# Chapter 16
# Individual Differences in Object Versus Spatial Imagery: From Neural Correlates to Real-World Applications

**Maria Kozhevnikov and Olesya Blazhenkova**

**Abstract** This chapter focuses on individual differences in object and spatial–visual imagery both from theoretical and applied perspectives. While object imagery refers to representations of the literal appearances of individual objects and scenes in terms of their shape, color, and texture, spatial imagery refers to representations of the spatial relations among objects, locations of objects in space, movements of objects and their parts, and other complex spatial transformations. First, we review cognitive neuroscience and psychology research regarding the dissociation between object and spatial–visual imagery. Next, we discuss evidence on how this dissociation extends to individual differences in object and spatial imagery, followed by a discussion showing that individual differences in object and spatial imagery follow different developmental courses. After that we focus on cognitive and educational research that provides ecological validation of the object–spatial distinction in individual differences—in particular, on the relationship of object and spatial–visual abilities to mathematics and science problem solving and then to object–spatial imagery differences between members of different professions. Finally, we discuss applications of the object–spatial dissociation in imagery for applied fields, such as personnel selection, training, and education.

**Keywords** Visual imagery • Object–spatial dissociation • Individual differences • Visualization abilities • Cognitive neuroscience • Educational applications

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S. Lacey and R. Lawson (eds.), *Multisensory Imagery*,
DOI 10.1007/978-1-4614-5879-1_16,

## 16.1 Introduction

This chapter focuses on individual differences in object and spatial–visual imagery both from theoretical and applied perspectives. The research reviewed here is based on a new approach to examining individual differences in visual imagery that relies on a key distinction between object and spatial imagery. *Object imagery* refers to representations of the literal appearances of individual objects and scenes in terms of their shape, color, brightness, texture, and size. *Spatial imagery* refers to representations of the spatial relations among objects, parts of objects, locations of objects in space, movements of objects and their parts, and other complex spatial transformations. First, we review cognitive neuroscience and psychology research regarding dissociations in object and spatial–visual imagery. Next, we discuss evidence on how this dissociation extends to individual differences in object and spatial imagery, followed by a discussion showing that individual differences in object and spatial imagery follow different developmental courses. After that we focus on cognitive and educational research that provides ecological validation of the object–spatial distinction in individual differences—in particular, on the relationship of object and spatial–visual abilities to mathematics and science problem solving and then to object–spatial imagery differences between members of different professions. Finally, we discuss applications of the object–spatial dissociation in imagery for applied fields, such as personnel selection, training, and education.

## 16.2 Object Versus Spatial Imagery: Evidence from Neuroscience and Psychology

Since the 1980s, cognitive neuroscience has provided strong evidence that higher level visual areas of the brain are divided into two functionally and anatomically distinct pathways, the object pathway and the spatial relations pathway (e.g., Kosslyn and Koenig 1992; Ungerleider et al. 1982). The object (occipitotemporal or ventral) pathway processes information about the visual–pictorial appearances of individual objects and scenes, in terms of their shape, color, brightness, texture, and size, while the spatial relation (occipitoparietal or dorsal) pathway processes information about the spatial relations among, and movements of, objects and their parts and complex spatial transformations. The distinction between perceptual processing of object properties versus spatial relations extends to visual mental imagery and working memory (Farah et al. 1988; Kosslyn 1994; Kosslyn and Koenig 1992; Levine et al. 1985; Mazard et al. 2004). For example, Levine et al. (1985) demonstrated that lesions to temporal cortex disrupt performance on a spatial imagery task, but not on an object imagery task. In contrast, lesions to posterior parietal cortex have the reverse effects (see also Farah et al. 1988). Mazard et al. (2004) examined the neural basis of spatial versus object imagery tasks using positron emission tomography (PET) and revealed that superior parietal areas are more strongly activated during spatial imagery tasks, but the anterior part of the ventral pathway, including fusiform, parahippocampal, and hippocampal gyri, is more active during object imagery tasks. Furthermore, recent evidence suggests that the visual–spatial sketchpad component of working memory consists of separate visual (object) and spatial subcomponents (Courtney et al. 1998; Darling et al. 2006, 2007; Logie and Marchetti 1991; Logie 2003). The above object–spatial dissociation emphasizes that visual–object processing is functionally and anatomically independent from visual–spatial processing, and they are underpinned by separate ventral and dorsal functional organizations, respectively (Borst et al. 2011).

## 16.3 Dissociation in Individual Differences in Object Versus Spatial Imagery

Despite the cognitive and neuroscientific evidence establishing the existence of object imagery as different from spatial imagery, most of the previous studies on individual differences in visual imagery have focused primarily on understanding individual differences in spatial imagery. These studies attempted to characterize processing differences between participants having high versus low spatial ability for solving, for example, mental rotation (Carpenter and Just 1986), spatial working memory (Miyake et al. 2001), and mechanical, physics, or engineering problems (Kozhevnikov et al. 2007). The results of these studies have suggested that the ability to generate, maintain, and transform spatial images is related to capacity limitations of spatial working memory as well as the availability of central executive resources (e.g., attention allocation) (Miyake et al. 2001). Furthermore, research on the neural underpinnings of spatial ability has revealed an inverse relationship between spatial task performance and associated neural activity (Lamm et al. 1999; Reichle et al. 2000; Vitouch et al. 1997), suggesting that better performance is associated with less neural activity in task-relevant regions (i.e., *neural efficiency*). Vitouch et al. (1997), for example, found that in a spatial comparison task low-spatial-ability participants showed greater activation in right parietal cortex than high-spatial-ability participants. Similarly, Lamm et al. (1999) showed that low-spatial-ability participants showed greater activation in parietal cortex when solving spatial rotation problems and that this activation was more extended into frontocentral regions than that of high-spatial ability participants. Reichle et al. (2000) showed an inverse relationship between functional magnetic resonance imaging (fMRI) blood-oxygenation-level-dependent (BOLD) signal change in parietal cortex and spatial ability (measured independently from performance on the fMRI task) when participants used a spatial strategy to encode and remember text descriptions of objects. Together these studies show that high spatial ability is associated with less activation, and thus more efficient neural resource use, in regions identified as mediating spatial processes.

