Artists' Drawing Strategies Serve to Overcome Visual Processing Limitations *

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Abstract

Most people learn to draw casually at an early age, but learning to create accurate observational drawings usually require extensive practice. Why is accurate drawing so hard? And what distinguishes people skilled at accurate drawing from those who are not? Empirical research has primarily studied these questions for the task of copying a source picture. This article argues that the difficulty of copying tasks can be explained by limitations of visual memory and peripheral vision. In addition, variation in the control of eye movements could explain mixed findings regarding the relationship between perceptual skill and drawing skill, and regarding the role of prior knowledge in drawing. We explore the hypothesis that artists aiming to create accurate drawings from observation employ a broad suite of strategies for coordinating their eye movements with drawing actions, enabling them to transfer information from the source image to their drawing within the limitations of visual memory and peripheral vision. We advocate for further study of these strategies in naturalistic scenarios that extend beyond copying tasks.

1 Introduction

"Drawing ... is one of the simplest and yet most endlessly complex of human activities."
— Catherine Goodman (2019), artist and cofounder of the Royal Drawing School

What are the processes by which people create pictures of what they see, using only a pen, pencil, or brush? People draw for many reasons, including to explore ideas, to communicate with others, and to make art (Fan et al., 2023). Drawing is one of our most basic creative pursuits, and often a starting point in fine art, architecture, filmmaking, engineering, and design. In observational drawing, one draws from an original subject, such as a still life or live model in the studio, or *plein air* painting of a landscape or city scene.

A large body of empirical research has investigated two related questions: *Why is drawing hard?* And, *what distinguishes people skilled at accurate drawing from those who are not?* (Chamberlain and Wagemans, 2016; Chamberlain et al., 2021; Robles et al., 2022). Most of this work studies *copying tasks*, in which a participant must draw a copy of an existing picture. These studies have gathered a wealth of data on possible correlates of copying ability, including susceptibility to visual illusions, eye movement frequency, ability to relate 3D shapes, and ability to trace over pictures. These findings have been interpreted with respect to various hypotheses in terms of perceptual skills ("non-artists make more perceptual errors"), attention ("artists have greater attentional flexibility"), perceptual flexibility ("artists have greater ability to switch between local and global judgments"), and others. However, existing evidence does not provide compelling support for any of these hypotheses as explanations for either why drawing is hard or what is distinctive about skilled drawing.

To address the question of *Why is it hard to draw a copy of another picture?*, we propose that the profound limitations of peripheral vision and visual memory account for the difficulty of copying. In addition, variation in

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the control of eye movements could explain mixed findings regarding the relationship between perceptual skill and drawing skill, and regarding the role of prior knowledge in drawing. To address the question of *What distinguishes people skilled at accurate copying from those who are not?*, we conjecture that skilled drawing entails employing effective strategies to compensate for the limitations in human peripheral vision and visual memory, and that gradual improvements in drawing skill reflect the improved use of these strategies. We survey a range of common drawing strategies to highlight the importance of these strategies. The explanations that we offer in this paper lead to a variety of predictions concerning the ways that eye and hand tracking behavior could be used to predict copying accuracy. We close with a call for studying artists' drawing strategies, and for the study of ecologically-valid drawing tasks beyond copying.

2 Limitations of vision and memory make copying hard

In a paper entitled "Why Can't Most People Draw What They See?", Cohen and Bennett (1997) summarized skills necessary for observational drawing: perceiving the subject, deciding which parts of it to draw, translating those parts to a page through motor commands, and assessing the drawing. They assessed participants' skills through various tasks of drawing from a photograph or tracing a photograph, and concluded, by process of elimination, that drawing is difficult because non-artists misperceive objects.

But follow-up studies have produced mixed conclusions, suggesting that the question is far more complex and difficult to answer than Cohen and Bennett initially suggested (Chamberlain and Wagemans, 2016; Chamberlain et al., 2021; Chamberlain and Wagemans, 2015; Perdreau and Cavanagh, 2014, 2015). While the question concerns all forms of observational drawing, prior work has mostly studied copying tasks, where participants must directly copy a picture provided to them; typically, the source picture is itself a line drawing to be precisely copied. Taken together, existing studies have yet to produce strong conclusions concerning why copying is difficult. Here we explore the hypothesis that accurate copying of line drawings is difficult in large part owing to severe limitations in visual memory and peripheral vision, inspired in part by recent developments in picture perception (Hertzmann, 2024; Martin et al., 2025).

2.1 Copying as information transfer

Copying a picture can be thought of as an information transfer problem: how best can one transfer information from the source to the target by freehand copying, given constraints on vision, memory, and visuomotor control?

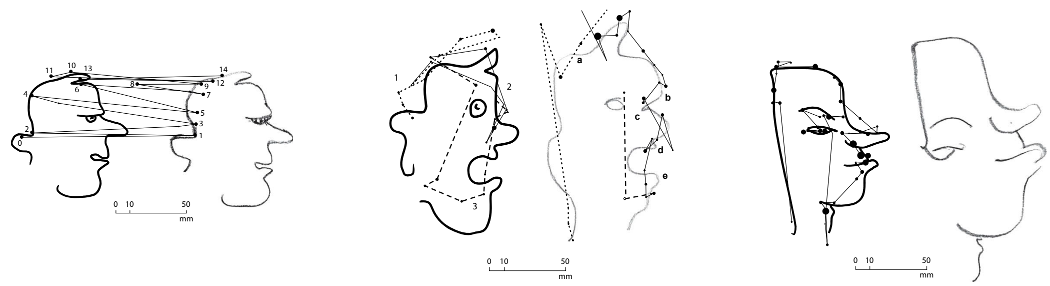
It could be that people copy pictures by first forming a mental representation of the source picture in its entirety, and then producing a complete drawing based on this representation. However, that possibility seems unlikely, given that people frequently move their eyes over the source drawing throughout the copying process (Tchalenko and Miall, 2009) (Figure 1A). When people attempt to draw without referring back to the source, the results are typically distorted (Figure 1C), suggesting that something more complex must be at play.

