DRAWING THE SPATIAL RELATIONSHIPS BETWEEN THE FEATURES COMPOSING A HUMAN FACE:

OBJECTIVELY MEASURED ERRORS AND EVALUATIONS OF PERCEPTION-BASED AND MEMORY-BASED THEORETICAL ACCOUNTS OF DRAWING ACCURACY

by

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ABSTRACT

Drawing the Spatial Relationships Between the Features Composing a Human Face: Objectively Measured Errors and Evaluations of Perception-Based and Memory-Based Theoretical Accounts of Drawing Accuracy

by

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A series of studies is described, which aims to understand the psychological factors associated with the accuracy of observational drawings of the spatial relationships between the major features found in a face. Study 1 presents an objective measurement scheme that quantifies drawing errors for multiple spatial relationships. Results reveal that the errors in drawing multiple spatial relationships were reliably biased in single directions, such as drawing the face too round, the eyes too far up the face, and the nose too narrow. Study 2 aimed to determine if a major source of such errors involves how the spatial relationships between facial features are represented in long-term memory. Results showed that long-term memory representations of such spatial relationships contain systematic directional biases that are similar to those observed in an observational drawing task. Further, several spatial relationships in a memory-based drawing task reliably predicted their depiction in an observation-based drawing task, suggesting that observational drawing performance is partially guided by top-down processing of information in long-term memory. Study 3 evaluated whether misperception of the model stimulus contributes to the production of drawing errors. Participants observationally drew images of upright and rotated faces. As with patterns of perceptual error, participants erred more in drawing the vertical position of the eyes in upside down faces relative to upright faces; no such effect was observed for drawing the inter-ocular distance. Also similar to patterns of perceptual error, participants erred more in drawing the vertical position of the eyes in 90 degree rotated faces compared to upright faces. However, the finding that the inter-ocular distance was drawn more accurately for 90 degree rotated faces relative to upright faces contrasts with previous findings that the inter-ocular distance is perceived less accurately in 90 degree rotated faces. These studies demonstrate the benefits of complementing subjective accuracy ratings with objective measurements of drawing errors in research investigating the psychological processes associated with drawing performance. Unlike subjective ratings of drawing accuracy, objective measurements allow analyses of specific drawing errors, including allowing one to determine the specific types of drawing errors that are affected by experimental manipulations and that are predicted by performance in non-drawing tasks.

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1. General Introduction

The production of drawings is a behavior spanning most of human history, as evident by the discovery of the paintings found in the Chauvet Cave in France and the El Castillo Cave in Spain, which have been dated to be approximately 32,000 and 40,000 years old, respectively (Clottes, 2003). Additionally, drawing is a behavior produced throughout most of the human lifespan, as most children draw as early as age two, and often even younger (Kellogg, 1970), and many motivated adults continue to produce visual art into old age. Further, the behavior of drawing is a culturally valued behavior for both aesthetic and communicative purposes. This is evident by the fact that many paintings have been sold for millions of dollars, by the existence of many kinds of draughtsman professions, and by the strong presence of required drawing/painting instruction in the United States' elementary and high school education systems (U.S. Department of Education, Institute of Education Sciences, 2012). Thus, drawing is a universal and important human behavior.

In addition to its cultural significance, drawing is also scientifically significant from a psychological perspective. Developmentally, drawing is a skill that is acquired over time. For typical young children, drawing begins with non-representational scribbles early on and progresses through stereotyped stages into productions of more sophisticated depictions of recognizable objects and scenes (Kellogg, 1970). In the case of adults, continued formal and extensive training in drawing can lead to the development of highly skilled performance that is not typically acquired in adults who do not engage in such training (e.g., Kozbelt, 2001), indicating that learning is an essential component of drawing. With respect to cognition, drawing is a highly complex behavior requiring multiple stages of information processing, such as: (1) the perceptual and attentional processes relating to the encoding of the objects being drawn

(Ostrofsky, Kozbelt & Seidel, 2012), (2) memory processes that aid drawing when a model is not directly observable (Loring, Martin, Meador & Lee, 1990; Matthews & Adams, 2008), (3) motor processes that allow the hand to execute intended marks (Cohen & Bennett, 1997) and (4) decision-making processes that guide the sequence of marks made in the drawing and support the evaluation and/or modification of the emerging drawing (Cohen & Bennett, 1997; Kozbelt, Seidel, ElBassiouny, Mark & Owen, 2010).