In contrast to individual differences in spatial imagery, individual differences in object imagery have received less attention in the psychometric, cognitive psychology or neuroscience literature. Surprisingly, contemporary psychology research on individual differences still retains the implicit assumption that visual–spatial ability is the only form of visual intelligence. It has long been expected that this single visual–spatial dimension would predict performance in various professional fields that require imagery and those individuals who are high in visual–spatial ability would excel equally in either science or visual arts (e.g., Gardner and Hatch 1989; Gardner 1999). For instance, Gardner proposed the existence of spatial intelligence (sometimes referred as visual–spatial), which he defined as the ability to perceive the visual–spatial world accurately, and suggested that spatial intelligence is equally important to navigators, pilots, designers, sculptors, and artists. Recently, several psychological and neuroscience studies have provided support for distinctions between visual–object and visual–spatial imagery at the individual differences level (Kozhevnikov et al. 2002, 2005). Kozhevnikov et al. (2005) identified two types of individuals based on their imagery abilities: individuals with high object imagery ability, *object visualizers* (also called *object imagers*), and individuals with high spatial imagery ability, *spatial visualizers* (also called *spatial imagers*). Object visualizers used imagery to construct high-resolution images of the visual properties (e.g., shape and color) of individual objects and scenes. In contrast, *spatial visualizers* tend to use imagery to schematically represent spatial relations among objects, perform spatial transformations, and do not regard surface properties, such as color and texture, as relevant (see also Nicholson and Humphrey 2003; Lacey et al. 2011). Object visualizers were found to outperform spatial visualizers on object imagery tasks (e.g., Degraded Pictures Test, Kozhevnikov et al. 2005) that require generation of high-resolution images, while spatial visualizers were found to outperform object visualizers on spatial imagery tasks (e.g., Mental Rotation Test, Shepard and Metzler 1971, or Paper Folding, Ekstrom et al. 1976) that require spatial visualization and transformation.

Based on the above distinction between visual–object and visual–spatial abilities, a number of theoretically guided assessments of visual–object ability have been recently designed, including objective performance measures (e.g., the Degraded Picture Task, see example in Fig. 16.1) as well as self-report cognitive style questionnaires assessing individuals' preferences for visual–object versus visual–spatial modes of information processing (Blajenkova et al. 2006; Blazhenkova and Kozhevnikov 2009; Kozhevnikov et al. 2005, 2010). These studies consistently demonstrated that all visual–object and visual–spatial ability measures loaded onto two distinct visual–object and visual–spatial factors, respectively (which were also separate from a verbal factor). This indicates that individuals are usually aware of their most efficient mode of visual information processing and that self-report measures (VVIQ—Vividness of Visual Imagery Questionnaire in Marks 1973; OSIVQ—Object–Spatial Imagery and Verbal Questionnaire in Blazhenkova and Kozhevnikov 2009) could be reliably used to identify an individual's particular strengths and weaknesses in the use of object or spatial modes of information processing.

Recently, in order to investigate the neural underpinnings of individual differences in object versus spatial–visual processing, Motes et al. (2008) conducted an

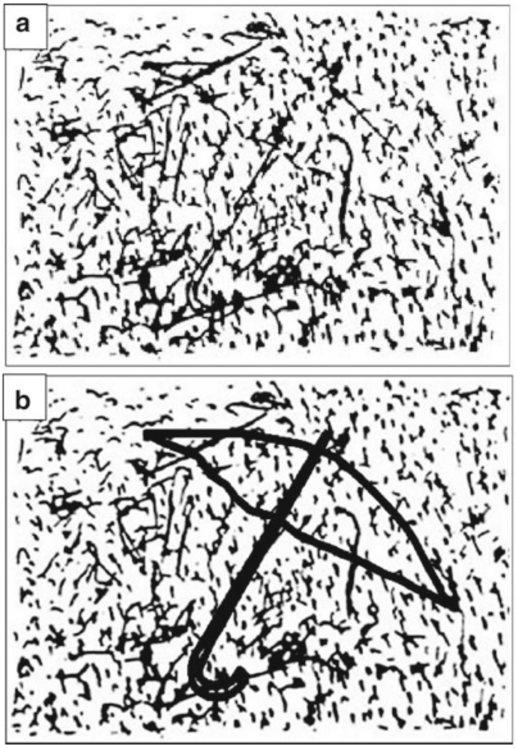


**Fig. 16.1** Example of the Degraded Picture Task. (**a**) Example item (umbrella) from the degraded picture task. (**b**) The outline of the umbrella hidden in the picture. The task was to recognize the object depicted in a degraded picture (from Kozhevnikov et al. 2005)

