformations) dimensions. Study 2 replicated the finding of the dissociation between visual-object and visual-spatial play preferences, and further showed that these visual play preferences are distinct from verbal play preferences (supporting [Hypothesis 1](#)). The factor structure of visual play preferences appeared to be consistent with the previously-found object and spatial dimensions of individual differences in visualization ([Kozhevnikov et al., 2005](#); [Blajenkova et al., 2006](#); [Blazhenkova and Kozhevnikov, 2009](#)), suggesting that visual play preferences may develop in correspondence with individual differences in visualization, along the object and spatial visual dimensions. The verbal play preferences appeared to form a separate dimension, consistent with the Object-Spatial-Verbal model of cognitive style ([Kozhevnikov et al., 2005](#)).

Furthermore, correlational analyses (Studies 1 and 2) revealed that visual-object, visual-spatial, and verbal play preferences were differentially related to individual differences in visual-object and visual-spatial visualization (supporting [Hypothesis 2](#)). Both visual-object play preferences and visual-object visualization abilities were positively associated with aptitude ratings in art, whereas both visual-spatial play and visual-spatial visualization were positively associated with aptitude ratings in science (supporting [Hypotheses 3](#) and [4](#)). The examination of each particular play preference in relation to different types of visualization (Study 1) demonstrated that visual play preferences' relationships with

spatial versus object visualization tended to be inverse. Likewise, play preferences' relationships with art versus science aptitudes demonstrated an inverse linear trend.

Even though our study does not provide evidence for causal relationships between play, visualization abilities and specialization aptitudes, it contributes to a larger theoretical framework to understand possible mechanisms and the role of play in the development of visualization abilities and future specialization preferences. These current results are in line with previous experimental research evidence that demonstrated a causal relationship between play and development of visualization skills ([Sprafkin et al., 1983](#)) and other literature showing that play preferences and visualization abilities may reciprocally shape one another's development ([Casey, Winner, Brabeck, & Sullivan, 1990](#); [Kersh et al., 2008](#); [Serbin and Connor, 1979](#)). Based on these relationships between play and visualization, we suggest that visual-spatial games may require good abilities in spatial visualization and diminished object visualization, and vice versa for visual-object games. Possibly, engagement in a certain play activity may not only enhance the development of a certain visualization strength, but also may inhibit the development of other visualization strengths. At the same time, high development of a certain visualization ability may not only encourage interest in specific visual games, but may at the same time limit interest in others. Conceivably, the trade-off relationship between object and spatial visualization abilities, reported in previous research ([Kozhevnikov et al., 2010](#)), may manifest in play behavior and constrain the development of play preferences. The divergence between visual-object and visual-spatial processing that appears in play preferences may last into adulthood and manifest in specialization preferences. We hope our results and suggestions inspire future experimental tests of the causal relationships between different types of visual play, visual ability, and specialization aptitudes.

Both studies demonstrated that neither visual-object nor visual-spatial play preferences were positively related to verbal processing as assessed by OSIVQ-verbal and humanities aptitude, whereas verbal play preferences correlated with these verbal assessments. However, Study 2 showed a moderate positive relationship between verbal play preferences and self-report (but not performance) measures of object visualization and visual-object play preferences. These findings, indicating a connection between the visual-object and verbal dimensions, are consistent with previous studies (see a discussion in [Blazhenkova and Kozhevnikov, 2009](#)). For example, there is evidence that verbal information automatically activates visual pictorial imagery ([Sadoski, 1985](#); [Wharton, 1980](#)), and that mental images generated from concrete verbal descriptions elicit activations in both visual and language brain areas ([Mazoyer et al., 2002](#)). However, previous and current research indicate that despite this connection, visual-object and verbal dimensions tap different constructs. Overall, our research demonstrated that differences in play preferences are associated with distinct visual-object, visual-spatial, and verbal dimensions of individual differences ([Kozhevnikov et al., 2005](#); [Blazhenkova and Kozhevnikov, 2009](#)) and cannot be explained solely by a visualizer-verbalizer dichotomy ([Paivio, 1983](#); [Richardson, 1977](#)).