Despite the broad scope of psychological issues related to drawing production, this behavior has been a largely ignored topic of empirical inquiry for the vast majority of the history of psychological science, particularly with respect to the study of adult drawing[1]. However, in the last 15 years or so, there has been a dramatic increase in the number of empirical investigations that have focused on understanding drawing production in normal adults (e.g., Chamberlain, McManus, Riley, Rankin & Brunswick, 2013; Cohen & Bennett, 1997; Cohen & Earls, 2010; Cohen & Jones, 2008; Glazek, 2012; Kozbelt, 2001; Matthews & Adams, 2008; Mitchell, Ropar, Ackroyd & Rajendran, 2005; Ostrofsky, Kozbelt & Cohen, submitted; Ostrofsky et al., 2012; Perdreau & Cavanaugh, 2011; Tchalenko, 2009). Specifically, this research has focused on the topic of *observational drawing*, the behavior where individuals attempt to copy as accurately as possible the visual information inherent in a directly perceivable model stimulus (most commonly, a photograph), with little-to-no emphasis on creative or aesthetic factors. The vast majority of observational drawing research has concerned itself with understanding the psychological mechanisms associated with the large individual variability in the ability to draw an accurate reproduction of a model. Unsurprisingly, this research has

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[1] As one exception to this statement, there is a relatively large literature considering the drawings of neurologically impaired adults. As reviewed by Chatterjee (2004), this research mostly concerns itself with understanding specific types of drawing deficits associated with a wide array of neurological disorders.

repeatedly shown an expertise effect, where trained visual artists produce more accurate observational drawings than untrained non-artists (e.g., Cohen, 2005; Glazek, 2012; Kozbelt, 2001; Ostrofsky et al., 2012). As this research (and everyday experience) can attest to, most individuals who lack extensive training and practice in drawing perform poorly on the task of accurately depicting an observed model. The focus of much of the research on drawing conducted to date has aimed to determine the cognitive factors that contribute to the production of non-artists' error-laden drawings, and relatedly, the information-processing factors that develop alongside the acquisition of sophisticated drawing ability in highly skilled trained artists.

This dissertation is a continuation of the effort to understand the psychological processes contributing to the presence of errors in the drawings produced by non-artists. Throughout the remainder of this document, all references to drawing, unless otherwise noted, is narrowly conceptualized as the behavior of observational drawing. Further, all references to ability or skill is specifically related to the degree of accuracy of copying information inherent in a model stimulus without any consideration of potentially interesting creative or aesthetic factors related to drawing. In the following sections of this general Introduction, I will provide a brief review of the empirical literature to date related to this topic. Specific emphasis will be made on organizing these findings around what I see as the two dominant theoretical accounts that relate to understanding drawing ability, namely, what I term the *perception-based* and *memory-based accounts*.

1.1 The Perception-Based Theoretical Account of Drawing Ability

1.1.1 Theoretical Principles.

The perception-based theoretical account of adult drawing ability generally holds that drawing accuracy is largely determined by the degree of accuracy with which an individual perceptually encodes the model stimulus being drawn (Cohen & Bennett, 1997). This idea is rooted in the well-established idea that everyday perceptual processes do not result in a veridical representation of the light-patterns reflected off objects and detected by retinal photoreceptors (e.g., Gregory, 1997; Rock, 1997). Rather, the visual system makes complex computations on visual input, which often results in transformed perceptual representations of the retinal pattern of stimulation. Because any given pattern of light entering the eye could theoretically be generated from an infinite number of different objects (the *inverse-projection problem* of vision), some have argued that statistical inferential processes biased by previous experience are at the heart of these computations (e.g., Howe & Purves, 2005, Purves & Howe, 2005). Such computations aim to infer the actual structure of the objects that are being perceived rather than consciously reproducing a particular pattern of retinal stimulation. Clear demonstrations of inferential perceptual processes come in the form of the many perceptual constancies (such as those related to size, shape, color and brightness perception) and visual illusions (such as the famous Muller-Lyer, Ebbinghaus Circles, horizontal-vertical and Ponzo illusions) that are widely experienced by individuals to varying degrees.