fMRI study in which object and spatial visualizers were scanned while performing an object-processing task in which they were instructed to study and visualize line drawings of common objects to later identify whether different properties of the drawings were present or not. Both spatial and object visualizers showed bilateral task-related activity in the lateral occipital complex (LOC), but object visualizers showed significantly lower LOC activation than spatial visualizers even though object and spatial visualizers performed equally well on the behavioral aspects of the task. Given that LOC mediates object processing (Amedi et al. 2005), the data suggest that the object visualizers used their neural resources more efficiently than spatial visualizers (that is, they show less brain activation in corresponding areas indicating fewer recruitment of object-processing neural resources) while exhibiting the same level of performance at the behavioral level. In addition, object visualizers showed less neural activity in right dorsolateral prefrontal cortex (DLPFC). The DLPFC is associated with executive attentional processes brought online when task demands exceed basic processing capacity (Rypma and D'Esposito 2000). Overall, the results indicated that object processing draws from a relatively independent pool of object-processing resources, and thus constitutes an independent ability that spatial visualizers do not seem to possess to the same degree as object visualizers.

Furthermore, the results of Motes et al. (2008) indicate that high object-processing ability is associated with more efficient use of visual–object resources resulting in less neural activity in the object-processing pathway. The important implication of this study is that high-object or high-spatial individuals might rely on their processing strengths and fail to engage task-relevant cortical resources if the imagery task does not suit their strengths. Thus, important considerations for future neuroimaging studies are that imagery ability is not a unified construct and that the degree and localization of brain activity will vary considerably depending on participants' imagery abilities and the type of imagery required for the task.

## 16.4 Developmental Differences in Object Versus Spatial Imagery Abilities

Another line of evidence regarding the dissociation between object and spatial imagery in individual differences comes from developmental research. Blazhenkova et al. (2011) conducted a cross-sectional study in which they examined the development of object and spatial abilities across a wide range of ages (8–60 years old). The participants ($N = 646$) were recruited from schools and universities from three countries with developed educational systems (Russia, USA, and Singapore). The participants were administered a number of tasks testing object imagery ability (the Degraded Picture Task, Kozhevnikov et al. 2005; VVIQ, Marks 1973) and spatial imagery ability (Mental Rotation, Shepard and Metzler 1971; Paper Folding, Ekstrom et al. 1976). The participants' object and spatial abilities were computed by averaging the normalized $z$-scores on object and spatial imagery tasks, respectively, across all age groups. The analyses of developmental trends across age groups for object and spatial abilities revealed significant age-related changes which were different for each of the abilities (see Fig. 16.2). The development of spatial ability increased in adolescence, followed by gradual decline. In particular, spatial ability measures tended to peak between the ages of 14 and 16, and slowly declined after that, consistent with the results of previous studies (e.g., Vandenberg and Kuse 1978). In contrast, object ability measures also tended to increase in children but did not show the same age-related decline in adults as spatial ability measures did, and even tended to increase with age. This is consistent with previous research which indicated that certain aspects of visual–object processing tend not to decay with age and, moreover, may even increase in older individuals (Campos and Sueiro 1993; Siu et al. 2011; Van Leijenhorst et al. 2007).

Overall, the above studies demonstrated that object and spatial abilities follow different developmental courses. This further supports the idea that these two abilities are different, and also raises important questions for education and training. If, indeed, the critical window for spatial ability development is between the ages of 14 and 16, this would imply that teaching science courses that require spatial ability (such as physics, geometry, or chemistry) might be most effective during these ages. In contrast, because there is no specific critical window in the development of object imagery ability, educators could be more flexible on when courses that rely on object imagery ability (e.g., visual art) are introduced into the school curriculum.

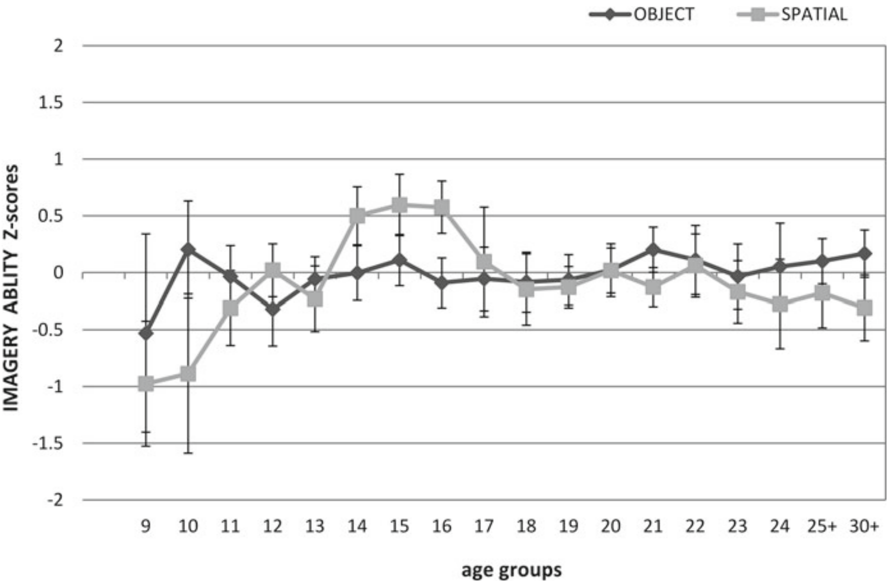


**Fig. 16.2** The developmental trajectories for visual imagery abilities: (**a**) object and (**b**) spatial. The bars represent 95% confidence intervals (based on the data from Blazhenkova et al. 2011)

