30 Expertise in Drawing

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Introduction

Visual art is one of humanity's great achievements (Murray, 2003). The archaeological evidence of prehistoric art, most gloriously manifested in the cave paintings of Chauvet, Lascaux, and Altamira, suggests *Homo sapiens* has engaged in visual art for the entirety of our existence as a species, certainly since the so-called "creative explosion" (Pfeiffer, 1982) some 30,000 years ago. In historical times, great artists like Michelangelo have been accorded quasi-divine status (Vasari, 1996), and contemporary museum attendance and the prices of notable paintings at auction bespeak art's continued significance. Decorative visual art is a ubiquitous outlet of creative expression, appearing in every known human culture (Brown, 1991). Visual artistry has likewise been identified as a fundamental domain of the mind (Feist, 2004; Gardner, 1983).

Art's importance stems partly from the fact that humans are predominantly visual creatures. Much of the brain is involved in efficiently processing diverse streams of visual information (including form, color, and motion) to establish a stable, interpretable percept despite ambiguous, transient, or incomplete input (Palmer, 1999). Artworks involve another kind of visual degradation; even highly realistic images, in which artists attempt to mimic what they see as closely as possible, entail significant information loss compared to the real world – with a concomitant set of choices on the part of the artist about what to depict and how to depict it (Gombrich, 1960). Throughout history, visual artists have exploited many technical devices to facilitate the perception and recognition of the content of images, including means of rendering contours, depth cues, and illumination (Melcher & Cavanagh, 2011).

That the modality of vision is so central to art raises a potentially thorny problem in demarcating and characterizing visual art as a self-contained domain of expertise. Performance differences in art are obvious. Accomplished artists can create strikingly convincing depictions of visual scenes, while most adults find even rudimentary aspects of observational drawing difficult. Historically, artists as well as scholars across many domains have attributed variability in drawing skill to differences in visual perception, encapsulated in the claim that artists see the world differently from non-artists (Kozbelt & Seeley, 2007). Over the last few decades, psychologists have conducted substantial empirical research on this issue, advancing several categories of psychological explanations.

In this chapter, we review current psychological research on artistic expertise, exploring the evidence suggesting possible perceptual differences between artists and non-artists via two venerable and prominent theoretical accounts, which we term the "bottom-up" and "top-down" explanations. Our discussion emphasizes the skills required for the production of realistic depictions, rather than merely receptive aspects like appreciation or connoisseurship. While researchers have produced some interesting findings on artistic expertise, many conceptual and methodological issues remain unresolved, and we conclude the chapter by discussing some of these. The crucial issue relevant to the classic expertise literature is the extent to which depictive skill may entail robust, general advantages in perception and attention, which, beyond simply reflecting an acquired body of domain-specific patterns, represent artists' enhanced ability to solve the same kinds of problems as the human visual system does generally.

Making Representational Depictions

Understanding the nature of expertise in visual art requires understanding the nature of artists' activity. While there are many modes of artistic expression, we focus on the observational rendering of realistic two-dimensional images (especially drawing) as paradigmatic of many of the most interesting aspects of visual artistry. Realistic observational drawing involves creating a depiction of an external model stimulus with the goal of achieving visual accuracy. A visually accurate rendering is "one that can be recognized as a particular object at a particular time and in a particular space, rendered with little addition of visual detail that cannot be seen in the object represented or with little deletion of visual detail" (Cohen & Bennett, 1997, p. 609). Given the visual system's organization, whereby numerous streams of visual input are processed in parallel, there are many ways of achieving visual realism across media and styles, all of which are to some degree artificial – that is, based on invented techniques that capture only a subset of visual experience (Gombrich, 1960; Willats, 1997). Contrast the paintings of masters like Jan van Eyck and Diego Velázquez, which are virtually nonoverlapping in terms of specific aspects of style, yet share a profound (if intuitive) fidelity to the visible world.

Irrespective of style, observational drawing entails intense and prolonged perceptual engagement, with plausible long-term ramifications on artists' basic perceptual and attentional capabilities. Consider, in information processing terms, the seemingly simple act of drawing a pear from observation. One must translate a fleeting iconic sensation of the pear's appearance into a longer-term representation to understand its relative proportions and three-dimensional structure, as observed from a particular viewpoint. One must attend to and make decisions about the key points of concavity on the surface of the pear to establish a proportional framework, engage a motor program to execute those marks on the paper, and then assess the accuracy of those marks with an eye to potentially revising them. Once proportions are roughly established, how should the pear's form be conveyed? Outline? (How heavy? Continuous or broken? If broken, where?) Shading with the side of the pencil lead? (Where to begin and end? How to modulate the tone?) Shading using lines? (Parallel, cross-hatched, or haphazard? Straight or curved? At what angle relative to the light source? Deployed to emphasize discrete planes? Should darkness be established by denser line allocation or pressing harder on the pencil? How should one distinguish the pear's mottled texture and local color versus shading due to the play of light?) Clearly, even drawing a simple object entails navigating many decisions, implicitly or explicitly, with the constituent perceptual and attentional processes representing a specialized mode of engagement – one which, while utilizing many of the same fundamental mechanisms, seems far removed from everyday processes used for navigation and object categorization (Kozbelt & Seeley, 2007).

The supposed distinction between everyday perception and whatever special mode of perception might best capture artists' expertise is a debatable and multifaceted issue. Is artistic expertise rooted in very specific classes of stimuli with which artists have direct experience (like faces in portraiture), in specialized knowledge of artistic styles they might deploy (like realism or Impressionism), in the use of particular media of artistic expression (like charcoal or oil paint), or in the actual experience of producing art? To what extent do specifically aesthetic or creative modes of cognition (e.g. Cupchik, 1992; Martindale, 1990), which may differ substantially from both everyday perception *and* a mode of perception emphasizing visual realism, contribute to artists' expertise? In terms of visual processing advantages, is the expertise of artists better characterized as domain-specific (i.e. tied to particular categories of familiar stimuli) or domain-general (i.e. applying to visual processing in more general, flexible ways)?