The present study provides a new account of sex differences in play behavior. In contrast to previous studies that explained sex differences in play preferences with reference to visual processing in males and verbal processing in females ([Bradbard and Parkman, 1984](#); [Emmott, 1985](#); [Erikson, 1951](#); [Kersh et al., 2008](#); [Serbin and Connor, 1979](#)), the current study demonstrated sex differences in play preferences across the two dimensions of visual play. Consistent with other studies, we found that females prefer verbal games; however, we also found that females preferred visual-object games, while males preferred visual-spatial games (supporting [Hypothesis 5](#)). However, the general structure of visual play preferences (e.g., alignment along the visual-object and visual-spatial dimensions) remained largely the same in both sexes (supporting [Hypothesis 6](#)), suggesting that differences in visual play preferences cannot be reduced to sex differences. Nevertheless, some noteworthy sex differences appeared in the separate analysis for males and females. Play

preferences with an aesthetic component appeared to involve both object and spatial visual processing for males, while for females they were associated primarily with visual-object processing. Such differences in play preferences may indicate different approaches and strategies used by males and females, who could enjoy and exercise different aspects of games, and differentially use their visual strengths (e.g., a child constructing from paper could focus on this activity's aesthetical-pictorial versus its spatial-structural properties). Congruently, other studies have demonstrated that males and females construct different types of structures from building blocks (Erikson, 1951; Kersh et al., 2008), use different neural circuits (as revealed by fMRI), and allocate their attention differently while solving the same spatial tasks (Jordan et al., 2002).

Our research also found that sex differences in both visual-object and visual-spatial childhood play preferences were relatively similar in participants of various ages, suggesting that these sex differences may be relatively stable across generations despite historical changes. Besides, the object-spatial factor structure of visual play preferences was relatively similar in children and adult age groups. These findings may indicate that, despite the historical changes in society, there were no substantial changes in sex differences and structure of childhood play preferences. Thus, Hypothesis 7 was not supported. It should be noted, though, that using retrospective reports of childhood play experiences is a very constrained measure of possible historical changes. In fact, older participants' reports about their childhood time can be biased by their current experiences and contemporary society influences. Interestingly, we found that children and older adults, overall, had higher ratings of play preferences as compared to younger adults. Possibly, children rated their play preferences higher because they referred to their current or very recent play experiences. The older adults' amplified ratings of their childhood play preferences may be understandable based on previous literature demonstrating an increase in the number of earlier memories in older adults (i.e., the reminiscence bump; Jansari and Parkin, 1996; Rubin and Schulkind, 1997). It may be also because older adults tend to experience fewer negative emotions and demonstrate more emotionally positive autobiographical memories than younger adults do (Mather and Carstensen, 2005). Since childhood play refers to positive emotional experiences, it may cause the higher ratings of these experiences in older adults. In addition, our data showed a relatively more sharp increase in object relative to spatial play ratings in older adults. Possibly, visual-object play experiences have a higher ratings in older participants because of their current cognitive abilities. As indicated by previous research, visual-spatial ability begins to decrease after adolescence, whereas visual-object behaves as a crystallized ability which does not show age-related decline and may even increase with age (Blazhenkova et al., 2011; Vandenberg and Kuse, 1978).

It must be acknowledged that the current study assessed childhood play preferences based on recall in adult participants using their retrospective self-reports, which is a reliable and valid (Brewin et al., 1993; Sallis, 1991; Yarrow et al., 1970) but limited way of assessing play preferences. Future studies may be able to detect and track age-related differences by jointly assessing visual-object and visual-spatial play preferences as well as visualization abilities in different ages. However, this may be quite challenging due to difficulties in the early detection of visualization abilities (Blazhenkova et al., 2011; Schneider, 1998; Voyer et al., 1995). The Play Preferences Questionnaire employed in the current study is a rather exploratory instrument, which does not incorporate an exhaustive list of play activities. In addition, the descriptions of games were rather general, and potentially could be interpreted differently by different participants. For example, a preference for playing with 'puzzles' may depend on the type of puzzles, for example, wooden blocks or jigsaws. However, the current results (revealed factor structure, good reliability of the scales, and positive correlations with the criterion measures) create a theoretical basis and suggest promising perspectives for the further development of a comprehensive, reliable, and valid assessment of visual play preferences. Such an instrument should include a wider range of games tapping visual-object, visual-spatial, and verbal

dimensions. Another recommendation for the future design of visual play assessments would be specifying different visual play preferences more precisely. Such instruments should not be restricted to questionnaires and may include choice pictures of toys or play activities to measure the preferences. It would be also beneficial to develop a measure of play type exposure. An explicit no exposure option may be included for respondents who have not experienced a particular type of play. These future instruments should be validated using objective measures of play behavior and performance tests.