## 16.5 Object and Spatial Imagery Abilities in Mathematics and Science Education

Numerous studies have been carried out to understand the role of visual representations in mathematics and science learning (e.g., Larkin and Simon 1987; Mandl and Levin 1989; Plass et al. 1998; Winn et al. 1991). However, most studies investigating the effect of visual imagery on learning have treated imagery as a general and undifferentiated skill. We should take into account, however, that since imagery might rely on different types of representations (either object or spatial), different people might have a strong preference for one type or another. In fact, Hegarty and Kozhevnikov (1999) found consistent differences in students' preferences for using spatial–schematic representations that encode spatial relations and object–pictorial representations that encode the visual appearance of the objects. In their study, participants solved mathematical problems and reported on their solution strategies. Use of spatial–schematic representations was associated with success in mathematics problem solving while the use of pictorial representation was negatively correlated with success. Use of schematic representation was also significantly correlated with the students' spatial ability. The results of this research therefore help to clarify the relationship between object imagery, spatial imagery, and math problem solving. While some visual representations promote success, others may present an obstacle to mathematical problem solving.

In another study, Kozhevnikov et al. (2002) reported that object and spatial visualizers tended to employ radically different strategies in science problem solving involving interpreting kinematics graphs. In their study, the authors controlled participants' background in physics by choosing only those object and spatial visualizers who had not taken physics courses either at high school or college level. The participants were asked to visualize and describe the situation depicted on the graph (position versus time). The results of the study showed that object visualizers preferred to use visual–pictorial imagery; they consistently preferred to use global strategies and interpreted the graph literally as a picture of the situation. In contrast, spatial visualizers showed a consistent preference for spatial imagery; they attempted to interpret each interval of the graph successively, part by part. The problem-solving task studied in this article, interpretation of kinematics graphs, required students to interpret a visual–spatial representation as abstract and break it down into different intervals, so that "global" object–pictorial representations hindered success in this task, similar to solving mathematical problems as described in Hegarty and Kozhevnikov's (1999) study.

It is remarkable that a significant group of college students, object visualizers, had difficulty interpreting graphs as abstract schematic representations and instead interpreted them as pictorial representations. Object visualizers will clearly have difficulty solving mathematics problems and interpreting graphs. Instructing students to "visualize" mathematical problems will probably not be successful. How might we best teach these students to represent and solve science and mathematical problems? How can we encourage them to construct spatial representation of the relations between objects in a problem and discourage them from representing irrelevant pictorial details? One possible approach is to teach object visualizers to represent and solve physics and mathematics problems by using verbal–analytical strategies rather than spatial strategies that might be dependent on spatial working memory resources that they do not have. Another possible way of teaching object visualizers is to give them explicit instruction on how object, spatial, and verbal representations relate to each other. Having all these types of representations available and demonstrating how each of them translates into the others might help object visualizers translate concrete pictorial representations into a more schematic spatial form. For instance, microcomputer-based learning (MBL) technologies were designed specifically to pair physical events with their graphical representations in real time and thus provide students with the possibility of exploring connections between them. Students see the graph made by a moving object with the results appearing instantly with each move made by the object. Researchers found a significant change in students' ability to interpret kinematic graphs and overcome graph-as-picture misconceptions after MBL intervention (e.g., Linn et al. 1987; Kozhevnikov and Thornton 2006; Mokros and Tinker 1987; Thornton and Sokoloff 1990). Moreover, it has been shown that teaching students to relate between different types of representation, as in MBL instruction, can significantly increase their performance on spatial tests (Kozhevnikov and Thornton 2006).

We should note, however, that although pictorial images do not contribute to mathematics problem solving and graph interpretation in physics, this type of imagery has been found to be very useful for enhancing memory (Presmeg 1986a), as well as in social studies classes (Danzer and Newman 1992). Pictorial images can help to illuminate a subject and have been found to have mnemonic advantages (e.g., Paivio 1971; Presmeg 1986a, b, 1992) and to be highly correlated with visual memory measures (e.g., Marks 1973, 1983). Luria's (1982) case study, "The Mind Of A Mnemonist," describes an extraordinary mnemonist, known as "S," who was able to generate images of exceptional vividness and concreteness (his main mnemonic technique was to put different items to be memorized in places alongside streets in Moscow that he knew well and then to take an imaginary walk along these landmarks). However, Luria (1982, p. 388) reported that these vivid images were not flexible and helpful for the mnemonist in tasks dealing with abstract material. S's images were particularly vivid and stable and recurred thousands of times, so they soon became the dominant element in his awareness uncontrollably coming to the surface whenever he touched upon something that was linked to them even in the most general way. Similarly, Aspinwall et al. (1997) found that vivid concrete images may become uncontrollable while solving mathematical problems, "and the power of these images may do more to obscure than to explain" (p. 301). Therefore, it is plausible that object visualizers are especially good at generating vivid pictorial images that may help them succeed in cognitive tasks such as memory tasks, drawing, or painting but that hinder success on mathematical or physics tasks. Thus, the utility of a particular type of imagery depends in part on the task; it is not likely that any type of imagery is necessarily or universally superior to any other type. In summary, the results highlight the need for research that characterizes which type of imagery facilitates learning and reasoning in specific domains.