Despite a recent surge in research on artists and perception, many of these questions defy simple answers. Constrained by the nature of extant research, here we stake out the following positions vis-à-vis these questions. First, we focus on the necessity of having experience in making art for perceptual advantages to accrue, particularly since most researchers have tested visual artists, rather than art critics or historians (thus providing little guidance on possible perceptual advantages among members of these latter groups). Moreover, while knowledge of the effects of particular artistic media likely constitutes an important aspect of real-world artistic expertise (Kozbelt & Seeley, 2007), most laboratory drawing tasks involve just pencil and paper, minimizing the relevance of media-specific knowledge in empirical studies. Second, we focus exclusively on drawing tasks involving accurate, visually realistic depictions, where creativity is often explicitly discouraged; thus, the extent to which visual accuracy itself may be indirectly guided by specifically aesthetic or creative modes of processing is unclear. Third, in terms of domain-specificity versus domain-generality, we argue that artists' perceptual advantages show greater flexibility than in many standard pattern-matching accounts of expertise (as in chess – Chase & Simon, 1973), though this need not extend to very early stages or very low levels of visual processing. This latter point is perhaps most relevant to characterizing the nature of artists' perceptual expertise along theoretical lines in the classic expertise literature (e.g. Gobet & Charness, Chapter 31, this volume; Landy, Chapter 10, this volume).

Whatever the characterization of artists' mode of perception, artists themselves have often stressed the importance of perceptual factors in depictive skill. Leonardo 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). Cézanne described his own system for simplifying objects' forms by noting, "nature must be treated through the cylinder, the sphere, the cone" (Goldwater & Treves, 1972, p. 363). Ingres advised artists, "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 (Schlewitt-Haynes, Earthman, & Burns, 2002) suggests that from an early age they are highly involved with visually analyzing the world.

As Landy (Chapter 10, this volume) emphasizes, gaining expertise in complex domains crucially requires learning to *see* well. Across different domains, perceptual processes can play out in remarkably varied ways, including attending to important aspects of problems to control the time course of reasoning and performing important conceptual tasks by offloading them onto perceptual-motor processing networks. Among the aspects of perceptual learning most relevant to visual art are tuning perception and attention, in order to highlight visual features relevant to a particular task, and learning appropriate perceptual skills. How artists might engage perceptual and attentional mechanisms and translate them into superior drawing performance is a fundamental question in understanding artistic expertise, one to which we now turn.

Ways Artists *Might* See the World Differently

Consider some hypothetical relations between perception and drawing. If artists were born with perceptual systems uniformly superior to those of non-artists, they might effortlessly transcribe a percept into a recognizable depiction. This non-explanation assumes a categorical distinction between artists and non-artists, no variability in either group, and no learning. Moreover, it fails to characterize specific mechanisms whereby artists outperform non-artists. This mode may be approached by a few drawing savants like Nadia, who produced accomplished contour drawings when just a few years old (Selfe, 1977), or Stephen Wiltshire, who is capable of astonishing levels of iconic visual recall in reproducing aerial views of cities in large-scale drawings produced from memory over several days (Treffert, 2009). However fascinating, such case studies do not inform "normal" skilled drawing among competent artists, who typically engage in ongoing interactions between perception, cognition, and action (Tchalenko, 2009).

Alternatively, artists could hypothetically use identical perceptual processes as non-artists, possessing no measurable perceptual advantages and relying instead on non-perceptual factors like greater motivation in applying mundane processes to refine a depiction's accuracy. In this view, anyone with normal vision could learn to draw competently by applying a rote set of principles (along these lines, see some art education accounts, e.g. Edwards, 2012).

Discounting either extreme view, several more plausible middle-ground possibilities remain. For instance, many studies in the classic cognitive psychological literature on expertise attribute superior performance in domains like chess to the acquisition and organization of thousands of domain-specific patterns, or chunks (e.g. Chase & Simon, 1973; Gobet & Charness, Chapter 31, this volume). Chunks allow an expert to recognize and rapidly encode important features of a situation and to take appropriate action. Thus, grand master chess players can detect strategically important configurations of chess pieces and use them to reconstruct the positions of some two dozen chess pieces after looking at a mid-game board for only a few seconds (Chase & Simon, 1973; Gobet & Simon, 1998). However, if the pieces are put into meaningless configurations, grand masters' performances plummet, indicating that their apparent advantage in perception and memory is relatively fragile, being tied to specific patterns in memory.

Can a domain-specific, pattern-driven expertise account fully explain high-level performance in realistic drawing? While artists, like experts in other domains, certainly accumulate significant domain-specific knowledge during their training (Gombrich, 1960; Kozbelt & Seeley, 2007), they also develop the ability to render even novel objects convincingly. Moreover, as discussed below, artists outperform non-artists on perception tasks having nothing per se to do with drawing, suggesting a more general perceptual advantage (cf. chess). An important difference between visual art and chess is that non-chess players need never think about chess, while both artists and non-artists routinely need to understand the structure of objects and pictures.

There is some empirical support for the assertion that artists are superior to non-artists in some aspects of visual perception. For instance, Kozbelt (2001) compared artists and non-artists on drawing tasks (mostly copying line drawings, later judged on accuracy) and higher-order perception tasks requiring visual analysis. These included identifying the subjects of blurry photos or sets of blobs and lines, and finding a target shape within a more complex set of lines (see Figure 30.1). Artists outperformed non-artists on both perception and drawing tasks, providing empirical support for the idea that artists perceive the world differently (and in some respects better) than non-artists. Performance on the two types of

Figure 30.1 Kozbelt (2001) demonstrated that expert artists outperformed untrained novices in perceptual recognition tasks, such as identifying the objects depicted in blurry photos (left) and incomplete line drawings (middle), as well as detecting simple shapes embedded in complex collections of lines (right).

tasks was positively correlated; statistically controlling for performance on one or the other type of task suggested that artists' perceptual advantages are best viewed as a subset of their drawing skills. In sum, artists' perceptual advantages are real, and they are developed largely to the extent that they are useful in drawing.[1]

Additionally, researchers have addressed other aspects of perception associated with observational drawing skill, including superior local – as opposed to global – processing (e.g. Chamberlain, McManus, Riley, Rankin, & Brunswick, 2013; Drake & Winner, 2011), greater field independence (Gaines, 1975), more flexibility in switching between global and local attention (Chamberlain & Wagemans, 2015), better integration of local details into global representations of objects (Perdreau & Cavanagh, 2014), and better memory for changes to to-be-drawn objects and their depictions (Perdreau & Cavanagh, 2015). Some of these findings – as well as some inconsistent results and relevant methodological issues – are discussed in more detail below.

