Integrating Art Historical, Psychological, and Neuroscientific Explanations of Artists’ Advantages in Drawing and Perception

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Art historians, artists, psychologists, and neuroscientists have long asserted that artists perceive the world differently than nonartists. Although empirical research on the nature and correlates of skilled drawing is limited, the available evidence supports this view: artists outperform nonartists on visual analysis and form recognition tasks and their perceptual advantages are correlated with and can be largely accounted for by drawing skill. The authors propose an integrative model to explain these results, derived from research in psychology and cognitive neuroscience on how category knowledge, attention, and motor plans influence visual perception. The authors claim that (a) artists’ specialized, declarative knowledge of the structure of objects’ appearances and (b) motor priming achieved via proceduralization and practice in an artistic medium both contribute to attention-shifting mechanisms that enhance the encoding of expected features in the visual field and account for artists’ advantages in drawing and visual analysis. Suggestions for testing the model are discussed.

Keywords: artists, attention, drawing, motor priming, object recognition, perception, schemata, visual art

Skilled visual artists are able to create convincing representational drawings and paintings; in contrast, realistic rendering is extraordinarily difficult for most nonartists. How can we understand this profound disparity? One long-standing explanation is that artists perceive the world differently than nonartists. This view has been espoused by artists (Goldwater & Treves, 1972; Schlewitt-Haynes, Earthman, & Burns, 2002), art instructors (Dodson, 1985; Hale, 1964), art critics and historians (Fry, 1919/1981; Gombrich, 1960; Ruskin, 1857/1971), psychologists (Arnheim, 1954; Cohen & Bennett, 1997; Kozbelt, 2001; Mitchell, Ropar, Ackroyd, & Rajendran, 2005), and neuroscientists (Chatterjee, 2004; Livingstone, 2002; Ramachandran & Hirstein, 1999; Zeki & Lamb, 1994). However, far from resolving the issue, this claim raises a host of additional questions. If the assertion is true, what is the nature of artists’ perceptual differences? What mechanisms are involved? How are such differences related to drawing skill?

In this article, we attempt to integrate these perspectives into a unified account and offer a provisional explanation of psychological mechanisms underlying artists’ drawing and perceptual abilities. Although the psychological basis of skilled drawing remains a relatively neglected area of investigation, the available evidence supports the claim that artists do perceive the world differently, and in some respects better, than nonartists. By better, we mean objectively measurable superior performance on tasks relevant to meaningful computational goals, such as recognizing objects in blurry or otherwise degraded images. We review theoretical perspectives on artists’ perceptual abilities from several disciplines and examine supporting empirical evidence. We then propose an integrative, interdisciplinary model to account for these results. The model is derived from recent research in psychology and cognitive neuroscience on the roles played by category knowledge and motor planning in visual attention and perception. We argue that artists develop attentional strategies that enhance the encoding of expected features in the visual field. These strategies operate in two ways: (a) via specialized, declarative knowledge of the “structure of appearances” of objects and scenes and (b) via motor priming achieved through proceduralization and practice of productive techniques in artistic media. Both of these focus attention on stimulus features relevant for adequate depiction. Because these features are also diagnostic for identifying objects, we argue that artists’ attentional strategies account for their perceptual advantages as well. We conclude by proposing ways to test the model.

Artists’ Perceptual Abilities: Art History and Allied Domains

The nature of artists’ perceptual abilities has long been the subject of discussion and speculation by art critics, art historians, art instructors, and artists themselves. Perhaps the most influential account of perceptual differences between artists and nonartists is a view proposed by art critic and historian John Ruskin (1857/1971) and elaborated by art critic Roger Fry (1919/1981). Fry asserted that the functional attributes of an object’s appearances become “labeled” through habituation. This promotes the efficient recovery of perceptual information necessary to accomplish ordinary tasks in everyday contexts. However, it also interferes with accurate perception (and drawing), because it renders the actual
structure of a stimulus invisible to the viewer. Thus, to recover the visual cues necessary for accurate depiction, artists must overcome these perceptual biases by developing strategies that enable them to attenuate the “conceptual interference” of practical knowledge in object recognition.

The Fry–Ruskin model of artists’ methods is essentially a bottom-up perceptual strategy that treats the visual field as a kind of two-dimensional mosaic. In this view, artists are able to achieve clearer perception and produce more accurate depictions by adopting productive strategies that allow them largely to forget what they know, thereby eliminating perceptual biases. Techniques for achieving this “innocent eye” include Matisse’s use of a plumb line (Flam, 1995) to establish an accurate vertical and Alberti’s (1435–6/1966) use of a gridded canvas to accurately scale the features salient for a pictorial representation. Therefore, according to Fry and Ruskin, artists’ methods for accurate depiction function as perceptual strategies that enable them to see past the influence of cognition on perception to the true underlying visual form of a scene or the veridical structure of appearances.

The Fry–Ruskin model has been incorporated into art instruction techniques, but evidence for its effectiveness is mixed. For instance, one common method for promoting accuracy in drawing is to turn the stimulus to be depicted upside down (Edwards, 1979, pp. 52–55). Inversion should disrupt the usual conceptual interference from categorical knowledge of the object. Therefore, the Fry–Ruskin model would predict that inverted copies should be more accurate. However, Cohen (2005) reported that copying an upright versus inverted face had no effect on the accuracy of nonartists’ drawings. This result suggests that a thoroughly bottom-up approach to drawing may have limitations.

This sort of skepticism about the viability of the Fry–Ruskin thesis echoes concerns raised by art historian E. H. Gombrich (1960). Gombrich argued that the Fry–Ruskin concept of an innocent eye is grounded in a fundamental logical error. If, as Fry argued, labeling is the product of psychological processes constitutive of the biological function of vision, then cognition permeates vision and its influence cannot be overcome. Instead, Gombrich argued that artists must learn to harness perceptual biases to meet their depictive goals. This claim can be illustrated by the inverse problem in vision. The two-dimensional structure of the retinal image is consistent with an infinite number of inverse three-dimensional projections, or configurations of objects in the real world (see Winner, 1982, pp. 91–92). Therefore the retinal input to the visual system is ambiguous and underdetermines its appropriate three-dimensional interpretation. This entails that successful perception depends upon prior knowledge encoded in the visual system that constrains possible interpretations of the sensory input. Thus, a purely bottom-up perceptual strategy like the one proposed by Fry (1919/1981) is just not computationally viable.