## 16.6 Object–Spatial Imagery Dissociations in Different Professional Domains

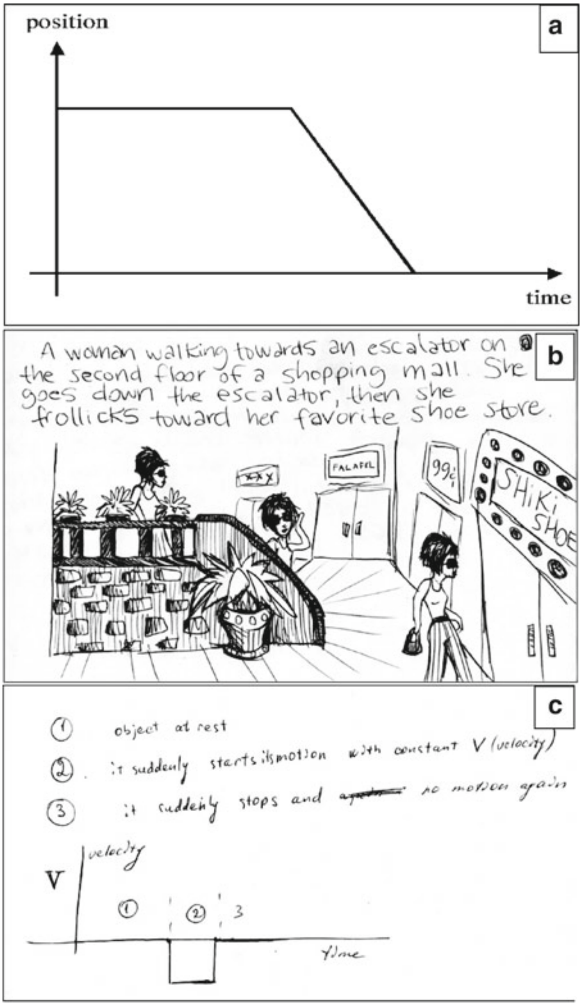
The previous research leaves open questions about the ecological validity of object imagery. In particular, it does not give a clear answer as to whether object imagery can support abstract thinking of any kind and whether it has more general applications and functional roles in real-life performance rather than supporting only memory functioning. In other words, the question is whether object imagery ability can be considered as an independent component of visual intelligence separate from visual–spatial intelligence. In order to establish an ability as an independent component of intelligence, it must meet the following principal requirements: (1) the ability must play a functional role, that is, it must be related to performance on complex tasks, such as educational or occupational tasks, and not just reflect a narrow ability, such as the ability to score highly on a specific test (Gardner 1999; Gottfredson 1997; Lubinski 2004; Sternberg 1985); (2) it must support high-level information processing, such as abstract representations or symbolic encoding (Carpenter et al. 1990; Galton 1880; Gardner 1999; Gottfredson 1997; Snyderman and Rothman 1987); and (3) it must have unique qualitative and quantitative characteristics, supported by behavioral and/or neurological evidence that distinguish it from other components of intelligence (Gardner 1999).

Currently, the only widely accepted component of visual intelligence is visual–spatial ability, which is included in most commonly used measures of intelligence (e.g., Stanford-Binet, Roid 2003; Wechsler Intelligence Scale, Wechsler 1997). Spatial ability was found to have all the essential characteristics of intelligence: ecological validity, capacity to support abstract spatial processing in engineering and scientific fields, as well as unique qualitative and quantitative characteristics supported by cognitive psychology research. The tests of spatial ability have been proven to be important criteria for predicting students' achievement in mathematics and a wide range of technical areas (see McGee 1979; Clarkson and Presmeg 2008) and in predicting performance in engineering, mechanics, and physics (Ghiselli 1973; Hegarty and Just 1989; Holliday 1943; Kozhevnikov et al. 2007; Kozhevnikov and Thornton 2006; Smith 1964). The ability to generate vivid colorful images of objects and scenes, however, was long thought to represent an aspect of visual–spatial ability, rather than constitute a separate imagery skill, despite the fact that the instruments assessing individual differences in imagery vividness have failed to establish significant correlations with spatial tasks (for review, see McKelvie 1995).

There is growing evidence that members of different professions might generate different types of visual images and manipulate them in different ways and that visual processing of object (but not spatial) properties might play a crucial role in the creative processes of visual artists (Blazhenkova and Kozhevnikov 2010; Kassels 1991; Miller 1996; Roe 1975; Rosenberg 1987; Winner and Pariser 1985). Visual artists characterize their images as typically pictorial and bright and report preferences primarily for object imagery, while scientists characterize their images as abstract and schematic and report preferences for spatial imagery (Blajenkova et al. 2006; Blazhenkova and Kozhevnikov 2009; Lindauer 1983). Several studies have shown that scientists surpass visual artists on visual–spatial ability tests, which required performing mental spatial transformations, while visual artists surpass scientists on tests which required generation of high-resolution, pictorial images (Kozhevnikov et al. 2005, 2010). For example, Blazhenkova and Kozhevnikov (2010) systematically compared the visual–object and visual–spatial abilities of visual artists, scientists (students and professionals) those in the humanities, and social scientists. Visual artists were significantly more accurate and efficient on all visual–object ability assessments (both self-reports and performance assessments) than science and humanities/social science groups, while scientists were significantly more accurate and efficient on all visual–spatial imagery assessments than the other two groups. Overall, the results indicate that visual–object ability is a reliable and unique predictor of specialization in visual art for college students and professionals. In contrast, visual–spatial ability was related to specialization in science, consistent with previous findings reported in psychometric literature (Ferguson 1977; Hegarty and Kozhevnikov 1999; Pellegrino et al. 1985). Furthermore, visual–spatial ability does not predict specialization in visual art (Blazhenkova and Kozhevnikov 2010).