It is also important to note that games included in the current Play Preferences Questionnaire were selected based on their loadings on visual-object, visual-spatial, or verbal factors. However, some childhood games may not exclusively tap visual-object, visual-spatial or verbal dimensions. For example, play with dolls appeared to require not only considerable visual-object processing such as caring about dolls' appearance or imagining facial expressions, but also social and verbal skills. Also, assembling puzzles and constructing from paper may require both visual-object and visual-spatial skills. An additional note is that some visual-object play activities such as drawing were classified as non-spatial, whereas they may involve some spatial processing. In particular, drawing may involve understanding spatial relationships and may not be purely 'object'; in fact, some types of drawing may be mostly spatial (e.g., technical drawing). However, in the context of childhood play behavior drawing mostly refers to creative artistic drawing, which requires mostly object-imagery: As established by previous research (Blazhenkova and Kozhevnikov, 2010), visual art is associated with object rather than spatial visualization. Based on our factor analyses, it seems that in the context of play activities, drawing (especially painting) tends to be more 'object' than 'spatial'. Study 2 included a variety of items related to drawing (exploring drawing media, drawing shapes, mixing colors, shading while drawing), and all of them appeared to load on the object play factor.

It should also be noted that there is a limitation in the availability of performance-based object visualization assessments, which is due to the relative novelty of the object visualization intelligence concept (Blazhenkova and Kozhevnikov, 2010), together with difficulties in the objective measurement of an ability which involves a considerable subjective component (e.g., brightness and colorfulness of imagery). The performance tasks of object visualization, used in the current study, were not established and validated tests. Besides, they mostly tapped shape visual processing, which also may be related to spatial visualization (Lehky and Sereno, 2007; Wang et al., 1999). Since the current study mainly focused on visual play preferences, it did not include performance measures of verbal ability or a very wide variety verbal items. Future studies should explore more thoroughly the relationships between different play preferences and various tests of visual and verbal ability.

Finally, we must acknowledge the limitations of a self-report measure used for assessing the Aptitudes in Different Academic Specializations. Perceived academic self-efficacy significantly relates to performance in college courses (Wood and Locke, 1987), and the current measure of Arts self-efficacy correlated with object imagery ability measures, while Science self-efficacy was correlated with spatial imagery ability measures. However, our measure did not actually tap aptitude as a performance outcome. Also, it included just with one question per specialization field, without separating subfields, e.g., physics, math, computer programming, or engineering. Future studies examining the relations between play, visualization and specialization should include objective measures such as professional membership, educational college specialization, as well as assessments of professional and educational success.

The present research uses the perspective of individual differences in object versus spatial visualization to link existing cognitive, developmental, educational, and occupational psychology research examining individual differences, visualization, and play preferences. It has several applications for both basic research and applied fields (e.g., theoretically guided development of play assessments, talent search, educational practices, and assisting children with developmental disabilities).

Knowledge about which particular combination of visualization skills are involved in specific visual games aids the understanding of individual differences, within an educational context and beyond. It may help educators, therapists, parents, and toy manufactures to foster the development of children's visualization skills through specific visual play activities (Verdine et al., 2014). Early identification of different kinds of visualization strengths and play preferences (including the object dimension) could be crucial for talent search programs, as gifted students are often currently overlooked on the basis of search criteria based on only mathematical and verbal ability assessments (Rieser et al., 1994; Wai et al., 2009; Webb et al., 2007). Precursors of artistic or scientific giftedness and specific visualization abilities can be recognized in childhood visual play. Similarly, understanding of play behavior in relation to visualization may aid the early identification and assistance of individuals with developmental disorders such as Autism spectrum disorder, which is characterized by uncommon visualization characteristics (Grice et al., 2001; Simmons et al., 2009), atypical play behavior, and unusual toy preferences (Dominguez et al., 2006). We hope future studies will examine how different facets of visualization abilities may affect specific play preferences, how different play experiences shape specific visualization abilities, as well as how they both create developmental opportunities for skills and preferences that last into adulthood.

Declarations

Author contribution statement

Olesya Blazhenkova: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Robert W. Booth: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

Data associated with this study has been deposited at Mendeley at the following link: <https://data.mendeley.com/datasets/jxbg69v778/draft? a=bc19cdfa-46e1-4100-a317-02c4dc1fd761>.

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