Overall, initial findings on the ways that the perception of artists is superior to that of non-artists are encouraging, but they raise as many questions as they answer. What specific cognitive mechanisms facilitate depictive skill? Do artists' advantages extend to low levels of perceptual processing? What kind of theoretical account would best characterize the nature of artistic expertise? In the next section, we review additional research on these issues, organizing it into the two broad theoretical perspectives on artists and perception that have dominated research in this area, namely, the bottom-up and top-down models.

Psychological Explanations for Skill in Observational Drawing

Perception involves an interaction between "bottom-up" and "top-down" processing. Bottom-up processing is derived exclusively from immediate sensory information processed by retinal photoreceptors. Top-down processing is influenced by additional cognitive processes beyond the raw sensory signal, including endogenous selective attention, explicit knowledge about the structure of common objects, and the integration of visual long-term memories into a final percept. By analogy, two major sets of explanations for drawing ability have been advanced, differentially focusing on the importance of bottom-up versus top-down processing to explain individual differences in depictive skill (Kozbelt, Seidel, ElBassiouny, Mark, & Owen, 2010; Ostrofsky, Kozbelt, & Seidel, 2012).

1 In passing, note that while such a claim is useful in demarcating an initial theoretical orientation for understanding artists' perception, it provides few details about specific processes and mechanisms, as well as the extent to which such advantages potentially transcend standard domain-specific, pattern-matching accounts of expertise.

Bottom-Up Explanations

Bottom-up explanations of drawing skill ultimately derive from the influential and long-standing idea of the "innocent eye" proposed by art historians John Ruskin (1971) and Roger Fry (1960). Couched in modern terms, this notion exploits the well-established notion that conscious perception of the environment does not perfectly reflect patterns of light entering the eye and stimulating retinal photoreceptors. The visual system transforms that information, resulting in a percept that functions to infer the actual structure of objects and scenes (Purves & Howe, 2005). These operations manifest themselves by the near-universally experienced phenomena of visual illusions and perceptual constancies. A classic instance of this involves the perception of circular objects that project to the retina as ellipses; when asked to draw the ellipse or match it to one of a set of ellipses of different eccentricities, viewers' responses are biased toward more circular shapes, as if contaminated by the knowledge of the object's true shape (Hammad, Kennedy, Juricevic, & Rajani, 2008; Taylor & Mitchell, 1997; Thouless, 1931, 1932). While such non-veridical percepts are adaptive for everyday object recognition and visually guided action, the innocent eye perspective argues that they interfere with veridical perception, creating problems in drawing accurately. In this view, skilled artists draw well because they can somehow suppress the influence of such transformations and are instead guided predominantly by the veridical two-dimensional appearance of the models they are drawing. A similar logic underlies some recent accounts of perception in art. For instance, Livingstone, Lafer-Sousa, and Conway (2011) found poorer stereopsis among art students compared to non-artists and higher rates of strabismus, which compromises stereo vision, among accomplished artists, including Rembrandt (Livingstone & Conway, 2004). Decreased stereopsis would give artists better access to monocular depth cues like perspective, shading, and occlusion, which are relevant to accurate depiction. In sum, the innocent eye view proposes that the degree to which one can perceive the veridical appearance of an object or scene determines how accurately one can draw it.

An emphasis on early perceptual encoding as the primary determinant of drawing accuracy also informs psychological research (e.g. Cohen & Bennett, 1997) on what may be called the misperception hypothesis of drawing errors. This hypothesis has been supported by several studies assessing how accurately individuals perceive and draw identical stimuli. For instance, Mitchell, Ropar, Ackroyd, and Rajendran (2005) administered drawing and perceptual judgment tasks based on the Shepard illusion, whereby vertical lines are perceived as longer than horizontal lines when they are the same objective length; this illusion is exaggerated if the lines are embedded in a depicted three-dimensional object like a table, versus in a two-dimensional quadrilateral. Similarly, Ostrofsky, Kozbelt, and Cohen (2015, Experiment 2) administered drawing and perceptual judgment tasks pertaining to a shape constancy illusion – specifically, that individuals perceive angles to be closer to 90 degrees when embedded in a three-dimensional object like a cube than in a two-dimensional pattern when the angles are the same objective size (see Figure 30.2). Both studies revealed congruent patterns of errors in the perceptual judgments and drawing tasks and positive correlations between perceptual judgment errors and drawing errors. Thus, at least with respect to the perception of relative line length and angle size, the degree to which one misperceives a feature of an object appears to predict the degree to which one errs in drawing it.

In light of these findings, an important question for the innocent eye theory is whether skilled artists enjoy general advantages in perceptual processing in conjunction with their drawing advantages. This has been addressed via two methodological strategies: comparing perceptual

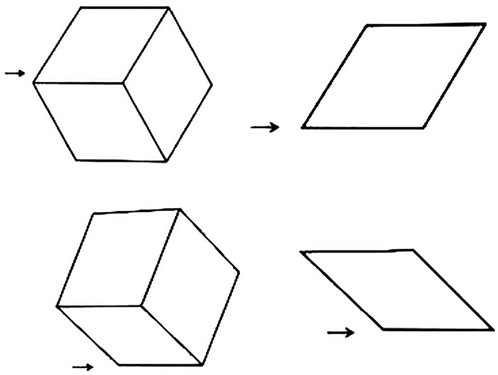

Figure 30.2 Shape constancy effect, whereby the size of an angle is perceived to be closer to 90 degrees when embedded in a representation of a 3D cube than when embedded in a representation of a 2D parallelogram. The angles pointed to with an arrow in the top row are both 57 degrees; the two angles pointed to in the bottom row are both 136 degrees.

processing of experienced artists versus inexperienced non-artists, and/or assessing correlations between general indices of drawing skill and perceptual judgment accuracy when the stimuli used in the two tasks are very different. In such studies, drawing skill is measured by having participants draw from a standardized model (e.g. a photograph of a face, octopus, or hand), and drawing accuracy is assessed either by independent raters' subjective judgments or objective measures of differences between the drawing and model. Researchers employing one or both of these methods have used varied tasks and measures, yielding mixed evidence for the "innocent eye."