Gombrich (1960) argued that artists use their understanding of the structure of objects to profitably bias their perception. In creating realistic drawings or paintings, artists must be sensitive to cues that will induce the illusion of an object or scene in viewers. These cues, or diagnostic features, can be defined as the subset of image features that suffice for object recognition in a given context (Schyns, 1998). Thus, in contrast to the Fry–Ruskin thesis, artists do not see past the conceptual interference of knowledge but rather see with a novel class of knowledge. Gombrich called this class of knowledge schemata. His conception of schemata is similar to that used in cognitive psychology (e.g., Rumelhart, 1980; Solso, 2003): a general mental structure used to organize knowledge and increase understanding, which generates expectations about a situation. Gombrich supported his argument about artists’ use of schemata with reference to how-to manuals used to train artists throughout history (e.g., Cennini, early 15th century/1954). These manuals, and their modern counterparts (e.g., Dodson, 1985; Hale, 1964, 1983; Hamm, 1963), typically provide verbal descriptions and simplified line drawings to highlight the basic proportions and forms of objects. These instructions supply artists with explicit, declarative knowledge of the structure of common object types and means of depicting this information in a given medium. Nonartists lack this specialized knowledge.

This abstract knowledge is literally artificial, that is, embodied in the artifacts created by artists. Gombrich asserted that realistic techniques have to be developed largely from scratch and with reference to other images. Comparison only to nature is insufficient, because nature does not inform the step-by-step means of achieving realistic depictions. This problem is compounded by the fact that there is no ideal, fixed set of perceptual cues that is necessary for realistic depiction; paintings in rather diverse artistic styles can induce comparable realistic perceptual experiences in viewers. Gombrich argued, as a result, that artists seeking realism must engage in a hypothesis-testing process in which disparities between achieved depiction and their perception of the world are resolved. They test sets of marks against their perceptual experience and evaluate their practical success: in Gombrich’s (1960) formulation, “making comes before matching” (p. 116).

The acquisition of schemata influences artists’ perception in various ways. First, schemata can simply call attention to features and characteristics of an object or scene that might otherwise go unnoticed. As an eminent art instructor (Hale, 1983) remarked, a novice attempting to draw a human figure “will see only those bodily forms which up to that time have been brought to his attention” (p. 13). Second, schemata provide artists with knowledge of the relative placement and proportion of objects and object parts. This can help direct attention to their expected relative positions in the visual field. For instance, the central features of a face form an inverted equilateral triangle connecting the corners of the eyes to a point at the bottom center of the lower lip (Hamm, 1963, pp. 5), and standard human figures are about eight head-lengths tall (Hamm, 1963, p. 39). Third, and very important, artists’ schemata include means of achieving desired effects in a rendering. For example, artists have long known that three-dimensional form can be suggested when lines are joined to form a T because the stem invariably appears to go behind the crossbar (Hamm, 1963, p. 48; Willats, 1997); since the Renaissance, artists have known that accurate spatial depth can be achieved by lines converging toward a single vanishing point (Alberti, 1435–6/1966; Kubovy, 1986). These robust heuristics for depiction, which generalize across perceptual contexts and thus transcend the depiction of specific object types, can profitably bias artists’ perception by providing general systems for what to attend to when translating what they see into a drawing or painting.

Artists have long recognized and endorsed such systems for visual analysis. For instance, Leonardo da Vinci remarked that “a painter ought always to have in mind a kind of routine system to enable him to understand any object that interests him” (Kelen, 1990, p. 23). Paul Cézanne described aspects of his own system for
simplifying the basic forms of objects by noting that "nature must be treated through the cylinder, the sphere, the cone" (Goldwater & Treves, 1972, p. 363). The fundamentally perceptual nature of such systems was underscored by Jean-Auguste-Dominique Ingres, who advised artists to "draw with your eyes when you cannot draw with a pencil" (Goldwater & Treves, 1972, p. 217). Consistent with these remarks, a questionnaire study of contemporary artists suggests that from an early age they are highly involved with the visual world, routinely engaging in detailed and vivid visual games and visual analyses (Schlewitt-Haynes et al., 2002).

Artists’ Perceptual Abilities: Psychology and Neuroscience

Is there empirical evidence for the assertion that artists perceive the world differently than nonartists? The art historical accounts described previously are suggestive, but they offer little direct support for this claim. Psychological studies of adult artists’ perceptual, drawing, and cognitive abilities are surprisingly scant, given the importance of these issues for understanding the basis of visual art-making. Even book-length treatments of the psychology of visual art (e.g., Arnheim, 1954, 1969; Hoffman, 1989; Solso, 2003) do not typically address questions about the nature and basis of artists’ perceptual, drawing, and cognitive processes. Likewise, studies focusing on kinematic aspects of drawing (e.g., Goodnow & Levine, 1973; Lacquaniti, Terzuolo, & Viviani, 1983; Van Sommers, 1984) often fail to establish meaningful links with higher-order aspects of cognition that might apply to artists and artistic rendering.

Although empirical work is limited, perceptual psychologists and neuroscientists have speculated about possible relations between artistic production and perceptual processes. For instance, Arnheim (1954) suggested that both perception and artistic creation involve understanding significant structural features of patterns via principles of visual organization. Hagen (1980) proposed that artists may be particularly good at attending to momentary or variant visual information, in contrast to the kind of invariant information that would lead to conceptual interference among nonartists in the Fry–Ruskin account. Moreover, if artists know how to achieve certain perceptual effects in their work, then they should also be able deliberately to obscure structurally important features when this would serve their esthetic ends (Hochberg, 1980).