Instead, people seem to transfer picture information piece-by-piece, studying one portion of the source, and then copying that portion. They might first encode these parts into working memory before planning their next stroke, or they could begin to plan their strokes while viewing the source. Throughout this process, the person wound need to actively maintain some mental representation of the copy-in-progress, as well, to know which parts are finished and which still need work.

Hence, copying a picture requires a coordinated series of eye movements and hand movements, to simultaneously study portions of the source, to plan and execute strokes, and to update a model of the copy. A person could select eye fixations and the order in which to draw strokes in many different ways, and some of these approaches might be better than others at transferring information accurately and efficiently.

2.2 The Vision-Memory Bottleneck

Each step in the copying process is severely constrained by visual limitations that impact the transfer of information from a source picture to a target drawing. These limitations include constraints on how much information can be encoded from a single eye fixation and how faithfully information can be maintained in visual memory.



A Direct copying B Memory copying C Direct Blind copying

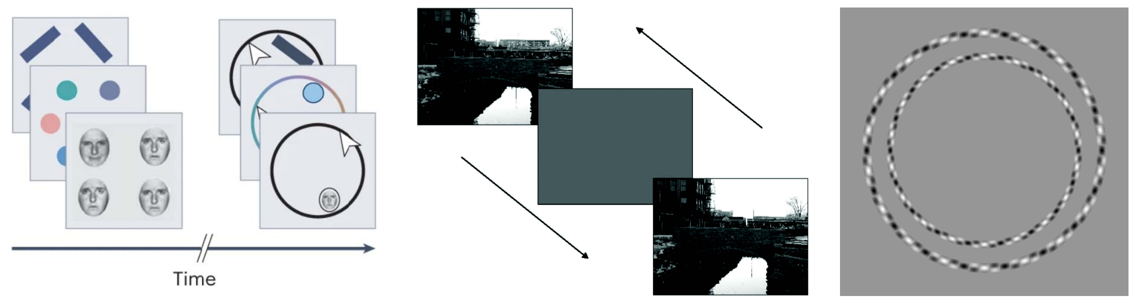
Figure 1: Examples of copying drawings under different conditions, from Tchalenko and Miall (2009). Source shown on left and copy on the right, with eye fixations and saccades shown with dots and lines, and dot size proportional to fixation duration. A: Direct copying, showing only fixations relating to the back of the head. B: Memory copying, in which the subject may not view the source while drawing. Overall proportions and elements are preserved, but many details are lost or inaccurate, indicating an inability to remember all visual details. Different subjects used different strategies to attempt to memorize the source. C: Direct Blind copying, in which the subject can see the source, but cannot see their own drawing. Details are accurate, but arrangement on the page is not, nor are the relative proportions. Localizing the arrangements of objects is difficult without being able to look at the drawing. (All figures Creative-Commons licensed, CC-BY.)

The first constraint comes from the limitations of peripheral vision. Foveal vision covers only the central 1-5 degrees of visual angle (depending on the definition); peripheral vision comprises the rest of the visual field. Peripheral vision has lower acuity than foveal vision, and is represented in a more compressed form (Balas et al., 2009; Freeman and Simoncelli, 2011; Rosenholtz, 2016), so that viewers are unable to discern detailed pictorial information in peripheral vision. Hence, viewers must move their eyes over a picture to perceive detail in different parts of a picture; one function of peripheral viewing during picture viewing is to identify potential regions of interest for future fixations (Ludwig et al., 2014).

The second constraint comes from the limitations of visual memory, which include limitations on both in the number of items that can be maintained and the fidelity with which visual details are preserved (Brady et al., 2024), as demonstrated by continuous report paradigms (Figure 2A). These limitations operate rapidly and automatically: prior work has found that spatial memory becomes distorted within 50 msec of removal of the stimulus (Cohen, 2005; Werner and Diedrichsen, 2002), becoming biased toward the prototype of the category that the stimulus belongs to (Huttenlocher et al., 1991). As such, these limitations prevent the formation and maintenance of memory representations for all of the information contained in a visual scene (Hollingworth and Luck, 2008; Zhang and Luck, 2008; Luck and Vogel, 1997; Brady et al., 2011; van den Berg et al., 2012; Fougnie et al., 2012; Schurgin et al., 2020; Luck and Vogel, 2013; Bays et al., 2024).

Hence, a large body of results from the vision sciences shows that due to limitations in both peripheral vision, people do not perceive entire pictures at once. Moreover, due to limits of visual memory, people do not store mental representations equivalent to entire pictures. "Change blindness" provides a demonstration of both of these limits: viewers are often unable to detect local changes in images of scenes (Figure 2B), except when fixating on the region that changes, showing that entire pictures are not persistently stored in visual memory (Simons and Rensink, 2005). In one such study, viewers later reported having seen a picture that was actually a composite of the previously-fixated-on portions of different pictures (Martin et al., 2025). The illusion in Figure 2C provides another demonstration: details in the picture seem different when they appear in peripheral vision rather than in foveal vision, and, no matter how much one studies different parts of the picture, the illusion never fades, illustrating that human observers never store a complete mental representation of the whole picture.

Taken together, we refer to the limitations of peripheral vision and visual memory as the *Vision-Memory Bottleneck*, a limited information channel through which the artist must transmit scene and picture information to determine how to draw the next stroke. It is very easy to underestimate the limitations of peripheral and visual memory; indeed, most of the time people are not even aware of these limitations (Cohen et al., 2016; Rosenholtz, 2020; Linton et al., 2022).