According to the perceptual-based theoretical account, since observational drawing is a visually-guided behavior, a consequence of the above-mentioned principles is that the transformations of visual input that produce non-veridical perceptual representations should also result in drawings that deviate from the specific appearance of the model being reproduced (Cohen & Bennett, 1997; Cohen & Earls, 2010). For instance, individuals who perceive stimuli that induce a size constancy effect should also show evidence of a size constancy effect in their drawings. That is, an individual who perceives an object set at a relatively far perceived distance to be larger than it appears should additionally draw the object as larger than it appears. Thus, according to this perspective, a major source of the reproduction errors present in a drawing is the misperception of the actual, viewpoint-specific appearance of a model stimulus.

Following this, improvements in drawing ability throughout development are hypothesized to coincide with improvements in the ability to perceptually encode the actual appearance of the model being drawn (Cohen & Jones, 2008). Here, individual variability in drawing ability is thought to be tightly related to individual variability in perceptual ability. Consequently, highly skilled artists capable of producing highly accurate drawings are predicted to have advantages in perceptual processing ability (from the standpoint of accurately perceiving the appearance of a stimulus) relative to non-artists, who reliably create inaccurate drawings.

Thus, the perceptual-based theoretical account (throughout the remainder of the document referred to as the *misperception hypothesis*) proposes that drawing ability can largely be explained by understanding the ability, or lack thereof, to veridically perceive visual stimuli. The misperception hypothesis has inspired many empirical studies aiming to test one or both of its two most general empirical predictions, which hypothesize that: (1) a stimulus that causes a specific pattern of perceptual error should additionally cause a congruent pattern of drawing error, and (2) the degree of one's ability to accurately perceive a visual stimulus reliably predicts the degree to which one can accurately draw a model stimulus from observation. In the following section, I will review the findings generated by such studies.

1.1.2 Empirical Evidence Pertaining to the Misperception Hypothesis.

As stated above, one of the central predictions of the misperception hypothesis is that there should be a congruency in the patterns of error in perceiving and drawing a given stimulus. In other words, the direction of errors caused by the visual system's transformation of the bottom-up visual stimulus should be similar across performance in perceptual and drawing tasks. This prediction has been previously tested with respect to the perception and drawing of relative line-length (Mitchell, Ropar, Ackroyd & Rajendran, 2005) and angles (Ostrofsky et al., submitted). With respect to relative line-length, Mitchell and colleagues (2005) utilized the well-known Shepard Illusion (Shepard, 1990). When one is presented with two identically-sized parallelograms side-by-side in different orientations, vertically oriented lines are perceptually judged to be longer than horizontally oriented lines of equal length. Further, the illusion that vertically oriented lines are longer than their equal-in-length horizontal counterparts is exaggerated when the parallelograms are presented as tabletops with legs attached to the corners. Since visual information concerning line length is computed in such a way as to result in this systematic pattern of perceptual judgment errors, the misperception hypothesis of drawing predicts that drawing errors of line length should follow this same pattern.