More recently, some researchers (e.g., Latto, 1995; Ramachandran & Hirstein, 1999; Zeki & Lamb, 1994) have argued that artists’ techniques are effective because they take advantage of discrete processes in the visual cortex. Latto (1995) remarked that "the techniques used by artists and the forms they select succeed because they exploit the properties of the visual system, and, through their work, artists have indirectly been defining the nature of visual processes, often before [they] have been investigated scientifically" (p. 68). As an illustration of this view, consider Livingstone’s (2002, pp. 71–73) argument that the esthetic mystique of the Mona Lisa’s smile derives from Leonardo’s deployment of different spatial frequency information in the painting. Livingstone argued that the smile is most apparent at low spatial frequencies (coarse-grained image features) and least apparent at high spatial frequencies (fine-grained details). Thus, when a viewer looks directly at her mouth, the smile disappears because the coarse-grained contours defining her expression are invisible to foveal vision. However, when a viewer looks away, her smile reappears because the same contours are easily perceived peripherally. This difference reflects the fact that the receptive fields of cells involved in foveal vision are simply too narrow to recover coarse-grained image features. Livingstone argued that this perceptual effect generates a dynamic facial expression that enlivens the painting and that Leonardo’s ability to control these effects reveals his tacit understanding of the operation of basic visual processes. Other examples include Latto’s (1995) discussion of the use of half-shadows and irradiation by painters from Campin to Seurat to enhance lateral inhibition effects in figure-ground segregation, and Zeki and Lamb’s (1994) discussion of Calder’s use of luminance contrast to enhance the perception of motion in his mobiles.

Such examples are provocative but indirect, because they rely only on the evidence of works of art themselves, without examining artists’ perceptual, drawing, or cognitive abilities in the laboratory. However, some empirical studies do reveal differences between artists and nonartists in these regards. For instance, artists score higher on tests of visual memory (Hermelin & O’Connor, 1986; Rosenblatt & Winner, 1988; Winner & Casey, 1992) and field independence (Gaines, 1975), and they are better at generating and transforming mental images (Winner & Casey, 1992). These factors could plausibly enhance some aspects of perceptual processing.

Is there evidence that perceptual differences do contribute to drawing ability? Cohen and Bennett (1997) addressed this issue in a study designed to discover why most people cannot draw what they see. They identified four potential sources of drawing errors: misperceiving the object to be drawn, poor motor coordination, making poor representational decisions, and misperceiving one’s emerging drawing. A failure in any one of these would lead to inaccurate rendering. To identify the most likely source(s) of errors, Cohen and Bennett had participants draw under various conditions (e.g., freehand or tracing), and other participants later judged the accuracy of the depictions. Overall, Cohen and Bennett’s results indicated that poor motor coordination, making poor representational decisions, and misperceiving one’s own drawing did not account for most drawing inaccuracies. Therefore, they concluded that the main reason most people cannot draw what they see is that they misperceive the object to be drawn.

This finding implies that artists are superior at some aspects of perception that contribute to their ability to draw accurately, which is consistent with the art historical accounts described previously. However, because Cohen and Bennett (1997) used a process of elimination to infer object misperception as the main source of drawing inaccuracies, the basis of their conclusion was indirect. Mitchell and colleagues (2005) supplied the missing evidence linking drawing strategies to perceptual advantages in a study of the Shepard illusion. They found that nonartists copy parallelograms adorned with table legs less accurately than unadorned parallelograms and that the degree of perceptual distortion is correlated with the severity of error in drawing (see also Lee, 1989). These findings echo those of Thouless (1931) and Taylor and Mitchell (1997). Thouless found that participants tended to draw flat circular objects presented obliquely as more circular than their elliptical retinal projection. Taylor and Mitchell found that
this effect holds only when participants are informed that the object was a circle at an angle, not an ellipse face-on. These investigations document the perceptual basis of nonartists’ limited drawing ability and imply that artists can overcome these limitations by superior perceptual skill (though the studies were not focused on artists per se).

Kozbelt (2001) investigated artists’ perceptual skills directly, by comparing the performance of artists and nonartists on a variety of drawing and perception tasks. The drawing tasks mostly involved accurately copying line drawings. In the perception tasks, participants were asked to identify the subjects of out-of-focus photographs and fragmented images and to find simple shapes embedded in complex visual patterns. Not surprisingly, artists outperformed nonartists at drawing; however, artists were also superior on the perception tasks, even though these have nothing per se to do with drawing. This demonstrates an advantage in visual analysis that confers an advantage in form recognition, consistent with other findings (Cohen & Bennett, 1997; Mitchell et al., 2005) and art historical accounts (e.g., Fry, 1919/1981; Gombrich, 1960).

Further analyses by Kozbelt (2001) compared participants’ performance on the drawing and perception tasks. Across all participants, performance on drawing and perception tasks was positively correlated. Thus, if a participant was good at drawing, that participant also tended to do well on the perception tasks. Partial correlations revealed additional nuances in the relationship between drawing and perception. First, when artists’ perceptual advantage was statistically accounted for, they still outperformed nonartists on the drawing tasks. This suggests artists’ perceptual advantage is by itself insufficient to explain their success at drawing; other processes, such as motor skill or perceptual-motor integration, also contribute to their drawing advantage. In contrast, when artists’ drawing advantage was statistically accounted for, they no longer outperformed nonartists on the perception tasks. This indicates that artists’ advantage on drawing largely explains their advantage in perception. Further, it suggests that artists’ perceptual advantage is developed mainly to the extent that it is useful for drawing.