A Visual Memory Continuous Report B Visual Scene Change Detection C Entanglement illusion

Figure 2: **Limitations in peripheral vision and visual memory across timescales. A:** Continuous report paradigms provide additional evidence for fundamental limitations in visual memory. In these tasks, observers view an array of items and after a brief delay must precisely reproduce a probed feature using a continuous response wheel. The distribution of response errors reveals systematic limitations: precision decreases monotonically as more items are held in memory (set size increases), and precision further declines with longer delays. These patterns demonstrate that visual memory representations are inherently noisy rather than all-or-none, with the degree of noise increasing as attentional and memory resources are taxed. Figure adapted from Brady et al. (2024). **B:** "Change blindness" demonstrations also reveal profound limitations in peripheral vision and visual memory. In these displays, two versions of a scene alternate, differing in a single prominent detail. Despite repeated viewings, observers often fail to detect even large changes unless they happen to be fixating on the changing region. This striking failure to notice changes indicates that detailed visual information outside the focus of attention is not gathererd or maintained across successive eye fixations, even when the scene remains visible. Figure adapted from Simons and Rensink (2005). **C:** The "Entanglement illusion" by Kitaoka (2019) demonstrates limitations of peripheral vision and visual memory over even the briefest timescales. The picture contains two concentric rings. When fixating on any part of the figure, the rings in peripheral vision do not appear distinct. Moreover, no matter how long one views the picture, the illusion never goes away, indicating that the entire picture is never represented in visual memory.

Taken together, the existence of the Vision-Memory Bottleneck indicates that vision, memory, and action must be tightly coordinated during drawing.

2.3 The Vision-Memory Bottleneck necessitates iterative drawing strategies

We suggest that the Vision-Memory Bottleneck can help to explain why copying is hard. At the moment when an artist[1] puts pen or pencil to paper, their next stroke must be informed by information from the source and the rest of their drawing, and the bottleneck limits how much information is available at that moment. An artist cannot simply memorize the source drawing and then draw it from memory (Figure 3A). Instead, copying a drawing requires complex, iterative strategies coordinating eye and hand movements, in order to manage and transfer information from source to target via a very limited information bottleneck. Transferring information from source to copy is a bit like transferring water between two pots with a leaky teacup: only a bit can be gathered from each dip in the source, and one must move quickly to the destination with highly-coordinated actions.

Figure 3B shows one possible way of thinking about each step of the drawing process: an artist fixates their eyes on the source, gathers a foveated visual encoding of the picture, and uses it to update a mental representation, which, together with information from prior experience, is used to plan a stroke and to draw it. This process could be repeated for each step of the drawing. During the process, the artist might also fixate locations on the drawing itself, both to update their mental representation of the drawing and to help draw the stroke. Information flow from the source to the drawing is severely limited by the information obtained from each fixation (due to limitations of peripheral vision), the limitations of working memory representations, and difficulties in planning and executing strokes. These limitations in turn make strategies for selecting fixations and drawing strokes very important. Sensorimotor skill could also limit drawing ability, although it is notable that Cohen and Bennett (1997) do find that novices have no difficulty with accurate tracing.

In order to support these assertions, we imagine various counterfactual scenarios that relax limitations of vision or memory, and argue why we might expect people to employ much simpler copying strategies in these scenarios. The fact that people generally cannot employ these simpler copying strategies indicates the importance of each of these limitations. Each of these counterfactuals generates a prediction, namely, a drawing strategy that ought to be easy without the corresponding limitation.

No pictorial memory limitation. Suppose that an artist had sufficient visual memory to accurately remember the entire source picture. Then they would have no need to look at the source picture more than once: they could commit it to memory, and never look at it again. Yet amateurs and professional artists frequently gaze at the source picture during drawing, and not being allowed to view the source image during drawing leads to the loss of details (Figure 1B (Tchalenko and Miall, 2009; Bainbridge et al., 2019).

Moreover, pictorial memory limitations affects an artist's mental representation of their own drawing. If artists could commit their drawing-in-progress to memory, and update that memory as the drawing changes, then they would have no need to study their own drawing. Yet, copying without being able to view one's own drawing leads to mismatched proportions and spatial relationships (Figure 1C). This mismatch could also be explained by difficulty in updating one's mental representation of the drawing from propioception, or mismatch between the drawing plan and motor execution. Additionally, the fact that people with aphantasia can copy pictures (Bainbridge et al., 2021; Balas, 2024) rules out conscious mental imagery as necessary for copying.

No working memory limitation. Suppose, on the other hand, that artists had limited visual memory for pictures, but effectively unlimited working memory for planning strokes. Then, while viewing the source picture, they could plan out the entire sequence of strokes in advance, store this sequence to working memory, and then execute on the drawing, without ever referring back to the source picture, or with only occasional glances to compare proportions. But, as discussed above, not referring back to the source picture leads to significantly degraded drawing accuracy (Tchalenko et al., 2014).

[1] We follow the literature in using the term "artist" to refer to individuals skilled in accurate observational drawing, and "non-artist" for those who are not. However, this terminology does not match typical use—many kinds of art do not require drawing skill (e.g., sculpture, abstract painting, conceptual art, music, film directing and acting, etc.); many people who are not professional artists can draw well.