Shape Constancy. Shape constancy refers to individuals not perceiving the actual shapes of objects as changing, even as their apparent shapes change due to different viewpoints. This factor creates an illusion whereby the apparent shapes of objects are perceived to be closer to their assumed "real" shape than they veridically appear, when embedded in a three-dimensional scene, like the ellipse example described earlier. Several researchers have assessed the relationship between drawing skill or experience and experience of the shape constancy illusion (Cohen & Jones, 2008; McManus, Loo, Chamberlain, Riley, & Brunswick, 2011; Ostrofsky, Cohen, & Kozbelt, 2014; Ostrofsky et al., 2012; Thouless, 1932). Some of these studies have shown negative correlations between general drawing skill and the degree to which individuals experience shape constancy (Cohen & Jones, 2008; Ostrofsky et al., 2014). However, other studies have failed to replicate this finding, using a similar shape constancy task but different stimuli (McManus et al., 2011; Ostrofsky et al., 2012). Notably, studies focusing on the degree to which artists versus non-artists experience the shape constancy effect have generally failed to demonstrate reliable group differences (Cohen & Jones, 2008; Ostrofsky et al., 2012). Thus, while greater drawing skill appears to be associated with a weaker experience of this perceptual illusion in some studies, this relationship does not appear to generalize across all types of stimuli inducing shape constancy effects. Furthermore, there is not yet sound evidence that artistic experience is associated with reduced susceptibility to shape constancy.

Size Constancy. Size constancy entails individuals not perceiving the physical size of objects to change as they move closer or farther away, despite the fact that their apparent size does. When two objects of the same apparent size are interpreted as being at different distances, viewers experience an illusion whereby the "far" object seems larger than the "near" object. Some researchers have demonstrated that general measures of drawing skill are negatively correlated with the degree to which individuals experience size constancy (Ostrofsky et al., 2012, 2014). In such studies, participants typically adjust one stimulus to match the size of another, with depth cues either present or absent. Ostrofsky et al. (2012) found that both artists and non-artists show size constancy effects (i.e. more accurate performance in the non-depth condition versus the depth condition) and that artists experience size constancy reliably less than inexperienced non-artists do. However, non-artists' baseline performance was far more accurate in the non-depth condition than was artists' performance in the depth condition; thus, artists cannot simply override size constancy effects, as implied by a strong version of the innocent eye view. Moreover, two other studies, using different tasks to measure the illusion, have failed to find any reliable differences between artists and non-artists (Chamberlain & Wagemans, 2015; Perdreau & Cavanagh, 2011). In sum, evidence on possible relations between greater art experience and/or skill in drawing with more accurate size perception remains mixed.

Lightness Constancy and Other Visual Illusions. Lightness constancy involves individuals not perceiving changes of an object's "real" level of brightness across changes in the luminance conditions of the environment. When two patches are equated in apparent brightness, but the first is perceived to be under a shadow and the second is not, individuals experience an illusion whereby the first patch seems brighter than the second. One study comparing artists and non-artists demonstrated that both groups experienced this illusion to the same degree (Perdreau & Cavanagh, 2011); to our knowledge, no researchers have extended this paradigm to compare individuals varying on drawing skill, irrespective of artist versus non-artist status. Finally, Chamberlain and Wagemans (2015) compared artists' and non-artists' experience of the Ebbinghaus illusion (involving relative size perception), the Müller-Lyer illusion (involving relative line length), and the Rod-and-Frame illusion (involving line orientation), likewise finding no group differences and null correlations between the degree to which participants experienced these illusions and general measures of drawing accuracy.

Summary of Bottom-Up Results. A strong version of the innocent eye hypothesis is not supported by empirical evidence. There has been no strong evidence that skilled or experienced drawers are completely able to suppress their experience of visual illusions that are produced by perceptual constancy mechanisms. However, a more moderate version of this idea, arguing that skill in drawing is associated with perceptual processing advantages, has received some empirical support – mostly in the form of correlational evidence demonstrating that individuals skilled at drawing perceive some visual stimuli more accurately than less skilled individuals. This finding has been most consistently demonstrated when the visual features that participants draw and perceptually judge are identical in type and appearance (Mitchell et al., 2005; Ostrofsky et al., 2015). When stimuli in perception and drawing tasks differ from one another, both in terms of the stimulus appearance and the features being assessed for drawing and perceptual judgment accuracy, the evidence is quite mixed: some researchers find relations between general drawing and perceptual accuracy, and others do not. This conclusion may be due to the use of perceptual and drawing tasks that are highly dissimilar. It may also indicate that drawing and perceptual processing are not best characterized as a single general capacity encompassing all types of visual features. Rather, some individuals may be strong in drawing and perceptually processing some visual features (e.g. angles), but weaker with respect to others (e.g. brightness and size), and the ability to accurately draw and/or perceive different visual features may be independent of each another. This idea has been supported by evidence like the observations that the magnitudes of size and shape constancy errors are not inter-correlated and differentially predict general drawing accuracy (Ostrofsky et al., 2012). Thus, the relationship between accurately drawing and perceiving visual stimuli may be feature-specific rather than generalized (see Ostrofsky et al., 2015).

Top-Down Explanations

Besides the limited and conflicting empirical evidence described above, there are theoretical arguments as to why a purely bottom-up view is necessarily inadequate as an explanation of drawing skill. Critically, bottom-up explanations implicitly conceive of drawing as involving passive processing of visual information inherent in the model object. In contrast, top-down explanations emphasize a wide array of higher-order processes, such as explicit domain-specific knowledge, active decision-making, and endogenous shifts of attention, as major factors inherent in drawing skill (Ostrofsky et al., 2012). In this view, knowledge-driven influences can facilitate, rather than merely interfere with, perception and drawing accuracy. In its pure form, the top-down view is thus strongly opposed to the bottom-up view.

The top-down position is most closely associated with art historian E. H. Gombrich (1960; see also Kozbelt & Seeley, 2007). Gombrich argued that the inverse optics problem in vision, whereby a retinal image can arise through an infinite number of possible configurations of real-world objects, applies to depiction as well. When artists render the three-dimensional world on a two-dimensional surface, some information must be lost, and other information emphasized, to convey the illusion of three-dimensional form and space. Artists achieve this goal not by suppressing what they know but rather by harnessing their knowledge of the structure of appearances via specialized knowledge, or schemata, to meet their depictive goals. Gombrich supported his argument with reference to how-to manuals used to train artists throughout history (e.g. Cennini, 1954). These manuals and their modern counterparts (e.g. Dodson, 1985; Hamm, 1963) supply artists with explicit, declarative knowledge of the structure of common object types and means of depiction in a given medium, which non-artists lack. Observational drawing is not guided exclusively by visual information inherent in the model; rather, long-term graphic memories representing the features, proportions, and spatial configuration of common objects are activated and partially guide the production of an observational drawing.