That artists’ perceptual advantage is by itself insufficient to explain their success at drawing might seem to contradict Cohen and Bennett’s (1997) finding that motor skill did not represent an intrinsic limitation on nonartists’ drawing ability. However, Cohen and Bennett explicitly argued that the apparently negligible role of motor control results from nonartists’ “insufficient knowledge of the mark-making instrument [rather] than of inadequate motor coordination” (p. 620). This suggests that technical proficiency with the tools particular to an artistic medium is a means of training one’s eyes to identify diagnostic stimulus features. Thus, medium-specific technical skill may be a way of explaining perceptual differences between artists and nonartists. This claim parallels Ruskin’s (1857/1971) comments about the importance of drawing to artists’ vision:

a brush, being soft at the point, causes so much uncertainty in the touch of an unpracticed hand, that it is hardly possible to learn to draw first with it, and it is better to take, in early practice, some instrument with a hard and fine point, both that we may give some support to the hand, and that by working over the subject with so delicate a point that attention may be directed to the most minute parts of it. Even the best artists need occasionally to study subjects with a pointed instrument, in order thus to discipline their attention; and a beginner must be content to do so for a considerable period. (pp. 28–29)

In addition to the psychological investigations cited previously, eye movement studies have further elaborated the hypothesized roles of perceptual and motor skills in accurate drawing. Because eye movement data document the dynamic, detail-by-detail capture of visual information as depictions are built up, they also inform specific aspects of drawing. For instance, Millal and Tchalenko (2001) compared the eye and hand movements of a respected portraitist named Humphrey Ocean with those of several nonartists as they drew faces. They found that the artist’s fixations were twice as long when drawing as when he was not drawing. His eye movements were also precisely targeted and better coordinated with hand movements when drawing: he would typically look at a single location on the stimulus, draw the contour depicting that feature, and then do the same with other locations. In contrast, nonartists’ looking times did not differ when they were drawing versus not drawing, and they showed poor coordination between eye and hand movements: instead of focusing on one location on the stimulus at a time, they would try to take in several before attempting to draw. These results suggest that Ocean has developed a special strategic mode of perception targeted to the requirements for accurate depiction in his medium.

Evidence from other eye movement studies supports this claim. For example, Cohen (2005) found that artists make more frequent eye movements than nonartists, and that a higher gaze frequency was correlated with greater drawing accuracy in the two samples. Moreover, experimentally lowering gaze frequency (i.e., requiring longer looking times while drawing) inhibited performance in both groups. Cohen interpreted his result in terms of Ballard, Hayhoe, and Pelz’s (1995) deictic system hypothesis, whereby frequent eye movements help circumvent working memory limitations by storing pointers to important locations rather than abundant perceptual information directly. Finally, Sutton and Rose (1998) found that the natural progression toward visual realism in children’s drawings was accompanied by a spontaneous increase in attention to the stimulus and that simple but explicit instructions to pay attention to the stimulus increased the visual realism of the drawings. Notably, greater visual realism was achieved by children who looked at the stimulus longer and more often, especially while they were drawing a particular visual element, rather than prior to drawing, between elements, or after the drawing was completed.

Converging evidence on the importance of strategic factors in skilled drawing comes from functional magnetic resonance imaging (fMRI) research. Solso (2001) scanned the brain activity of Humphrey Ocean and a nonartist while they drew faces. Compared to the nonartist, Ocean showed more activation in his right prefrontal cortex, an area associated with complex associations, the manipulation of visual forms, and the planning of fine motor responses. In addition, he showed less activation than the nonartist in the fusiform face area. This suggests that he was focused less on the generic identity of the stimulus as a face and more on the analysis of its abstract local features. Solso’s conclusions are highly consistent with Gombrich’s (1960) emphasis on the importance of knowledge-driven, strategic factors in depiction: “the novice seems to be ‘copying’ the face; the artist is ‘seeing beyond’ the features . . . . the artist ‘thinks’ portraits more than he ‘sees’ them . . . . this skilled artist engages in a ‘higher-order’ interpreta-
tion of the perceived face and may rely on an abstracted representation of a face” (Solso, 2001, pp. 33–34).

In sum, the available empirical evidence is consistent with the long-standing claim that artists see the world differently, and in some sense better, than nonartists. This perceptual advantage appears to be linked to strategic top-down factors, rather than reliance on a purely bottom-up approach. It is developed primarily to the extent that it is useful for drawing, and it seems at least partly derived from some aspect of motor skill (likely media specific). We now propose a model to explain this set of findings.

A Visuomotor Skill Model

We postulate two main sources of artists’ advantages in drawing and perception: (a) artists’ specialized, declarative knowledge (Gombrich, 1960), which plays a productive role in hypothesis-testing processes in object recognition (Kosslyn, 1996), and (b) motor plans derived from the proceduralization of this declarative knowledge through extensive practice in an artistic medium (Anderson, 1987). We argue that both of these factors contribute to shifts of selective attention that enhance the encoding of expected features in the visual field and inhibit the perception of distractors (Kanwisher & Wojciulik, 2000), and that this provides a viable mechanism for artists’ observed perceptual advantages (Kozbelt, 2001). A schematic diagram of the model is shown in Figure 1. We now elaborate the component processes of the model and describe how they can account for artists’ advantages in drawing and perception.

Influences of Schemata on Perceptual Hypothesis Testing

Gombrich’s (1960) characterization of how artists learn, develop, and implement schemata is essentially an interactive hypothesis-testing process in which they identify and adjust the salience of cues that are diagnostic for the recognition of depicted objects. This dynamic resembles Kosslyn’s (1996) general hypothesis-testing model for visual search and object recognition. Kosslyn argues that perception proceeds in a piecemeal fashion, beginning with a subset of image features that are normally sufficient for object identification and filling in details only as needed for a given task (see Figure 1). Specifically, sensory inputs are first held in a short-term buffer, from which a pattern-recognition subsystem extracts the basic structure of the image. Next, this output is matched to prior knowledge of objects’ general shapes stored in associative memory (Kosslyn, 1996; Thompson & Kosslyn, 2000). If the system makes an adequate match between a visual pattern and a stored record of an object’s shape or function, the process is complete. However, if the output of the pattern-