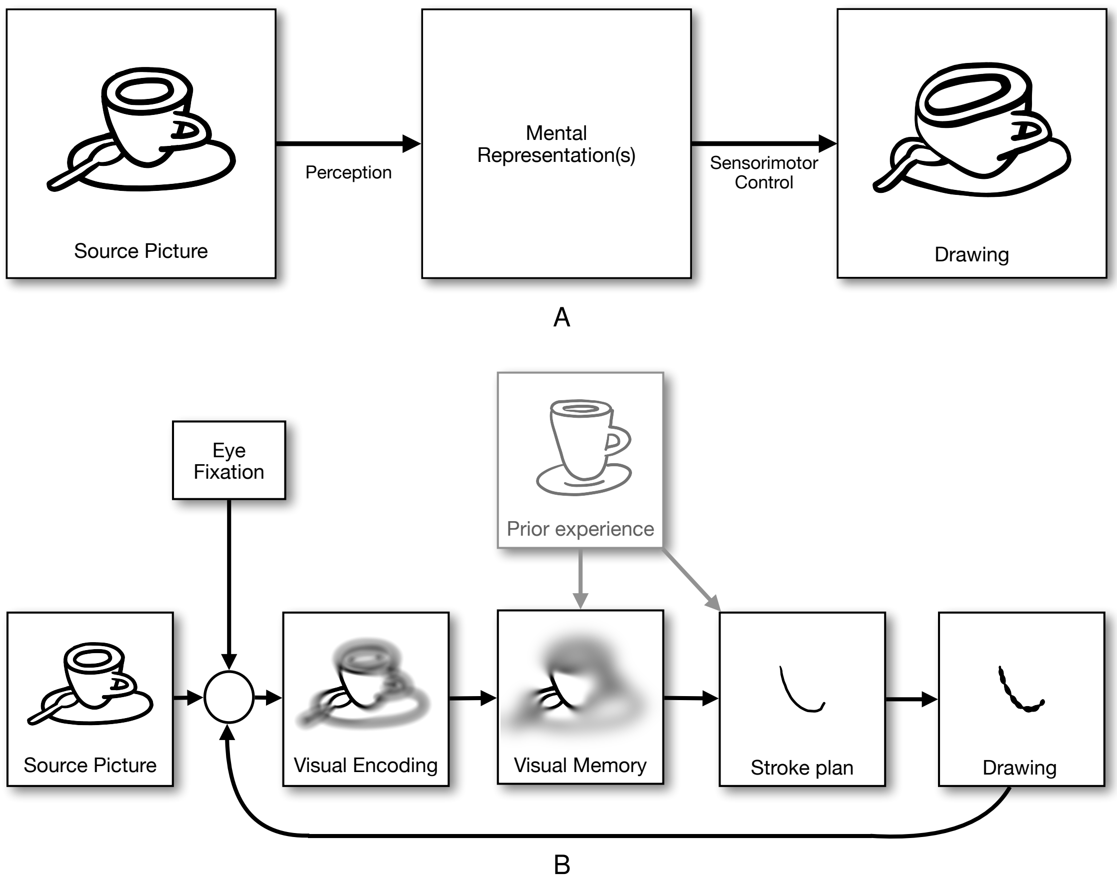


Figure 3: A: The process of copying a picture has three parts: perceiving the source, storing the perception in memory, and performing actions that result in a complete drawing. This process transfers information from the source to memory, and then to the drawing. But there may not be one single, unified mental representation, and it is unlikely that the contents of the source picture ever reside in visual memory all at once. B: Information is usually transferred piece-by-piece. During a single eye fixation, the limitations of peripheral vision and visual memory, which we refer to as *The Vision-Memory Bottleneck*, limit how much information can be transferred from the source through multiple processing stages: visual encoding, visual memory, stroke planning, and then drawing. Prior experience can also impact each of these steps. Accurate drawing of planned strokes might also require eye fixations on the drawing, further degrading visual memory representations of the source.

No peripheral vision limitations. Suppose that artists had limited visual memory, but that peripheral vision was as detailed as foveal vision. If so, then an artist's eye movements would be optional; they ought to be able to copy a picture with fixations only at the centers of the source and target pictures. Yet, artists' eye movements are tightly linked to the particular lines they are drawing at any individual moment (Tchalenko, 2007; Tchalenko and Miall, 2009; Liu et al., 2025). We predict that only allowing an artist to fixate on picture centers would likewise lead to greatly degraded drawing accuracy.

Accurate correspondence. Copying a picture requires, even if implicitly, determining some correspondence between locations in the source and the copy. If people could easily determine correspondence, then copying a picture would be a simple matter of connect-the-dots: for each stroke in the source, decompose it into a sequence of locations on the page, and then connect those locations in the copy. However, we claim that people cannot easily determine correspondences. Indeed, one exercise for copying a picture is to draw a grid over the source and target drawing, and then copy cell-by-cell; this technique externalizes the correspondence.

There are a few ways that inability to determine accurate correspondences may follow from visual limitations. For example, if visual memory were unlimited, one might be able to view the drawing while mentally superimposing the source picture. Or, if peripheral vision were more accurate, perhaps artists would be able to determine a point's location on the page more easily at a glance.

2.4 Fixation selection could explain correlations of perceptual skill with copying skill

One line of studies has argued that artists who are skilled at copying pictures also have superior perceptual skills, as measured by a battery of visual tasks including visual search, mental rotation, accurate judgments of visual illusions, and object recognition (Kozbelt, 2001; Glazek, 2012; Chamberlain et al., 2014; Drake et al., 2024). While this evidence might be used to suggest that artistic training leads to domain-general improvements in perceptual processing, existing measures and evidence find such a correlation only for some perceptual tasks, and not others (Ostrofsky et al., 2013; Chamberlain et al., 2021; Robles et al., 2022).

An alternative explanation comes from analyzing eye movements during drawing. Eye tracking studies have found that differences in eye movements correlate with copying task performance: greater copying accuracy is associated with more frequent eye movements between the source and drawing (Cohen, 2005), greater time spent looking at the source (Glazek, 2012), shorter individual fixation times, larger saccade distances, and greater variability in saccade distance (Park et al., 2022). The importance of faster fixations and more-frequent saccades may be a consequence of the severe limits that the Vision-Memory Bottleneck places on the information that can be transferred from each fixation on the source.

Based on this evidence, we hypothesize that artists select eye fixations more effectively than non-artists, in ways that aid drawing and other visual tasks. Hence, differences in eye fixations can also help to explain why previous studies found differences in performance on some perceptual tasks. For example, one study found superior performance by skilled artists on the Embedded Figures Task (Chamberlain and Wagemans, 2015), which requires locating a specific shape in a picture, and another found that skill at this task is associated with artistic training (Chamberlain et al., 2021). In such visual search tasks, performance depends on eye fixations (Rosenholtz, 2020): the viewer that fixates on the correct target location faster will solve the task faster, which depends in part on identifying promising locations in peripheral vision (Ludwig et al., 2014). Hence, improved performance on the Embedded Figures Task could be explained solely by strategies for selecting eye fixations.