In order to test this prediction, Mitchell and colleagues (2005, Experiment 2) presented participants with Shepard Illusion stimuli (either with or without the contextual cue of table legs) and asked them to draw the two models as accurately as possible. Since relative line length is an unambiguous property of drawing accuracy, the researchers were able to objectively quantify drawing error by simply measuring the lengths of the reproduced lines composing the parallelograms. After the drawings were complete, the researchers asked the participants to verbally estimate the lengths of the vertical and horizontal lines in each model in order to get a measurement of perceptual judgment. The results indicated that subjects experienced the classic illusion in their perceptual judgments. In contrast, drawing errors exhibited the classic illusion pattern only in the contextual-cue condition. When participants drew the plain parallelograms, vertical and horizontal lines of equal length were not drawn at significantly different lengths. Consistent with these results, perceptual and drawing errors were positively correlated in relation to the contextual-cue models, but not significantly correlated for the plain parallelogram models. These results suggest computations made on visual information guiding perceptual judgments and drawing behavior, at least in relation to line length, are only similar when model stimuli contain 3-D contextual cues, but not when contextual cues are absent in model stimuli.

Using the same methodological strategy, Ostrofsky and colleagues (submitted) tested the misperception hypothesis with respect to the perception and drawing of angles. Two angle illusions were used, only one of which was one produced by the processing of 3-D depth cues. The 3-D depth cue-induced angle illusion was the *shape constancy effect* (Hammad, Kennedy, Juricevic & Rajani, 2008), whereby angles embedded in stimuli that appear as 3-D cubes are perceptually judged to be closer in size to 90 degrees than identically sized angles embedded in stimuli that appear as plain, 2-D parallelograms. The other angle illusion was the *isosceles-scalene triangle illusion* (Kennedy, Orbach & Loffler, 2008), whereby angles embedded in scalene triangles are perceptually judged to be smaller than identically sized angles embedded in isosceles triangles. Ostrofsky and colleagues tested the misperception hypothesis by presenting two samples of participants (one for each of the illusions) angles embedded in cube versus parallelogram stimuli in one experiment and angles embedded in isosceles and scalene triangle stimuli in another experiment. Across both experiments, participants were asked to make a perceptual judgment and a drawing of the target angle with the goal of reproducing the exact size of the angle. In both experiments, there was a strong degree of congruence in the patterns of error in the perceptual judgment and drawing tasks. That is, participants both perceptually judged and drew the size of a given target angle to be closer to 90 degrees when embedded in cubes than when identically sized target angles were embedded in parallelograms. In addition, participants both perceptually judged and drew the size of a given target angle to be smaller when embedded in a scalene triangle compared to when an identically sized target angle was embedded in an isosceles triangle. Further, the magnitude of participants' experience of these illusions was reliably correlated across performance in the perceptual judgment and drawing tasks for both illusions. These results suggest that there are transformative computations made by the visual system on angle-based information that affect the processing of information guiding both perceptual judgments and drawing performance.

Interestingly, whereas Mitchell and colleagues (2005) found a dissociation in the perception-drawing relationship between line-length illusions that did or did not involve the processing of 3-D depth cues, Ostrofsky and colleagues (submitted) found no such dissociation for angle illusions. Thus, there is some evidence that is consistent with the proposition that, regardless of whether 3-D depth cues are present are not, a major source of drawing errors is the misperception of the model stimulus, as systematic patterns of drawing error are associated with and predicted by congruent patterns of perceptual error.

Even though Mitchell et al. (2005) and Ostrofsky et al. (submitted) found evidence largely consistent with the idea that that individuals who made smaller drawing errors also experienced smaller perceptual errors for relative line-length- and angle-based visual information, another question raised by the misperception hypothesis is whether there are more general perceptual advantages enjoyed by individuals with stronger drawing ability relative to those with comparably weaker drawing ability. That is, do more skilled drawers perceptually encode stimuli more accurately than do less skilled drawers, with respect to performance in tasks not directly related to drawing?