![Figure 1. Visuomotor model for artists’ perceptual advantages. Declarative schemata and motor plans play complementary roles in shifting selective attention, which enhances the encoding of expected features in the visual field and inhibits the perception of distractors: a) sensory inputs are initially retinotopically encoded in a visual buffer that includes area V1 in the occipital cortex; b) early visual processing can be construed as a feature extraction subsystem, in which diagnostic image features (e.g., color, orientation, contours, and patterns of intermediate complexity) are culled from sensory inputs encoded in the visual buffer; c) object recognition involves matching diagnostic image features (e.g., oriented contours, geometric patterns, and complex shapes) to category knowledge; d) if there are competing adequate matches, the closest match is used to instantiate a perceptual hypothesis about the expected identity of the stimulus in spatial working memory; e) information drawn from long-term memory is used in conjunction with spatial schemata to prime the visual system and direct attention to expected diagnostic features at particular locations; f) when the task involves interaction with the environment (e.g., reaching, grasping, or drawing), motor plans derived via proceduralization from declarative schemata function as action schemata to prime the visual system and direct attention to features diagnostic for the action (e.g., depicting an object in a particular artistic medium).](image-url)
recognition subsystem does not adequately match any object representation in memory, the closest match is used to generate a perceptual hypothesis about the form and identity of the object in the image. Although this perceptual hypothesis is maintained in spatial working memory, additional category information concerning possible object properties is extracted from long-term memory. This information is used both to shift attention and to prime the pattern-recognition subsystem to the expectation of particular image features, objects, or object parts. The purpose of these processes is to identify and locate features in the visual field sufficient to confirm or disconfirm a particular perceptual hypothesis about the identity of the object. Therefore, this attention-shifting mechanism acts to tune visual processing to the content of perceptual hypotheses, by augmenting and amplifying the appearance of obscure contours that were previously unnoticed (cf. Hale, 1983). This entails that generating a perceptual hypothesis about the identity of an image is one of the mechanisms driving attentional processing (Cavanaugh, 1991; Schyns, 1998).

Several lines of evidence support Kosslyn’s (1996) attention-shifting mechanism as an explanation of artists’ perceptual advantages. For instance, the hypothesized use of schemata for shifting attention and enhancing the perception of diagnostic image features would explain artists’ highly targeted, strategic eye movements while drawing (Miall & Tchalenko, 2001; see also Sutton & Rose, 1998). Similarly, Cohen (2005) speculated that artists’ deictic strategies and associated high baseline gaze frequencies allow them to focus attention on small portions of an image, which leaves them largely blind to information at other locations (Kanwisher & Wojciulik, 2000; Mack & Rock, 1998). In artistic production, this may reduce contextual effects that could lead to drawing inaccuracies. Moreover, in a different domain, expert radiologists are able to augment perceptual information with extensive domain-specific knowledge and to ignore irrelevant information (Lesgold et al., 1988). Analogous to the evidence from skilled artists, expert radiologists focus attention on very localized, specific aspects of X-ray films to make diagnoses, rather than on larger areas, as less expert medical students do.

Besides behavioral data on the strategic deployment of attention, Kosslyn’s model is also consistent with research in cognitive neuroscience on the role of memory and attention in visual perception (for reviews, see Chun & Marois, 2002; Kanwisher & Wojciulik, 2000). This research has demonstrated that feedback projections exist from areas of prefrontal cortex associated with working memory to areas of inferior temporal cortex associated with object recognition. These inferior temporal regions are in turn connected to areas V4 and V5, which are responsible for recovering color, form, and motion cues from retinal input. These feedback projections increase the excitatory response of neuronal populations that encode the perception of expected targets and inhibit their response to irrelevant distractors, just as described by Kosslyn’s (1996) model. Indeed, this research indicates that one function of selective attention is to amplify the sensitivity of the visual system to features that are diagnostic for a task. For instance, Sigala (2004) found that feature-selective neurons in the macaque inferior temporal cortex were tuned for features that were specifically diagnostic for a particular categorization task, reflecting perceptual sensitization to such features. Therefore selective attention directly affects the way the visual system analyzes visual inputs into cues for object identity.

Schyns (1998) expanded upon this point about the role of category knowledge and attention in perception. He argued against the existence of invariant sets of image features determined solely by bottom-up processes (see also De Winter & Wagemans, 2006). Instead, Schyns found that categorizing the content of an image can alter the way the visual system organizes even very basic features such as edges and texture gradients into salient perceptual cues such as occlusion boundaries, which define the outlines of objects, and local volumes, which define object features (see also Moore & Cavanaugh, 1998). Image features are subject to changes in perceptual salience based on the hypothesis guiding attention. Thus, the way an artist analyzes visual inputs into object cues can be influenced by his or her knowledge, goals, and choice of artistic medium (e.g., fine details are more relevant in drypoint etching than in fresco painting). As an illustration of this principle, Bonmar, Gosselin, and Schyns (2002) demonstrated that differences in perceptual learning can alter the analysis of cues in ambiguous images, for instance in the role of coarse- and fine-grained features in alternate perceptions of Salvador Dali’s painting, Slave Market with Disappearing Bust of Voltaire. One region of this painting can be interpreted as depicting either two standing women or as Voltaire’s face. To achieve this bistability, Dali needed to understand which perceptual cues were likely to be diagnostic for either interpretation and to be able to realize and balance these cues in oil paint. Although Dali’s painting is perhaps an especially interesting example of this process, the same logic applies to any artist wishing to induce the perception of an object or scene via marks made on a surface in an artistic medium.

In sum, Kosslyn’s (1996) hypothesis-testing model provides a mechanism for how the declarative knowledge embodied in artists’ schemata (Gombrich, 1960) impact perception. Schemata function as perceptual strategies to direct artists’ attention to the locations of stimulus features that are relevant for adequate depiction; because these features are also diagnostic for object identity, this process drives artists’ perceptual advantages in form recognition as well. Essentially, artists know what to look for and where. However, despite its usefulness in detailing mechanisms that we hypothesize underlie artists’ perceptual advantages, Kosslyn’s model is limited in that it does not explain how declaratively encoded schemata become translated into drawing skill. Recall that some traditional accounts of artists’ perceptual advantages (e.g., Ruskin, 1857/1971) and empirical results (Kozbelt, 2001) emphasize media-specific motor skill as another key factor in artists’ perceptual advantages. We take up this issue next.