Another example is shape constancy, a tendency to perceive, or to draw, shapes as less foreshortened than they are (Reith and Liu, 1995; Hammad et al., 2008). One study found correlations between shape constancy and artistic skill (Cohen and Jones, 2008), but other studies failed to replicate these results (McManus et al., 2011; Ostrofsky et al., 2012). Likewise, drawing studies have found a tendency to draw with reduced foreshortening, among both novices (Matthews and Adams, 2008), trained professionals (Schmidt et al., 2009), and historical artists (Verstegen, 2010). One possible explanation for these mixed results comes from a case study (Hertzmann, 2025) in which drawings seemed to show reduced foreshortening only when the artist worked rapidly. Hence, differences in foreshortening could be explained by drawing speed, at least in part. Drawing rapidly limits the amount of time spent looking at the source, the time spent looking at the drawing, and the frequency of eye movements between source and drawing. Indeed, when drawing, novices spend less time looking at familiar objects than unfamiliar objects, which correlates with less-accurate drawings for familiar objects (Glazek, 2012).

Conversely, studies that did not find a correlation between perceptual skill and drawing could be explained by fixation selection not being significant to the task. For example, Ostrofsky et al. (2013) did not find such a correlation in a study involving perceptual grouping when users were instructed to fixate on the center of a pattern for 150ms.

Our hypothesis does not rule out other possible perceptual advantages of artists, such as differences in the resolution of peripheral vision. It is also worth noting that similar findings appear in medical imaging: medical imaging experts show improved perceptual skills compared to novices (Wincza et al., 2025), which can be partly explained by improved eye fixation selection (van der Gijp et al., 2017). Perhaps improved skill at eye fixation selection and perceptual tasks can come from experience in many visually-focused professions or activities. Our hypothesis here is similar to that of Kozbelt and Seeley (2007), who also argue that the correlation of perceptual and artistic skill can be understood in terms of improved selection of locations to look at when viewing a scene, i.e., that learning to attend to stimulus features relevant for depiction also leads to improved perceptual performance.

3 Artists employ distinct, iterative drawing strategies

Because of the Vision-Memory Bottleneck, an artist cannot simply form a complete mental picture and then record it on the page. Instead, drawing is an iterative process. An artist continually makes decisions, whether consciously or not, to develop their drawing on the page. These decisions concern coordinated eye and hand movements, gathering information from the source, and placing potentially thousands of strokes in the drawing. The severe limitations of the Vision-Memory Bottleneck necessitates targeted eye movements to gather relevant information just as it is needed.

Given the complexity of these choices, and the limited information available for decision-making at any instant, an artist must adopt some strategy or strategies: approaches to making decisions about eye movements and strokes. We use the term "strategy" to indicate that an artist may employ qualitatively distinct approaches, often describable in words. For example, an artist might choose to draw an outline of the subject first, or they might begin by drawing significant features like eyes, nose, and mouth. These strategies may describe either how an artist conceives of their process or describe unconscious patterns in how artists work, or both. These strategies may be take time to learn and employ effectively.

Artists and non-artists often exhibit very different drawing strategies, offering, at least in part, a possible answer to the question of *what distinguishes artists from non-artists*: drawing skill requires learning effective strategies. Surveying these strategies highlights the very different approaches that may be used by different people, and the need for understanding these drawing processes. For example, artists and non-artists draw elements in different orders (Xiao et al., 2022), and select different lines for depictions (Kozbelt et al., 2010).

In this section, we discuss strategies involved in the task of copying a source drawing, photograph, or 3D rendering. We decompose strategies into several categories, such as drawing individual strokes, determining drawing order, and determining overall composition. However, many of these strategies are entangled, since one stroke decision can affect several factors at once. We also consider the role of prior knowledge (schemata) in drawing.

3.1 Drawing individual strokes

Drawing simple shapes is a visuomotor skill (Plamondon, 1995), which lies largely outside the scope of drawing strategies that we discuss here. But there are a few ways in which artists may employ distinct strategies to draw individual strokes. Artists may choose to articulate arm movements differently depending on the shape, e.g., drawing from the wrist for small strokes and from the elbow or shoulder with rigid wrist for large curves.

Both amateur and professional artists coordinate eye and hand movements in systematic ways, across a range of drawing tasks. In the simple case of drawing straight lines without a source picture, Tchalenko (2007) finds two different strategies are used, both by artists and non-artists: close pursuit, in which eye movements follow the pencil when drawing to a specific point marked on the page, and, target locking, which eye fixed on a virtually-specified target, not explicitly marked on the page.

3.2 Transferring strokes from a source picture

Gaze-shift strategies (Tchalenko et al., 2014) are used to transfer strokes in observational drawing. We can conceptualize drawing a stroke as follows. At one moment, the artist fixates their gaze on some part of the subject, such as a picture or still life. Then they fixate their gaze on their drawing, and draw a stroke near the eye fixation. At this second moment, they can no longer see the subject. This means that the artist must transfer information from the first moment to the second via working memory and visual memory.

In recordings of drawing practice, however, Tchalenko and Miall (2009); Tchalenko et al. (2014) found more complex gaze-shift strategies. Rather than discrete eye-movements-then-strokes behaviors, they observed overlapping behaviors: artists drew continuously, with eyes glancing back and forth between the source and target pictures during drawing. It is as though the artist has two separate mental processes operating in tandem: hand motions that continuously draw, and eye movements that alternate between gathering information from the source image, and looking at the hand to guide and align it. The recordings of hand- and eye-tracked drawing sessions shown in Tchalenko (2013) are particularly instructive.