As for the capacity of visual–object ability to support abstract thinking, the prevailing view within the literature, beginning with Galton (1880) and persisting even in contemporary literature, has been to associate visual–object ability with concrete visual thinking, low intelligence, and an inability to form abstract visual representations (Aspinwall et al. 1997; Twyman 1972; Brewer and Schommer-Aikins 2006). However, historical analysis suggests that visual art might not only portray the concrete visual appearances of objects and scenes (e.g., landscapes or portraits in Renaissance art) but also represent abstract content, such as pure emotions and concepts using color and shape (e.g., Cubism and Abstract Expressionism) (Miller 1996). In order to investigate this issue further, several researchers (Blazhenkova and Kozhevnikov 2010; Kozhevnikov et al. 2005) compared how individuals, depending on their proficiency (due to experience or natural ability) in object versus spatial information processing, interpreted abstract visual–spatial representations, such as science graphs, and abstract visual–object representations, such as modern art. Scientists interpreted kinematic graphs in an abstract way, while visual artists interpreted them literally, as pictures (Kozhevnikov et al. 2005; Blazhenkova and Kozhevnikov 2010; see Fig. 16.3). If pictorial visual–object imagery is simply a concrete form of spatial imagery, it follows that scientists' proficiency in spatial processing would also help in interpreting visual–object information. If individuals of high proficiency in spatial processing are unable to do so while individuals of high proficiency in object processing are, this would suggest that the visual–object domain conveys a type of abstract information distinct from visual–spatial abstract information. Blazhenkova and Kozhevnikov (2010) compared how visual artists versus scientists interpreted abstract visual–object information (modern abstract art). Their results showed that visual artists tended to interpret abstract art as abstract representations; they referred to the paintings in terms of conceptual and emotional content that was not directly depicted but was related to the ideas expressed by artists. In contrast, scientists tended to interpret abstract art literally, sequentially, using spatial imagery strategies, which led them to concrete interpretations of the painting in terms of its surface features, such as colors or concrete objects resembling the shapes in the paintings, with less reference to emotional content of the pictures. The results indicate that scientists' proficiency in spatial processing is not sufficient for supporting abstract representations in the visual–object domain suggesting that visual–object imagery cannot merely be considered a concrete form of visual–spatial reasoning. Overall, the results indicate that object imagery can support abstract visual–object representations in the same way as spatial processing supports abstract visual–spatial representations and that the visual representations contained in abstract art indeed constitute a unique and meaningful symbolic system, irreducible to that used in the visual–spatial domain.

Finally, Blazhenkova and Kozhevnikov (2010) demonstrated qualitative differences between visual–object and visual–spatial imagery processes described by professionals across all stages of visual processing (*image generation, inspection, maintenance*, and *transformation*). At the *generation stage*, visual artists describe their images as vivid, pictorial, rich in color, detail, and texture, and generated holistically, as single perceptual units, with fine details present upon generation, and content that is not always deliberately generated. In contrast, scientists described their images as mostly schematic, reflecting primarily the structural properties of objects and scenes. Scientists' images tended to be generated intentionally and primarily in a sequential way, part by part.



A woman walking towards an escalator on the second floor of a shopping mall. She goes down the escalator, then she frollicks toward her favorite shoe store.

① object at rest
② it suddenly starts its motion with constant V (velocity)
③ it suddenly stops and ~~again~~ no motion again

**Fig. 16.3** Example of responses to a kinematic graph problem (**a**) given by a visual artist (**b**) and a scientist (**c**) (from Kozhevnikov et al. 2005)

During *the inspection stage*, visual artists tend to intentionally inspect their visual images in detail in order to explore their images' meanings, which are often ambiguous and multifaceted. In contrast, scientists' images are less likely to be purposely inspected, since scientists' images are usually generated specifically for rational, logical tasks, and thus their meanings tend to be unambiguous and apparent upon generation. During *image maintenance*, visual artists' images are stable and often persistent. Visual artists tended to maintain their images effortlessly, in contrast to scientists, who generally maintain only specific parts of their images through conscious effort. At the *image transformation stage*, many visual artists reported that their images were highly resistant to transformations. In cases when they do perform transformations, they tended to transform primarily visual–object properties (e.g., surface properties like color and shape) of their images, but not purely visual–spatial properties (e.g., rearranging the visual–spatial structure). Scientists, in contrast, reported themselves to be very efficient in spatial transformation and did not regard surface properties as relevant. Overall, the above findings suggest that visual–object imagery has unique qualitative characteristics at all four stages of image processing and that the properties of visual–object imagery at different stages of processing might be seen as emergent properties of the holistic nature of visual–object processing. Likewise, the properties of visual–spatial processing at different stages might be seen as emergent from the sequential nature of visual–spatial processing.