**Motor Priming via the Proceduralization of Schemata**

So far we have discussed schemata and their impact on perception in terms of their initial declarative content. However, the ways in which the knowledge comprising schemata are represented, implemented, and dynamically used over time need not be static. Rather, we argue that through extensive practice, this information is joined to general problem-solving heuristics and rerepresented as motor plans, which in turn shift attention to features diagnostic for recognition (as in Kosslyn, 1996). As detailed later, neuropsychological evidence demonstrates that motor planning contributes to shifts in selective attention in preparation for actions in much
the same way that declarative knowledge contributes to shifts in selective attention in object recognition (see Figure 1). Therefore we argue that motor plans and declarative schemata play complementary roles in explaining artists’ perceptual advantages.

The conversion of declarative schemata into a motoric representation is compatible with several classic theories of skill acquisition. For instance, according to Anderson (1987), individuals start to learn how to perform a task by using declarative knowledge, usually from instructions or a worked-out example. Early on, performance is slow as learners interpret how to do each step. They next develop declarative knowledge into more efficient procedural representations. These take the form of productions or “if–then” statements: if certain conditions are met, then perform some mental or physical action. The goal of this stage is to encode the knowledge so that it can be applied at the relevant point in the process of solving a problem. Through additional practice, procedural knowledge is organized and consolidated so the learner can take larger steps in the problem-solving process and execute even more complex motor actions. In a similar model (Fitts, 1964), one first consciously learns the basic steps to follow to perform a task, often using verbal cues, in an initial cognitive phase. Next, in an associative stage, the learner transitions from a reliance on conscious, verbal control to more automatic control, trying various task components and associating them with success or failure. In a final, automatic phase, performance is efficient and requires little conscious effort.

Such skill acquisition models can be readily applied to understanding how artists’ schemata evolve as drawing proficiency develops. Gombrich (1960) argued that artists-in-training first acquire novel declarative knowledge of the kind described in art instruction manuals. Initially, artists use this knowledge in a conscious, deliberate, and rather inefficient way. However, as artists gain experience in a medium, their knowledge does not remain passively represented in declarative form. Rather, they learn to dynamically implement this knowledge as they repeatedly strive to solve the problem of creating the illusion of a three-dimensional object or scene on a two-dimensional surface. Because artists cannot draw everything at once, they must develop serial strategies for developing depictions in a medium. Gombrich (1991) noted that an art “student must first commit himself to a format before he can begin to copy the model. There is nothing mechanical in this commitment; he must build up the model from scratch, as it were, before he can start comparing the motif with his representation” (p. 94). As artists gain drawing experience, they get feedback on their performance from their own critical assessments or those of other viewers. This helps them refine what visual cues are most diagnostic for recognition of objects in their renderings and media. These cues become integrated into artists’ procedures for working until the motor actions and visual attention processes in drawing become largely automatic. In this way, artists’ motor plans function to shift attention to diagnostic features in preparation for drawing actions, which contributes to their perceptual advantage.

Several lines of evidence demonstrate that motor planning can influence perceptual processing. For instance, Tse and Cavanaugh (2000) presented subjects with an apparent motion stimulus derived from a Chinese character. In the display, the character was presented one stroke at a time; however, each new stroke was added in its entirety, that is, all at once. In their experiment, native Chinese speakers and non-Chinese-speaking Americans were asked to report on the appearance of the final stroke. Non-Chinese-speaking viewers reported that the stroke appeared to be drawn from right to left, consistent with basic bottom-up grouping principles. However, Chinese speakers who also knew how to draw the character reported that the stroke was filled in from left to right, as it would be when one drew the character correctly. Thus, anticipatory expectations derived from knowledge of how to draw the character can override bottom-up perceptual processes and influence the way one perceives the stimulus.

The capacity of motor imagery to represent visual information and to contribute to drawing performance and recognition is also informed by research on visual agnosics. Visual agnosia is a deficit in visual recognition that is hypothesized to be due to a failure in categorization processing. Agnosic patients cannot recognize objects visually. However, they can recognize objects via other sensory modalities, their general cognitive abilities remain intact, and they usually have normal visual acuity and figure–ground segregation. Furthermore, they can match basic visual patterns, make quite accurate copies of line drawings, and in some cases describe the forms of familiar objects they do not recognize. One agnostic, known as DF, has developed idiosyncratic motor strategies to overcome some of her visual deficits (Dijkerman & Milner, 1997). Consistent with the usual behavioral deficits of agnosics, DF cannot visually identify the orientation of lines. However, she can copy their orientations correctly and can sometimes manually orient cards to fit narrow slots. DF’s visual deficits have been studied for a number of years. Over this time she has evolved a strategy of manually tracing a line in the air or over either the stimulus or the paper in preparation for copying. This strategy has become automatic, and she finds it difficult to avoid using it. To test the effect of this strategy on her perceptual performance, Dijkerman and Milner developed tasks to interfere with motor imagery, such as counting backward or tapping another finger while drawing the line. When performing these tasks, DF’s orienting performance fell to chance. This result reinforces the links between motor imagery, visual processing, and attention. If there were no links among them, DF would not be able to generate a motor representation of the spatial orientation of the stimulus to compensate for her visual deficits.

Data collected on another agnostic, AD, reaffirms the importance of motoric representations for perceptual processing (Wolk, Coslett, & Glosser, 2005). The visual abilities of AD are less seriously impaired than those of DF. In a series of tests, AD showed superior recognition of objects like a hammer or scissors, which have greater “manipulability” (a capacity to evoke an action that unambiguously affords recognition or implies how the object should be used), compared to objects with lower manipulability, such as the moon or a flag. He was also better at naming human versus nonhuman actions. These results suggest that AD’s recognition performance is mediated by sensory–motor representations of object features that are diagnostic for familiar actions.