What mental encodings do artists use during gaze shifts? It could be that artists directly encode pictorial imagery around a fixation. However, Tchalenko and Miall (2009); Tchalenko et al. (2014) argue that artists do not encode pictorial information, but instead encode a motor mapping, such as subsequent pencil movements. They offer two reasons. First, the simultaneity of gaze and drawing suggested a direct perception-to-motor transformation not dependent on memory. Second, in fMRI studies during a drawing task, brain activations were consistent with visuomotor mappings but not mental imagery (Miall et al., 2009). Interestingly, Perdreau and Cavanagh (2015) found that artists were better than non-artists at detecting changes to the source, indicating more-accurate mental representations of the source around fixations. Coen-Cagli et al. (2009) find that eye fixations on a source image align to drawing strokes, and suggest that hand movements that track fixations do not require working memory.

Using a visuomotor encoding seems faster and more efficient than an image representation. It is quite plausible that this is a skill that requires practice and experience to learn. Strategies vary across individuals, both as they learn, but also because people draw with different styles and techniques. Some artists are trained to draw with solid, definite lines; others draw "practice lines," moving the pencil lightly before drawing the final stroke (Miall and Tchalenko, 2001).

3.3 Determining drawing order

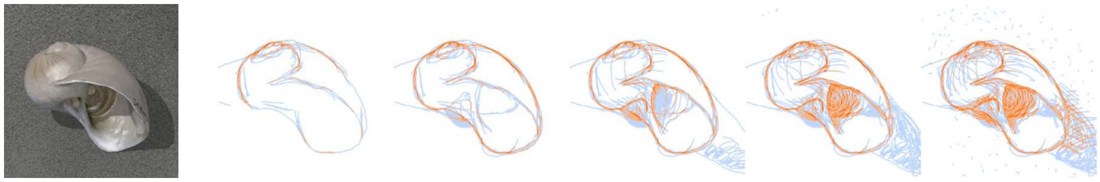
Getting good proportions in observational drawing is very hard. For novice art students, just fitting a drawing on the page is hard—they often find their drawing going far off the page, or else only occupying a tiny portion of the page. The challenge of accurate proportions is attributable to the Vision-Memory Bottleneck, which makes it difficult to judge size and shape relationships while drawing strokes, and also difficult to identify corresponding locations from source to target. For example, peripheral vision does not contain sufficient detail to simultaneously draw strokes in foveal vision, while maintaining awareness of the rest of the drawing.

Hence, an important skill to develop is to plan out a drawing, and, during the process, keep track of how the individual elements fit together into a larger composition. Many studies have found that artists first draw a rough overall sketch of the parts of a picture, and then refine details (Berger et al., 2013; Wang et al., 2021; Drake et al., 2024; Liu et al., 2025). People tend to start with outlines, but vary the order of other elements (Berger et al., 2013; Wang et al., 2021), Figure 4. Drawing order can often be summarized by a collection of procedural rules (Van Sommers, 1984) that, when systematized, can predict real drawing order more accurately than naive baselines (Fu et al., 2011; Wang et al., 2021). However, artists and non-artists tend to differ in their drawing orders (Xiao et al., 2022).

3.4 Identifying lines to draw

Photographs and 3D renderings do not directly provide lines to copy. Hence, when copying from a photo or 3D rendering, an artist must determine the lines themselves (Cohen and Bennett, 1997) (Figure 4). Effective line selection determines viewers' ability to understand shape from drawings (Cole et al., 2009).

Many lines used by artists for observation drawings can be categorized as determined by geometry, object shading, or both. Common line categories include occluding contours, creases, and hatching (Kennedy, 1974; Bénard and



A: Image prompt B: Progression of drawings over time

Figure 4: Consistency of drawing strategies, from Wang et al. (2021). A: Image prompt. Subjects were instructed to copy from the source photo by freehand drawing. B: Progression of tracing over time, averaged over multiple drawing subjects. Each figure visualized the percentage of drawing subjects that drew specific lines, with warmer colors indicating strokes drawn more frequently than those in cooler colors. Subjects show consistency in the choice of lines drawn earlier in the drawing process, focusing on outlines first, followed by fine details and shading later. (3D rendering from a fossil model by Digital Atlas of Ancient Life, CC0 1.0)

Hertzmann, 2019), and higher-order feature lines (DeCarlo, 2012) like suggestive contours (DeCarlo et al., 2003), and construction lines (Gryaditskaya et al., 2019). Identifying these lines from a photograph generally requires experience and is difficult to explain in simple language (as opposed to differential geometry).

It is tempting to predict that artists draw at shading gradients, since applying edge-detection to a photograph often produces a drawing-like image. But shading gradients on arbitrary photographs are a poor general predictor of line drawings, and vision is sensitive to other features besides edges (Sayim and Cavanagh, 2011; Hertzmann, 2021). For smooth surface outlines, the most-effective simple predictions are based on shading gradients for simplified-shading versions of the imagery (Cole et al., 2008; Wang et al., 2021), which can be explained in terms of real-world perception (Hertzmann, 2020) of abstracted shading (Pearson and Robinson, 1985; DeCarlo et al., 2003; Lee et al., 2007; Goodwin et al., 2007), whereas other lines can be explained in terms of cultural conventions (Hawkins et al., 2023). When drawing faces, people tend to draw similar sets of common facial features: eyes, nose, etc. (Berger et al., 2013).

When the set of lines is pre-specified, but artists are only allowed to select a subset of them, artists perform better than non-artists at selecting lines for accurate depiction (Kozbelt et al., 2010; Ostrofsky et al., 2012).

3.5 The role of prior knowledge in drawing strategies

If you know how things look—or how they could plausibly look—then you might study them differently when attempting to draw them. Hence, prior knowledge of typical object structure and appearance can replace careful observation, thereby helping to save time and effort and compensating for the Vision-Memory Bottleneck. A simple example of such useful knowledge is that a person's eyes normally lie halfway from the top to the bottom of their head; awareness of this fact can improve drawing quality (Ostrofsky et al., 2016). However, such *schemata* or knowledge of *prototypes* (Gombrich, 1961; Van Sommers, 1984; Cohn, 2012; Chamberlain and Wagemans, 2016) can also sometimes reduce drawing quality.