Domain-Specific Knowledge of Objects. Some researchers have found that individual variation in some aspects of observational drawings of objects can be predicted by individuals' drawings of those objects produced from imagination (Matthews & Adams, 2008; Ostrofsky, 2015). Such studies support the notion that individuals are influenced by "what they know" in addition to "what they see" when producing observational drawings. Relatedly, Gombrich's (1960) argument about the importance of explicit domain-specific knowledge of objects for accurate depiction has been directly supported, with regard to faces. A common error in drawing faces involves positioning the eyes too far up the head (Ostrofsky et al., 2014). On average, the eye-line is approximately halfway down the head (Ostrofsky, 2015). Ostrofsky, Kozbelt, Tumminia, and Cipriano (2016) randomly assigned inexperienced non-artists to either receive knowledge about proper eye placement or not. Participants receiving this knowledge produced smaller errors in vertically positioning the eye-line than those who did not, demonstrating that more accurate observational drawing is supported by possessing more accurate declarative knowledge of the structure of common objects.

In both laboratory and real-world instructional settings, explicit knowledge about object structure is typically communicated via language; other forms of skill and knowledge relevant to artistic expertise, perhaps especially those involving action and perceptual-motor integration, are harder to articulate. As Gombrich (1960), citing Quintilian, noted, "Not everything that art can achieve can be passed on" (p. 25). This distinction, between aspects of artistic knowledge that are easier versus harder to articulate, limits the kinds of artistic knowledge that can be imparted directly via instruction and reinforces the multifaceted quality of top-down influences on drawing.

Decision-Making and Efficient Processing of Object Features. Even so, knowledge of common objects' structures, without further refinement, may be insufficient to produce high-quality drawings. Not all features are equally useful for object identification; junctions of lines, for instance, are far more important than mid-segments of lines (Biederman, 1987). Artists may be sensitive to essential features of an object, explicitly or intuitively, and use this to decide which aspects to include or emphasize in a depiction; non-artists, lacking such sensitivity, would likely make less astute decisions. This proposition has been empirically supported in studies using a limited-line tracing task, in which participants use a standardized number of tape segments to trace over a photo inserted in a transparent sleeve, with the goal of producing a recognizable depiction (Kozbelt et al., 2010; Ostrofsky et al., 2012). Importantly, participants are not provided with enough tape to trace the entire object and thus must decide which features to emphasize. Kozbelt et al. (2010) found that artists' tracings of a face were judged as more accurate than those of non-artists, especially when rated by artist judges. Ostrofsky and colleagues (2012) replicated this finding using a photo of an elephant, and further demonstrated that the judged accuracies of the tracings were positively correlated with those of observational pencil drawings of an octopus. Moreover, artists included more of several categories of line junctions in their tracings of elephants than did non-artists (see Figure 30.3), a result echoing findings in a free-hand drawing task (Biederman & Kim, 2008). In sum, visual selection and decision-making – in particular, artists' spontaneous judicious selection of object features important for recognition – appear critical for realistic depiction.

Along similar lines, Perdreau and Cavanagh (2013) argued that artists' perceptual advantages arise from robust representations of object structure in memory, which can be used to encode and depict important aspects of objects (see also Kozbelt, 2001). Other evidence suggests skilled drawers are more efficient, not just more accurate, in perceptual processing of objects, compared to unskilled drawers. Perdreau and Cavanagh (2014) had artists and non-artists discriminate possible versus impossible figures

Figure 30.3 Some images of an elephant produced in the limited-line tracing task reported by Ostrofsky et al. (2012). The top row shows tracings produced by trained artists; the bottom row shows tracings produced by untrained novices.

under various exposure durations; drawing skill was operationalized by objective errors in copying a photograph of a house. A positive correlation was found between the prevalence of drawing errors and average time required to accurately discriminate possible versus impossible figures, indicating that individuals capable of producing more accurate drawings could more quickly perceive the holistic forms of objects. This enhanced efficiency appears to be specific to the visual form of objects, as opposed to being generalized across all forms of visual processing, since there was no relation between drawing skill and time required to accurately discriminate visually presented real versus nonsense words in a lexical decision task (cf. results on chess grand masters' perceptual encoding – Chase & Simon, 1973; Gobet & Simon, 1998).

Visual Attention. Beyond a possible attentional advantage with respect to selecting what features of an object to pay attention to, other researchers have suggested that extensive experience in drawing is associated with an ability to shift attention between different modes of processing. A high-quality observational drawing successfully reproduces both the global structure and local details of the model. Researchers have suggested that extensive experience in drawing may be associated with a more general advantage in the efficiency of shifting attention between the global and local aspects of a stimulus. Chamberlain and Wagemans (2015) had participants view stimuli containing squares or circles either at the local level (a non-square/circle global shape composed of individual square/circle local elements) or global level (a square/circle global shape composed of individual non-square /circle local elements) and respond if the display contained a circle or square (regardless of global or local level). On any pair of trials, targets could be presented at the same level (i.e. at either the local or global level for both trials) or different levels (e.g. at the local level for one trial and at the global level for the next trial). In the latter case, having to shift attention between global and local levels typically slows target identification, compared to consecutive trials at the same level (Ward, 1982), presumably due to mutual inhibition between the two levels. While both artists and non-artists experienced the expected change in reaction time, the cost of switching levels was significantly reduced for artists. This may be due to weaker inhibition between processes at the two levels, which could support artists' ability to process both a model's global structure and emerging drawing while also focusing on local details. Weaker inhibition between global and local processes may also explain artists' superior ability to integrate isolated local visual information into a global perceptual representation (Perdreau & Cavanagh, 2013).

Summary of Top-Down Results. There is considerable evidence supporting several aspects of the top-down view of artists' perceptual advantages: explicit knowledge about the structure of common objects; greater ability to analyze the structure of objects; and enhanced flexibility in shifting attention between different modes of perceptual processing all appear to be associated with greater depictive ability. Besides such empirical support, top-down advantages do more to ground artistic expertise in domain-specific knowledge and specific visual abilities than does the bottom-up view.