Neurophysiological evidence provides further support for our claim about the role of motor skill in artists’ perceptual advantages. The premotor cortex (area 6) is subdivided into two functional regions: the supplementary motor area (SMA) and the premotor area (PM). SMA is specialized for sequence learning, motor planning, and the execution of internally initiated movements (e.g., setting the appropriate motor program for hand orientation and finger movements when manipulating a familiar object).
In contrast, PM is specialized for representing how visual and auditory information is to be used to direct a particular movement and for executing movements stimulated by external sensory events, such as quickly orienting one’s hand to catch a line drive in a baseball game (Schubotz & von Cramon, 2003). Single-cell studies of nonhuman primates (Arikuni, Watanabe, & Kubota, 1988; Barbas & Pandya, 1987; Bates & Goldman-Rakic, 1993) and neuroimaging research on human subjects (Lu, Preston, & Strick, 1994) show that these areas are closely connected with dorsolateral prefrontal cortex (dLPFC). More specifically, the rostral regions of SMA and p.m., which are associated with the planning rather than the execution of motor actions, are closely interconnected with area 46 in dLPFC and consist largely of neurons tuned for spatial orientation (Lebedev & Wise, 2001; Parsons et al., 1995).

The dLPFC is associated with spatial working memory and is hypothesized by Kosslyn (1996) to be critical for directing the influence of perceptual hypotheses on the early visual system. The activation of the spatially tuned regions of SMA and PM is correlated with selective attention for locations, features, and objects (Schubotz & von Cramon, 2003). As a result, these premotor areas are hypothesized to play a role not only in motor planning but also in directing attention and visual recognition (Simon et al., 2002). Moreover, Jeannerod (1994) reported that these same premotor areas are activated when one explicitly imagines an action such as reaching or when performing mental rotation. This evidence suggests that motor plans can enhance the perception of environmental features relevant to an anticipated action, such as image features to be depicted while drawing. This supports the explanation for DF’s tracing behavior described previously: she may use motor imagery as a tact strategy to control the deployment of attention to enhance her limited perceptual abilities.

A final line of support for the impact of motor plans on perceptual processes comes from research on the receptive field properties of spatially tuned neurons in primate premotor cortex (Graziano, Yap, & Gross, 1994; Lebedev & Wise, 2001). Graziano et al. (1994) reported bimodal cells in the rostral regions of the macaque PM that respond both to visual and tactile stimuli. The visual receptive fields of these cells extend from the hand/arm location of their tactile field into the visual field. Therefore, the visual receptive fields of these populations of neurons are associated with, and shift relative to, hand or limb orientation, not gaze direction. These cells are hypothesized to specify locations of targets in the visual fields for potential movement (e.g., catching a ball perceived peripherally while foveating on a separate target). Lebedev and Wise (2001) reported that these areas of premotor cortex contribute to selective visual attention, suggesting an additional mechanism for the contribution of motor plans to artists’ perceptual advantages. Orienting one’s hand to a stimulus in preparation to trace an expected image feature at a location should enhance the visual encoding of diagnostic features, consistent with the findings on DF reported by Dijkerman and Milner (1997).

In sum, multiple bodies of evidence support our second claim that motor plans, derived from the proceduralization of artists’ schemata, can shift selective attention and enhance the perception of cues diagnostic for form recognition, further contributing to artists’ observed perceptual advantages.

**Unresolved Issues and Future Directions**

Although our model draws on an array of theory and evidence from several domains, many aspects of the model require testing to determine their validity and to detail the nature of artists’ perceptual processing. We now outline several ways of doing so.

First, the hypothesized dual source of artists’ perceptual advantages raises the issue of the extent to which declarative schemata and motor plans are jointly necessary for improvements in drawing skill and perceptual ability or whether either source in isolation would also yield substantial benefits. This could be tested in a factorial design by instructing nonartist participants on declarative schemata and/or giving them motor practice that would presumably begin to proceduralize the schemata and then observing the extent to which drawing skill and perceptual abilities change throughout the training regimen. Combining declarative knowledge with motor practice should improve drawing (and perhaps perception) more than the summed effects of either component in isolation. If this is the case, then a statistical interaction should be evident whereby participants exposed to both declarative schemata and motor practice would dramatically outperform participants in the other conditions.

Theoretically, the process of proceduralization should yield the greatest benefits only after declarative knowledge is combined with practice. Along these lines, Latto (1995) conjectured that motor skill may be a necessary factor for perceptual benefits: “though their works do not always demonstrate exceptional graphical skill, it does seem to be the case that great artists like Picasso always seem to possess that skill. Perhaps high graphical skill is necessary for the selection of successful forms” (p. 69, italics in original). This provocative comment is consistent with our model, whereby the full benefits of motor priming occur only after the acquisition of considerable skill in an artistic medium. Indeed, Kozbelt’s (2001) partial correlational results suggest that artists’ perceptual advantage is essentially a subset of their drawing advantage, and thus that their perceptual advantage may be largely the result of increased drawing skill. As a result, our model predicts that an improvement in drawing performance should likely precede a general improvement in perception ability. A related facet of this issue involves the perceptual and drawing abilities of populations such as art historians who do not draw but who are visually experienced and theoretically knowledgeable about artists’ schemata. Such people could be useful for understanding the relative roles of declarative schemata and motor planning in perception.