Schemata used during drawing might encompass everything from individual techniques and behavioral patterns, to formal knowledge and conceptual models, from two-dots-and-a-line for smiley faces to fine-grained knowledge of the musculoskeletal structure of the human body. Prior knowledge may come to short-term memory from long-term memory in a variety of ways, including conceptual knowledge from derived from long-term memory (Potter, 2012), recognition of familiar object classes (Schurgin, 2018), and improved working memory capacity for familiar categories (Asp et al., 2021).

For realistic drawing, schemata could accelerate sub-tasks that would normally be slow and cumbersome due to the Vision-Memory Bottleneck, for example:

1. When drawing an individual shape, a schema may allow one to draw a shape without looking back at the source as frequently. If an artist recognizes that a shape looks like a circle, they may remember it as a circle rather than trying to capture it as separate arcs. An artist may break objects into standard sets of parts, for example, copying a house by separately copying the doors, windows, and outline. Artists may also build conceptual

models "on-the-fly," based on recognizing some individual component shapes and their relationships, rather than explicitly representing each individual curve. As already discussed, shape constancy in drawing can be explained as a tendency toward more-canonical representations when drawing with less-careful observation.

2. People may employ production scripts for drawing specific object classes (Cohn, 2012), such as depicting people with stick figures by always starting with the head and then the torso. Such scripts embody techniques for depicting specific object classes.

3. Finally, schemata may allow an artist to review their drawing and identify problems without having to compare to the source. Knowing that a person's eyes normally lie halfway between the top and bottom of their head provides a simple and easy "check" an artist can make to evaluate their drawing without a series of visual comparisons to the source.

The use of schemata likely differs depending on drawing goals, say, for a professional painter producing highly accurate and detailed imagery, as opposed to a cartoonist producing highly-stereotyped imagery by reusing a small set of visual elements.

Schemata are sometimes described as unhelpful, because they can bias drawings toward conventional representations rather than accurate ones, e.g., drawing a face as a circle with two dots and a line. Conventional wisdom asserts that non-artists do not draw well because they "draw what they know, not what they see" (Luquet, 1927; Freeman and Janikoun, 1972); novices' drawing accuracy decreases for familiar objects (Glazek, 2012). But the complexity and range of different types of schemata, and their different uses means that we should avoid simple attempts to determine if schemata overall are "helpful or unhelpful." It seems more useful to pose a tradeoff between observation and prior knowledge: drawing from observation requires more time, skill, and focus. Indeed, prior knowledge can make drawing easier and faster, but at the risk of more-inaccurate depiction.

Relatively little is currently known about what experiences lead artists to acquire the full suite of schemata they use, or how their use of different schemata changes as they become more proficient. Most likely, it may be a combination of factors, including experimenting with different techniques, observing patterns in drawings, and learning techniques from formal training or textbooks. As artists become more proficient, it may be that they learn general representational strategies that allow discarding schema. Or perhaps they gather a "bag of tricks," a large collection of techniques to be separately deployed effectively in many different situations. Kozbelt and Seeley (2007) argue that artists develop motor plans from extensive practice, improving their problem-solving abilities and organizing procedural knowledge along the way.

Categorizing and understanding the roles of different types of schema, how they change over artistic training and experience, and how they are used in different situations, represents a broad and challenging research challenge.

4 Discussion: Toward Ecologically-Valid Drawing

Prior work on observational drawing has focused on two main questions, in the context of copying tasks: Why is drawing hard? And what distinguishes artists from non-artists? Here we have argued that the difficulty of copying tasks arise from the severe limitations in peripheral vision and visual memory, which constrain how much information about a source picture can be transferred to the target drawing at any point in time. As a consequence of the Vision-Memory Bottleneck, artists adopt different strategies to compensate and manage information flow through the bottleneck, ones that depend on learning and expertise.

For future studies, we advocate for studying the strategies and techniques used by artists. Much of this analysis can be performed by recording observable behaviors, including eye movements, hand movements, and/or strokes drawn over time (Van Sommers, 1984; Berger et al., 2013; Tchalenko et al., 2014; Wang et al., 2021; Drake et al., 2024; Liu et al., 2025), and annotating behaviors (Suwa and Tversky, 1997; Kantrowitz, 2014) and stroke types (Cole et al., 2008; Berger et al., 2013; Gryaditskaya et al., 2019; Xiao et al., 2022; Liu et al., 2025). Analyzing these behavioral traces can allow us to build phenomenological models of how various strategies commonly used by artists give rise to different outcomes. Comparisons with drawing instructional texts and artists' own descriptions of their processes could further enrich these models. Empirical studies of drawing processes could also help to reveal what distinct strategies artists

Figure 5: Blind drawing from life shows similar phenomena as in blind copying of a drawing (Figure 1(c)). Here the hairline was drawn much later than the eyes, and intersects the eyes instead of being above them. Moreover, relative facial proportions are often mismatched.

use to select eye movements to gather visual information (Kozbelt and Seeley, 2007). Furthermore, when combined with interviews, such studies could shed light on the metacognitive processes that determine which drawing strategies artists use at different stages of the drawing process, such as when initially studying a subject or evaluating the quality of a drawing-in-progress. Finally, they might advance understanding of how the use of various drawing strategies vary as a function of training and experience.