Theoretical and Empirical Reconciliations

So far, we have treated bottom-up and top-down theories as diametrically opposed. However, as in real perception, bottom-up and top-down processes likely interact and contribute to artistic expertise and drawing skill in varied ways. Kozbelt et al. (2010) outlined some ways in which bottom-up and top-down views might be conceptually reconciled. For instance, they may apply to different depictive problems; bottom-up methods may be best for resolving an object's two-dimensional proportions or clarifying details, while top-down methods may facilitate appropriate visual selection. Delineating the meaning of *knowledge* (and its interfering versus facilitating effects) on the two accounts is also clarifying; the bottom-up view engages generic knowledge of object types useful for everyday perception, while the top-down view regards knowledge as highly specialized, artificial, and domain- (or even medium-) specific, and useful for understanding object structure and means of achieving desired effects in depiction.

A more integrated understanding might also be had by conceptualizing bottom-up and top-down modes of perception as *strategies*, flexibly implemented to deal with perceptual ambiguities, rather than mechanistic perceptual processes without substantive consideration of context (see Ullman, 1984, for such an overtly strategic account of object perception involving temporally extended visual "routines"). A more bottom-up strategy might involve selecting the most characteristic lines, angles, or shapes upon which to construct forms, and assessing overall spatial relationships, for instance, in "apprehending the relation of forms and color to one another, as they cohere within the object" (Fry, 1960, p. 49). Novices may find bottom-up strategies particularly useful, along the lines of some art instruction manuals (e.g. Edwards, 2012; Hoffman, 1989). Top-down strategies may help resolve perceptual ambiguities based on expectations of a feature at a particular location or guide a decision to emphasize a diagnostic feature, enhancing recognition of a depicted object (Kozbelt & Seeley, 2007). As artists develop an expert knowledge base of declarative patterns and dynamic procedures for perception and depiction, top-down schemata (Gombrich, 1960) likely become increasingly important in guiding perceptual and motor processes, facilitating wise selection of viewpoint-dependent information that still accurately captures an object's structure (Kozbelt et al., 2010; Perdreau & Cavanagh, 2011, 2014). Finally, experienced artists may have substantial strategic flexibility, reverting to more bottom-up strategies when drawing unfamiliar objects or correcting depictive errors.

Further leverage in coordinating bottom-up and top-down views may involve reframing the issue away from perception and toward visual *attention* – specifically, the interaction between strategic shifts in attention guiding visual selection and the attentional enhancement of selected information and suppression of non-selected information (Chamberlain & Wagemans, 2015; Kozbelt & Seeley, 2007), as well as the role of attention in visually guided action (Seeley & Kozbelt, 2008). As noted earlier, a major problem in drawing is the moment-to-moment selection of what to attend to and render. Results from limited-line tracing tasks (Kozbelt et al., 2010; Ostrofsky et al., 2012; see also Tchalenko, 2009) suggest that the selection process differs between artists and non-artists and is related to drawing accuracy. While bottom-up and top-down strategic attentional shifts reflect the process of selecting what information to depict, an additional issue concerns subsequent processing of already-selected information. Consider the depth cue condition of a typical size matching task (e.g. Ostrofsky et al., 2012). That artists make smaller size constancy errors than non-artists may suggest that artists are better at focusing attention on task-relevant information – though it is clear to both groups what information on a size matching display is relevant. Along these lines, artistic skill may involve a capacity to bias attention toward enhancing the processing of target information and suppressing task-irrelevant information, resulting in a functionally larger pool of attentional resources.

Integrating top-down and bottom-up views can also take a more empirical turn, moving beyond studies that have examined only one or the other viewpoint (e.g. Cohen & Jones, 2008; Kozbelt et al., 2010), or pitted the two against each other

Figure 30.4 Some images of a face produced in the pixel drawing task reported by Kozbelt et al. (2014). The top row shows tracings produced by trained artists; the bottom row shows tracings produced by untrained novices.

(Cohen & Bennett, 1997; Ostrofsky et al., 2012). For instance, in one recent investigation (Kozbelt, Snodgrass, & Ostrofsky, 2014), artists and non-artists created depictions by placing 225 small squares of black tape within a 28 × 32 grid superimposed on a photograph of a face. Superimposing a standardized grid on the reference image, where each square may be either black or white, allows for objective binary coding of each "pixel" within the depiction. Moreover, the reference image can be processed via image manipulation software to preserve the position, coarseness, and size of the grid, and the number of black versus white elements; this can then serve as the "best" pixelated drawing, at least in bottom-up terms. An analysis comparing square placement in each drawing with that of a computer-generated version of the image revealed a large artist advantage in sensitivity to placing the squares appropriately – a bottom-up index of drawing skill. Subjective accuracy ratings by artist and non-artist judges also indicated that artists' ratings of other artists' renderings were considerably higher than any of the other three drawer–rater combinations (consistent with Kozbelt et al., 2010). This method provides a means for further integrating bottom-up and top-down explanations of drawing skill that transcends defining bottom-up advantages mainly in terms of overcoming perceptual constancies, by extending it to include other aspects of the bottom-up signal, like relative luminance across an image. It also allows an assessment of how participants process the bottom-up signal (in terms of matching the distribution of correct answer squares) compared to a top-down, caricatured deviation from that signal – in terms of systematic deviations from the "best" bottom-up depiction, in the service of greater expressiveness (see Figure 30.4).

Future Directions

Methodological Issues

We have identified instances where artistic experience and/or skill in drawing appears to be associated with domain-specific and domain-general advantages in visual perception, attention, knowledge, and decision-making. However, significant methodological questions linger in this body of research. For instance, virtually all the studies described above have adopted correlational or quasi-experimental methods, leaving the direction of causality ambiguous. Take findings like smaller size constancy effects among experienced artists compared to inexperienced non-artists (Ostrofsky et al., 2012) or an observed positive correlation between errors produced among non-artists in drawing versus perceiving angles (Ostrofsky et al., 2015). Such results could indicate that perceptual processing advantages precede and thus causally engender drawing advantages, or that developing drawing skill causes individuals to perceive more accurately or efficiently, or that they co-evolve or co-vary with additional unspecified variables (e.g. motivation). Quasi-experimental and correlational designs cannot disentangle these possibilities. Thus, an important direction for future research is adopting experimental approaches that would, for instance, directly manipulate experience in drawing to assess any effects on perception. Longitudinal studies, gauging the ongoing time courses of the acquisition of drawing skill versus various perceptual abilities, would be especially informative.