Another issue concerns the extent to which the knowledge that artists acquire in their training must be initially encoded in an explicit, declarative form. Following Gombrich (1960), we have argued that at least a substantial proportion of artists’ specialized knowledge is initially encoded in this way, and that through practice it is later rerepresented as procedural knowledge useful for drawing. However, our model does not rule out the possibility that some of artists’ knowledge can be acquired through implicit learning mechanisms (e.g., Reber, 1993), in which individuals reliably learn important associations and patterns of covariance in the environment but without conscious awareness of having learned anything or conscious access to the learned information. Indeed, in domains such as chess, identifying bird species, or sexing day-old chicks, experts often report that they have little conscious aware-
ness of how they make decisions (Horsey, 2002), suggesting such experts rely on an implicit knowledge base. In art, implicit mechanisms, which represent a bottom-up, data-driven form of processing, may be particularly important when an artist discovers new aspects of the visual world or techniques for rendering that have no precedent in existing schemata. However, purely implicit learning is inefficient, especially in complex domains, because implicit learning appears to occur only when relevant, predictive information is selectively attended (Jiang & Chun, 2001), and these cues are not always obvious. Presently we have argued that a declarative knowledge base helps direct attention to diagnostic features that are important for depiction but which would otherwise not be attended to (Hale, 1983). In this view, declarative knowledge may serve to bootstrap implicit learning processes, or other automatic mechanisms, to acquire these cues as training proceeds (Horsey, 2002).

Another basic question concerns how to characterize the diagnostic features of images to which artists shift attention in the course of perceptual hypothesis testing and motor priming. Artists are hypothesized to be sensitive to basic perceptual primitives (Arnheim, 1969; Lalot, 1995; Ramachandran & Hirstein, 1999), which are likely embodied in these features. One promising candidate for such primitives is Biederman’s (1987) set of “nonaccidental properties” of objects, which facilitate recognition over a range of viewpoints. These properties include curvature, parallelism, and cotermination and are embodied in several dozen “geons,” simple three-dimensional shapes that Biederman hypothesized are the basic building blocks of object identification. Because objects are defined not only by which geons they contain, but also by the geons’ configuration, much of the information diagnostic for recognition occurs where geons meet, at vertices (i.e., points with extreme negative curvature; see De Winter & Wagemans, 2006). Biederman reported that line drawings of objects remain highly recognizable even after being mostly erased, as long as vertices and other nonaccidental properties are preserved. In contrast, removing vertices and other nonaccidental properties severely impairs recognition, even when less overall line is deleted and when viewers have more time to look. Interestingly, techniques that have long been part of artists’ schemata for line drawing, such as T junctions (Hamm, 1963, p. 48) and end junctions (Willats, 1997), capture the same vertex information emphasized by Biederman and for the same reason: they are more effective at conveying form than silhouettes or undifferentiated outlines. Notably, such devices became historically more common when artists deliberately sought greater realism, as in ancient Greek vase painting (Kozbelt, 2006; Willats, 1997).

If artists are more sensitive to or aware of highly diagnostic geon or vertex information, then this should be discernible in laboratory studies. For instance, artists should be more likely than nonartists to spontaneously use vertices or other nonaccidental properties in their drawings, which would then contribute to higher ratings of accuracy or convincingness by viewers. Testing this assertion requires methodological precautions to rule out potential confounds and artifacts, such as group differences in motor skill, familiarity with a drawing medium, time on task, or stimuli that are too simple, as well as limiting the amount of line used for depiction to force participants to be economical in their choice of the most important visual information.

Another approach is to examine eye movements during difficult perception tasks that greatly slow processing, such as recognizing out-of-focus pictures. Miall and Tchalenko (2001) found that an artist showed more organized and strategic eye movements while drawing than did nonartists. Is this also the case when trying to identify degraded stimuli? Our model predicts that artists should be more adept at identifying which spatial locations of the image are diagnostic for recognition and thus that artists should likely fixate on those locations more than nonartists. The time course of such fixations, relative to the moment of recognition, could also inform the process of using diagnostic information in object identification (although fixations are not always associated with diagnostic features: see Silgea, 2004).

A general point raised by this discussion is whether artists’ perceptual and drawing advantages are better thought of as capacity differences, where no amount of training will make up for a deficit, or strategic differences, which are both learned and malleable. In part, such a distinction could reflect differences in viewing attention as a capacity resource versus attention as the selection of relevant information (see Jiang & Chun, 2001; Jimenez & Mendez, 1999). In line with Gombrich’s (1960) emphasis on the acquired nature of schemata, plus empirical findings on the intentional, executive aspects of successful drawing behaviors (Cohen, 2005; Miall & Tchalenko, 2001; Solso, 2001), our model favors learned strategic factors rather than innate or fixed capacities. In practice, there is almost certainly a complex longitudinal interplay between the development of perceptual and drawing skills (Schleweit-Haynes et al., 2002). However, notwithstanding individual differences in artistic talent (Winner, 1996), many art instructors hold that a competent level of realistic drawing is essentially attainable by anyone willing to work at it (e.g., Dodson, 1985; Edwards, 1979; Hale, 1964). By this view, it is perhaps not surprising to find that certain interventions, such as Cohen’s (2005) experimental manipulation to increase gaze frequency or Sutton and Rose’s (1998) instructions simply to pay attention to the object being drawn, can lead to improvements in drawing performance. However, more subtle questions involve the extent to which such training can lead to general improvements in perceptual ability, rather than just drawing skill, or the extent to which direct training on information diagnostic for object identity (e.g., T and end junctions, local curvature minima, geons, nonaccidental properties, etc.) may transfer to a rapid increase in drawing or visual analytic ability.

In this exposition of our model, we have focused on representational drawing as a paradigmatic example of art making. However, we interpret this as a limiting case that can be generalized to other aesthetic media and styles. The ideas described here also very likely extend to art of varying degrees of abstraction, because basic perceptual primitives and recognition processes appear to operate even in such cases, as in the Cubist paintings of Picasso or Braque (Kozbelt, 1995; Lalot, 1995; Mcmahon, 2000; Ramachandran & Hirstein, 1999). Once the basis of artists’ perceptual and drawing advantages begins to be better understood, it will be interesting to see how the resulting principles apply to other media and artistic styles. In any case, despite the rather limited empirical research on the nature of artists’ perceptual and drawing abilities to date, the model outlined presently suggests that these complex and important phenomena are amenable to investigation, and we are opti-
mistic about the prospects for ultimately understanding much about them.

References