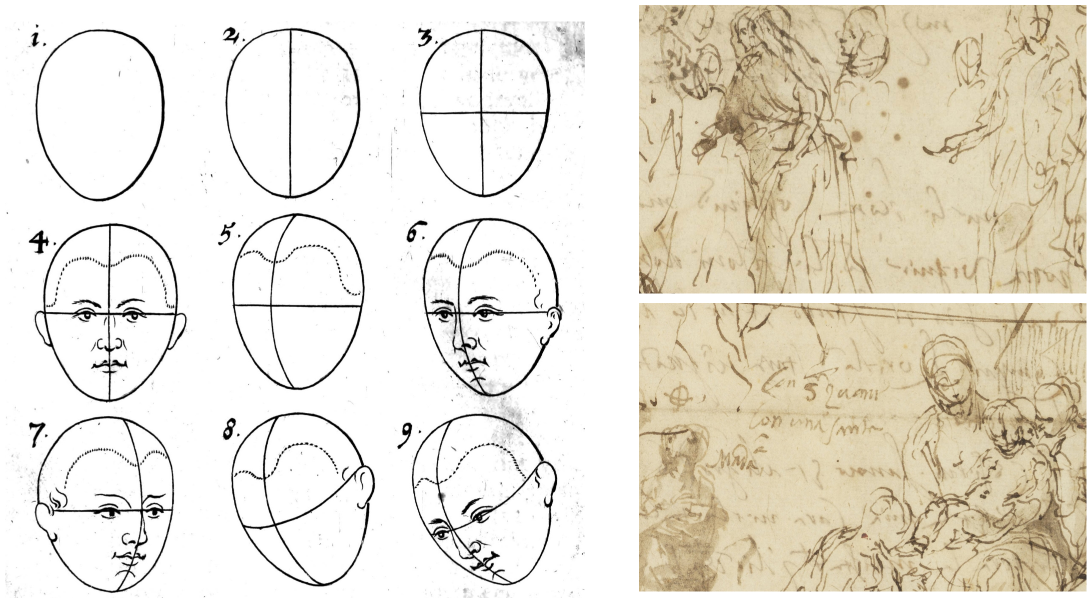
Copying tasks allow us to study some of the fundamental skills that are engaged when drawing from observation, while factoring out the complexities of viewing real-world scenes. However, copying from a source picture is, itself, an artificial task (Tchalenko et al., 2014); it is hard to imagine a common real-world situation where a professional artist or designer aims to precisely replicate a reference picture by freehand drawing. To make a precise copy, one can simply trace over a picture, or take a photograph.

Hence, we advocate for further study of ecologically-valid drawing tasks, including drawing from life. Drawing from life—rather than from other pictures—is one of most important activities in art history and art education. Drawing from life takes many forms, including drawing still lives (e.g., flowers or fruits), drawing live models (including portraits), and outdoor (*plein air*) drawings (such as landscapes and cityscapes). Drawing from life also adds many important challenges, including selecting a subject, forming a composition on the page, integrating information from parallax and binocular vision, and depicting shape and space, e.g., (Hertzmann, 2025). Fortunately, much of the evidence from copying tasks can generalize to ecologically-valid tasks; as one bit of evidence, observe that blind drawing from life can create the same kinds of distortions (Figure 5) as blind copying (Figure 1C).

It is worth studying how approaches vary between different kinds of artists and designers; architects, designers, and fine artists are all trained in drawing in very different ways, and may each be quite skilled at their crafts, with very different drawing skills. Some strategies may be shared between different drawing tasks, whereas others may vary.

One broad class of strategies are constructions. For example, a simple technique for drawing a person's head orientation is to draw an oval with a cross in it (Figure 6); more complex scaffolding can be drawn for full-body poses, whether in life drawing (Loomis, 1956; Gombrich, 1961) or comics (Lee and Buscema, 1984). Industrial designers use sophisticated construction techniques to design new products (Gryaditskaya et al., 2019). Perhaps the most well-known class of construction techniques is perspective drawing, such as one-point perspective (Kemp, 1990). This strategy produces compelling drawings, when used selectively (Elkins, 1994; Burleigh et al., 2018; Kemp, 2022).

An artist may aim toward many distinct goals in drawing, including capturing some aspects of visual experience; aesthetic appeal; creativity and exploration (Warburton, 2003; Kantrowitz, 2014), and problem solving (Suwa and Tversky, 1997). Different artists' goals may significantly affect their drawing processes and styles. Note that judging life drawings merely by how well they match photographs (Carson et al., 2021) fails to account for the ways that photographs fail to capture visual experience (Pepperell, 2015; Albert and Efros, 2016; Koenderink et al., 2016; Burleigh et al., 2018; Hertzmann, 2025), and may not achieve other goals of drawing as well.



A B

Figure 6: To draw a person's head, one effective technique is to first draw an oval, and then a cross for the facing direction (Gombrich, 1961, p. 168). Facial details can then be drawn. A: The technique illustrated by Willem Goeree, 1668, in *Inleydingh tot de practijck der al-gemeene schilder-konst*. B: The technique used by Paolo Veronese in two details of *The Mystic Marriage of Saint Catherine and other studies*, c. 1568.

Finally, we hope that a better understanding of the skills involved in drawing could help more people learn to draw. Cohn (2012, 2014) offers evidence that drawing skill is a matter of education, and that the widespread sentiment of "I can't draw" derives from cultural and educational misconceptions. Several acquaintances of the authors have worked from books of drawing exercises, including Edwards (2012); Loomis (1956), or taken a drawing class, and went from saying "I cannot draw" to "Wow, I drew that?"

The effectiveness of drawing exercises requires explanation beyond the psychological folk theories with which they are sometimes presented, e.g., (Edwards, 2012). For example, one exercise entails copying a picture upside-down, which is claimed to increase drawing accuracy (Edwards, 2012). Formal studies found that this exercise made little or no improvement to drawing accuracy (Cohen and Earls, 2010; Kozbelt et al., 2010). But this exercise may nonetheless be beneficial to students, by helping them practice drawing without reliance on schemata, or it may simply provide new students with encouraging initial experiences, helping to overcome self-criticism and anxiety about drawing. A clearer understanding of the skills required for drawing could lead to a more focused selection of exercises and feedback. Improving art education could help unlock the creative potential of this medium for more people.

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