Another major methodological issue, alluded to throughout this chapter, involves how expertise in drawing has been operationally defined; either with respect to drawing *experience*, typically through artist versus non-artist comparisons, or with respect to drawing *skill*, via measurement of depictive accuracy or errors in standardized drawing tasks. In a few instances, a single study has employed both operationalizations and found them to be similarly associated with performance on non-drawing tasks – for instance, comparing size constancy and visual selection advantages (Ostrofsky et al., 2012), or null effects on several visual illusions (Chamberlain & Wagemans, 2015). However, experience and skill are not synonymous: Cohen and Jones (2008) found that measured drawing skill was negatively correlated with shape constancy errors, while simultaneously not finding any difference between artists and non-artists in shape constancy errors; Chamberlain and colleagues (2013) found a similar pattern with two tasks measuring local perceptual processing ability.

Such conflicting results may be partly attributed to the fact that many contemporary modes of art-making do not involve observational drawing. Chamberlain et al. (2013) reported that many art students do not self-identify as strong observational drawers, and in many studies, “artist” participants are college-level art majors or *soi-disant* professional artists recruited from the community with no further specifications. This fact does not guarantee high or consistent levels of skill, just as, conversely, “non-artist” status does not imply low skill levels. Artist samples are likely to be multifariously heterogeneous – in academic or professional level, age, depictive skill level, as well as preferred media, style, and type of art produced. Notably, while some researchers have reported efforts to ensure high drawing skill among their artist participants (e.g. Chamberlain et al., 2013), others have not. More formalized, consistent, and transparent screening procedures should be adopted to resolve these issues. Additional selection criteria, involving, say, subgroups of artists with different aesthetic judgment criteria, could also be informative about both producing and judging depictions (Serafin, Kozbelt, Seidel, & Dolese, 2011). Along these lines, a useful test case of the nature, scope, and source of potential perceptual advantages associated with expertise would involve extending existing testing paradigms to samples of visually engaged art experts, such as historians, curators, or critics, who themselves do not draw: would they show similar perceptual trends as trained artists, compared to non-artists?

Just as researchers have used two putatively associated operational definitions of drawing expertise, they have also implemented multiple dependent measures of drawing accuracy.

The two main approaches are subjective accuracy ratings by independent judges (artists or non-artists) and objective metrics of drawing accuracy – each, alas, with some limitations. Ratings are arguably limited in their inherent subjectivity, though achieving high inter-rater reliability alleviates this concern somewhat (Amabile, 1982). Moreover, most drawing studies treat subjective accuracy ratings holistically – that is, representing a unidimensional accuracy continuum. However, this is a limited conceptualization. A drawing may show high accuracy in some respects (e.g. the relative spatial proportions of different features of a model), but low accuracy in other ways (e.g. inconsistent brightness gradients across the depicted object or unconvincing articulation of parts into a coherent whole). A few researchers have attempted to improve upon this by having judges provide separate accuracy ratings for different aspects of drawings. Cohen and Earls (2010) and Cohen and Jones (2008) had judges give separate ratings for isolated facial features and the spatial relationships between the features – but this remains unusual.

Holistic ratings also do not inform *which* aspects of a depiction contribute to an overall sense of realism. It is often assumed that artistic realism is self-evident. As Leonardo da Vinci noted, "A painter should not object to listening to the opinion of a layman. Even if a man is not a painter, he knows what the human form looks like . . . If someone is quite capable of judging the works of Nature, shouldn't we admit him capable of detecting our errors?" (Kelen, 1990, p. 139). However, realism remains a surprisingly slippery construct, and artists and non-artists sometimes differ significantly in their subjective accuracy ratings (Kozbelt et al., 2010, 2014), suggesting that the two groups may use different criteria or standards (see also Kaufman, Baer, Cole, & Sexton, 2008; Runco, McCarthy, & Svenson, 1994; Serafin et al., 2011).

The limitations of subjective ratings have incited the development of drawing accuracy measures that assess errors via objectively measurable differences between the drawing and model (e.g. Carson & Allard, 2013; Ostrofsky et al., 2015). Such methods have advanced researchers' ability to operationalize depictive accuracy with respect to proportions and the relative spatial positioning of a model's features, but they leave unaddressed other aspects of accuracy, like luminance gradients and the appearance of local features. Future research may benefit from adopting an integrated approach to assessing drawing accuracy using both subjective and objective measures, as in some recent studies (Chamberlain, McManus, Riley, Rankin, & Brunswick, 2014; Hayes & Milne, 2011; Kozbelt et al., 2014; Ostrofsky et al., 2014; Perdreau & Cavanaugh, 2014).

Considerable near-term progress in understanding artistic expertise could be made simply by addressing many of these methodological issues head-on – especially given the frequency of conflicting results on fundamental questions, like the relation of shape constancy to drawing accuracy. The basic replication, extension, and integration of findings, ultimately with a view to meta-analyses, would contribute greatly toward resolving many outstanding issues.

Conceptual Issues

Besides future directions stemming from methodological refinements, some broader conceptual issues also open promising avenues for exploration. For instance, in the context of the classic expertise literature, an issue raised near the outset of this chapter – determining the extent to which depictive skill may entail robust, general advantages in perception and attention – remains highly pertinent: indeed, a guiding principle in broad conceptualizations of the nature of artistic expertise. Much of the evidence to date suggests that artists do enjoy fairly generalizable advantages in some aspects of perception, perhaps most clearly in understanding object structure (e.g. Kozbelt et al., 2010; Perdreau & Cavanagh, 2014). Following the logic of Gombrich (1960), such an advantage can be attributed to artists routinely needing to solve the same kinds of problems in making depictions as the visual system does generally for understanding the world. The dynamic described throughout this chapter is consistent with Ericsson and Lehman's (1996) characterization of skill acquisition involving the adaptation of pre-existing mechanisms (in this case basic perceptual processes) to particular task constraints (making visually accurate two-dimensional artistic depictions based on observation of the three-dimensional world).