The differences between the holistic nature of visual–object processing and the sequential nature of visual–spatial processing as reported by visual artists and scientists, respectively, are consistent with cognitive neuroscience evidence on the distinction between object and spatial imagery. This suggests that object images are generated by pattern activation in a visual buffer (i.e., topographically organized areas in the occipital lobe, V1 and V2) on the basis of information stored in long-term memory and encoded globally as discrete perceptual units (Kosslyn 1994; Kosslyn et al. 2006). In contrast, spatial images are generated sequentially, part by part, via successive shifts of attention to represent spatial relations between objects or their parts. In general, global encoding and processing of images by the visual–object system would hinder flexible image transformations, but facilitate image generation and recognition, since the time needed to generate and activate an object image should not depend on an image's complexity. In contrast, sequential processing of images by the visual–spatial system facilitates flexible spatial transformations. Since scientists comprehend the structure of visual information by parts, their visual–spatial images seem to be more flexible and transformable. In contrast, visual artists' images are encoded as single, global perceptual units which are not easily transformable. In other words, parts of the image are locked into place with one another such that one part is difficult to transform without transforming the others (see Blazhenkova and Kozhevnikov 2010 for detailed discussion). Thus, both object and spatial imagery are uniquely suited to effective visual processing at different stages for different tasks.

## 16.7 Trade-Off Between Spatial and Object Imagery Abilities

Research indicates relative independence between the ventral and dorsal visual pathways, associated with object and spatial–visual processing, respectively (Courtney et al. 1998; Ungerleider and Mishkin 1982; Mazard et al. 2004), although this does not necessarily imply dissociation in individual differences in imagery.[1]

Recent studies revealed that there is a trade-off between object and spatial imagery abilities at the individual difference level, rather than independence

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[1] Object and spatial imagery abilities might be independent but also might tap the same underlying visual imagery ability. In the latter case, this underlying ability would not rely exclusively on object or spatial pathways but would also depend on other brain areas involved in visual processing (e.g., prefrontal cortex, early visual areas).

(Kozhevnikov et al. 2005, 2010). For instance, Kozhevnikov et al. (2010) studied five age groups with different professional specializations (visual artists, architects, scientist, and humanities) and reported that participants with above-average object visualization abilities had below-average spatial visualization abilities, and the inverse was true for those with above-average spatial visualization abilities. Visual artists had above-average object imagery and below-average spatial imagery skills, and the opposite pattern was seen in scientists. Humanities professionals were not different from average on either object or spatial imagery, and architects were above average only in spatial imagery (and no different than average in object imagery). No group showed both above-average object and above-average spatial visualization abilities, supporting the existence of the trade-off between object and spatial imagery abilities. Furthermore, within each age group, those specializing in different visual fields (art, science, and architecture) demonstrated similar total visual-processing resources which were differentially distributed across object and spatial visualization abilities.

Figure 16.4 illustrates the distribution of object (*Zobj*) versus spatial (*Zspat*) abilities in different professional groups. The first score, *Zobj* + *Zspat*, was created by adding *Zobj* and *Zspat* scores to reflect the overall amount of visualization (object and spatial) resources. The second score, *Zobj* − *Zspat*, was created by subtracting *Zspat* from *Zobj* to reflect the direction and magnitude of the trade-off between object and spatial visualization abilities. Only humanities professionals had a significantly lower *Zobj* + *Zspat* score than the other groups. The other three groups (visual artists, scientists, and architects) did not show any significant differences.[2] As for the *Zobj* − *Zspat* score, significant differences were found between the groups, indicating the largest magnitude of trade-off in scientists (favoring spatial) and visual artists (favoring object) and the smallest in architects and humanities professionals. The authors obtained similar results for other age groups including groups of gifted children of ages 10–13 specializing either in art or science. While total object and spatial visualization resources increased with age and experience, the trade-off relationship between object and spatial visualization abilities did not.

The origin of the trade-off between object and spatial abilities remains a puzzle. The authors speculated that the trade-off originates through a bottleneck, which restricts the development of overall visualization resources, rather than through preferential experience in one type of visualization. Future neuroscience studies might shed light on an interaction between attentional resources and visualization abilities and provide us with better understanding about how visual imagery might differ between individuals. From an applied perspective, the importance of these findings is that object and spatial visualization abilities might not develop independently in those with high ability and talent in visual professional

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[2] Humanities and social science students and professionals were included in Blajenkova et al. (2006) and Blazhenkova and Kozhevnikov (2010) to serve as a control professional group, since the humanities and social sciences lend themselves to visual forms of information processing less readily than do natural sciences. In addition, the imagery used by humanities/science professionals is more along the lines of logical representations of concepts and relationships among concepts rather than representing the arrangement of physical objects or graphs and data models (e.g., Wai et al. 2009).