Characterizing in detail how artists engage particular perceptual and attentional mechanisms and translate them into superior drawing performance remains a challenge. For instance, how deeply into the visual system do perceptual differences between artists and non-artists run? To date, research on relatively low levels of perceptual processing – such as psychophysical indices of perceptual organization thresholds among artists and non-artists on several Gestalt grouping principles (Ostrofsky, Kozbelt, & Kurylo, 2013) – has yielded null findings. Along similar lines, Perdreau and Cavanagh (2011) framed their investigation as "Do artists see their retinas?" and argued for an answer in the negative. Furthermore, Cohen and Bennett (1997) provocatively hypothesized a distinction between *illusions*, which are rooted in low-level, cognitively impenetrable mechanisms, and *delusions* due to the interfering effect of knowledge, which they argued are responsible for most drawing errors but which can in principle be overcome.

Finding meaningful artistic expertise-based psychophysical differences at very low levels of visual processing – such as visual acuity, color perception, or contrast sensitivity – may be daunting, but there is a precedent in the study of first-person action video game playing. In a noteworthy series of studies, Bevalier and colleagues (e.g. Li, Polat, Makous, & Bevalier, 2009), found systematic changes in low-level visual processing, such as enhanced contrast sensitivity, as a result of video game playing – even when conditions were randomly assigned. Such results inform ongoing general debates about the mutual influences of experience, cognition, and perception, at various levels of processing (see Firestone & Scholl, 2015; Landy, Chapter 10, this volume). Thus, it may yet be possible to find parallel deep changes in the perception of artists as they intensely engage the visual world with the goal of depicting it, though no direct evidence for this has yet been found (e.g. Perdreau & Cavanagh, 2011).

Additionally, understanding motoric aspects of artistic expertise, and their interaction with perception, is another issue awaiting in-depth exploration. Motor processes have been extensively studied in dance, sports, and other perceptual-motor-intensive domains (e.g. Rosenbaum, Augustyn, Cohen, & Jax, 2006; Williams, Ford, Hodges, & Ward, Chapter 34, this volume). Attempts to isolate fine motor differences as a function of artistic expertise have generally yielded null results (e.g. Cohen & Bennett, 1997); however, hand and eye movements are known to have strong bidirectional influences, so examining their mutual interplay may be necessary (Gowen & Miall, 2006). Consistent with other findings on expertise, recent work examining eye and hand movements in naturalistic drawing has found that artists can produce more motor output per unit of visually encoded material when drawing, relative to non-artists (Glazek, 2012); moreover, artists use a systematic eye–hand strategy while segmenting complex lines, while non-artists either segment arbitrarily or not at all (Tchalenko, 2009). Perceptual-motor integration themes feature prominently in many recent accounts of depiction (Kozbelt, 2001; Kozbelt & Seeley, 2007; Seeley & Kozbelt, 2008; Tchalenko, Nam, Ladanga, & Miall, 2014) and, together with the theme of embodied cognition (e.g. Lakoff & Johnson, 1999), are poised to become increasingly important in characterizing artistic expertise, as are explorations of individual-difference variables like personality and motivational factors (see Chamberlain, McManus, Brunswick, Rankin, & Riley, 2015).

Besides laboratory studies comparing artists and non-artists that have comprised the bulk of this chapter, other approaches, which can only be touched on briefly here, are also promising. One is a continued focus on special populations besides professional artists, broadly construed. For example, contemporary drawing prodigies represent a rich source of data on specific aspects of perceptual processing that undergird realistic depiction ability (Drake & Winner, 2012; Winner, 1996). Such investigations can be supplemented by archival studies of great artists bearing on questions of expertise development, as in the childhood work of Klee, Toulouse-Lautrec, or Picasso (Pariser, 1991), and contemporary case study accounts of accomplished artists, as in Solso's (2001) neuroimaging study of portraitist Humphrey Ocean.

Finally, the details of artists' domain-specific knowledge and schemata (Gombrich, 1960; Kozbelt & Seeley, 2007) themselves remain woefully under-characterized. For instance, the extent to which domain-specific knowledge and perceptual skills might be modulated across artistic media is an intriguing open question. Consider the task requirements of different media: the fine linear detail of drypoint etching versus large-scale perception and motor execution in mural painting versus three-dimensional spatial reasoning in sculpture: is expertise in such varied media associated with different constellations of perceptual strengths? Characterizing artists' knowledge base and its relation to specific perceptual and motor skills would also inform issues in the appreciation and connoisseurship of art (Bullot & Reber, 2013; Kozbelt & Ostrofsky, 2013), art education and pedagogy (Edwards, 2012), as well as better understanding how artistic expertise and skill facilitate creativity (Galenson, 2001; Kozbelt, 2008). Understanding artists' skills and knowledge is also relevant to linking the expertise literature with accounts of how the supposed basic mechanisms that undergird human artistry emerged and/or were co-opted in our evolutionary past (Turner, 2006).

Conclusion

Artists are situated at the intersection of a set of complex set of issues within the study of expertise, including visual perception and cognition, motor processes, historical and socio-cultural factors, and creative thought. The study of artistic expertise – past, present, and hopefully future – touches on a broad spectrum of issues within psychology and allied domains. The complexity and inherently interdisciplinary quality of visual art may be partly responsible for the seemingly late start of a significant research tradition on expertise in the domain of art, and, even at this date, the relative rarity of empirical studies on expertise in drawing.

However, the fact that researchers on artistic expertise have had to play catch up to other, better-established, domains of expertise is not completely disadvantageous. The ongoing development of models of expert performance in other domains provide means to gauge the extent to which – and precisely how – the domain of visual art may (or may not) differ from other domains. That visual artists creating depictions routinely need to solve many of the same problems as the visual system does generally suggests that some aspects of artists' perceptual advantages may transcend specific learned patterns and offer greater flexibility in visual analysis. To date, there are a number of suggestive findings, on the relation between certain aspects of early visual processing and the accuracy of depictions of isomorphic stimuli, on the importance of visual selection, and on likely artist advantages in understanding object structure, but little yet in the way of incontrovertible facts. Simply fleshing out the many lines of nascent or potential inquiry described above could be very informative, facilitating the testing of predictions about high-level performance in art-making based on empirical findings about experts in other domains. Reciprocally, the potentially deep influence of artists' expertise on their perceptual capabilities could conceivably re-characterize how expertise itself is typically understood.

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