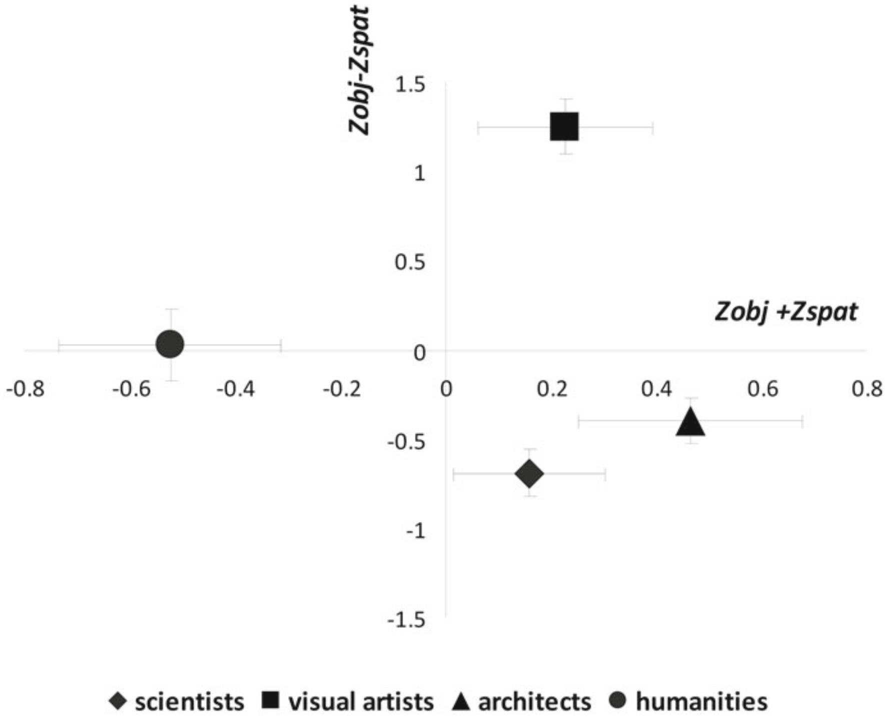

**Fig. 16.4** Zobj − Zspat versus Zobj + Zspat scores for different specialization subgroups of professionals. The bars represent ±*SEM* (from Kozhevnikov et al. 2010)

fields. Thus one important future research direction would be to investigate how specialized education in these fields might foster different types of visualization and what the best age would be to start specialized training that builds on these early-age predispositions.

## 16.8 Gender Differences in Object Versus Spatial Imagery Abilities

Research has demonstrated that females tend to outperform males on imagery vividness ratings (McKelvie 1995; Campos and Sueiro 1993), report higher use of object imagery, and outperform males on a number of tasks that require object imagery ability (e.g., shape recognition) (Blajenkova et al. 2006; Blazhenkova and Kozhevnikov 2009; Kozhevnikov et al. 2005). Males tend to outperform females on tasks that require spatial visualization and transformations such as mental rotation (Collins and Kimura 1997; Linn and Petersen 1985; Voyer et al. 1995). The opposite pattern of gender difference for visual–object and visual–spatial imagery provides additional support to the idea that visual–object and visual–spatial imagery involves different cognitive processes. However, the results of recent studies also showed that difference between spatial and object visualizers cannot be reduced to gender differences. Numerous men were reported to be object visualizers, and numerous women were identified as spatial visualizers (Blajenkova et al. 2006; Blazhenkova and Kozhevnikov 2009; Kozhevnikov et al. 2005). Furthermore, Blazhenkova and Kozhevnikov (2010) reported that specialization is a stronger predictor of object and spatial imagery abilities than gender.

## 16.9 Further Applications of Object–Spatial Imagery Research for Education and Training

One important direction for future research would be to further develop visual–object intelligence assessments. Current IQ tests either ignore visual–object ability or assess visual–object and visual–spatial ability as a unitary construct (mostly measuring spatial rather than object ability). Research by Kozhevnikov et al. (2005) investigated the relationship between the object–spatial dimensions and traditional IQ measures, including Raven's Matrices (Raven et al. 1998) and Verbal WASI, and found that WASI is unrelated to both visual–object and visual–spatial abilities, while performance on Raven's matrices tends to correlate only with visual–spatial ability (see also Blajenkova et al. 2006). Research has, in general, noted that visual ability was a neglected dimension in talent searches, despite its unique predictive validity (Webb et al. 2007), and criticized the existing system of identifying giftedness that is currently mainly restricted to verbal and mathematical ability, despite the purported intent of seeking and developing talents across multiple dimensions. Although some talent search programs include assessments of visual–spatial intelligence (e.g., Raven Matrices; Dental Admission Test, DAT Users Manual 2011), there are currently no assessment procedures for visual–object intelligence.

Similarly, our findings strongly suggest the need to develop appropriate training procedures to improve performance on visual–object tasks and comprehension of visual–object representations. While much attention has been paid in educational research to training visual–spatial abilities (e.g., Lohman and Nichols 1990; Lord and Holland 1997; Pallrand and Seeber 1984; Kozhevnikov and Thornton 2006), training of visual–object abilities has not received as much attention. Assessment and training procedures for visual–object ability would be of great value for identifying visual–object gifted individuals and helping them to realize their full potential and efficiently develop their skills in a professional field.

Recently there has been a great increase in the importance of object information and object-abstract representations in various media, including educational media, movies, advertisements, and contemporary art (Manovich 2001). Also contemporary media tends to use rapidly presented, emotionally charged visual stimuli that need to be processed holistically and quickly. Thus, in contemporary society, due to new task demands, the role of object imagery has been increasing, and thus, recognizing visual–object ability as a type of intelligence, separate from spatial, and developing individuals' visual–object abilities might be critical not only for success in visual arts but also in a wide range of professions and in everyday performance. In summary, the research reviewed in this chapter indicates the separate and independent status of object and spatial imagery abilities and suggests the importance of distinguishing between them for research, education, vocational guidance, and other applied fields.

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