Two general methodological strategies have been employed to date that have served to generate evidence bearing on this question. The first methodological strategy has involved participants engaging in unrelated perceptual and drawing tasks (Chamberlain, et al., 2013; Cohen & Jones, 2008; Drake, 2013; Kozbelt, 2001; Ostrofsky et al., 2012). Generally, these studies test for positive correlations between performance accuracy in the drawing and perceptual judgment tasks in order to determine if more skilled drawers show advantages on the perceptual task relative to less skilled drawers. Such findings are assumed to suggest that drawing ability is supported by the degree of accuracy in veridically perceiving visual stimuli. One such study is Cohen and Jones (2008). Here, participants produced a drawing based on a model photograph of a face and completed a perceptual matching task assessing the degree to which participants experience the shape constancy effect. Results revealed that subjective judgments of the perceived accuracy of the face drawings were negatively correlated with errors produced in the shape constancy task, indicating that the more accurate participants perceptually encoded shape-based information, the more likely they were to produce a drawing that was rated to be a more accurate reproduction of the model face. Similarly, Ostrofsky et al. (2012) had participants produce a drawing of a model photograph of an octopus and complete a perceptual adjustment task measuring size constancy and, like Cohen and Jones (2008), found a negative correlation between size constancy errors and perceived drawing accuracy was observed. This indicates that more accurate perceptual encoding of size-based information predicted stronger drawing accuracy. Since these studies administered drawing stimuli not obviously related to the stimuli used in the perceptual tasks (Cohen & Jones, 2008 – face photograph drawing task stimuli and window photograph perceptual task stimuli; Ostrofsky et al., 2012 – octopus photograph drawing stimuli and CGI sphere perceptual task stimuli), the positive correlations between drawing and perceptual performance suggest that stronger drawing ability is associated with a stronger general ability to perceive the veridical appearance of stimuli and to suppress processes resulting in perceptual transformations.

Another methodological strategy used to determine whether ability in drawing is related to more general-level perceptual advantages has involved comparing experts (trained artists) to novices (untrained non-artists) in performance in perceptual tasks not directly related drawing (Carson & Allard, 2013; Chamberlain, et al., 2013; Cohen & Jones, 2008; Gaines, 1975; Kozbelt, 2001; Ostrofsky et al., in press; Ostrofsky et al., 2012; Perdreau & Cavanugh, 2011; Thouless, 1932). Such studies look for an expertise effect, where artists show better perceptual performance than non-artists, to support the claim that skill in drawing is related to general-level perceptual advantages. Evidence that has been generated by such studies has resulted in mixed evidence in support of the claim that trained artists, on average, more accurately perceive visual stimuli than non-artists. On the one hand, it has been found that relative to non-artists, trained artists have been shown to better suppress size and shape constancy effects (Ostrofsky et al., 2012; Thouless, 1932), to be more field independent (Gaines, 1975) and have a stronger ability to recognize out of focus photographs of objects, incomplete images of objects, and segmented objects in the Group Embedded Figures Task (Kozbelt, 2001). On the other hand, despite the above-reported evidence that artists better suppress perceptual constancy processes and perform better in the Group Embedded Figures Task, other evidence has been reported which shows no expertise effect relating to shape and size constancy (Cohen & Jones, 2008; Perdreau & Cavanaugh, 2011) and Group Embedded Figures Task performance (Chamberlain, et al. 2013).

Such discrepant findings indicate that these expertise effects may not be particularly robust over different forms of measurements of these effects (e.g., over different stimuli, task demands, samples, etc.). Other studies have shown that, relative to non-artists, trained artists do not experience brightness constancy to a lesser degree (Perdreau & Cavanaugh, 2011), do not make more accurate perceptual judgments of angle size (Carson & Allard, 2013), do not experience advantages in basic-level perceptual grouping ability (Ostrofsky et al., in press), do not show advantages in visual search abilities (Perdreau & Cavanaugh, 2011), and do not show advantages in local processing ability as measured by the Navon and Block Design Tasks (Chamberlain, et al. 2013). Thus, as a whole, the evidence is generally weak with respect to supporting the claim that the skill in drawing displayed by trained artists, as a whole, is accompanied by general-level advantages in veridically perceiving bottom-up visual information.

With respect to general-level perceptual processing advantages, it seems that drawing ability, but not necessarily drawing experience/training, may be related to advantages in general-level perceptual processing. When assessed directly through correlational analyses testing for a relationship between drawing accuracy and perceptual performance, there have been many cases where perceptual performance has predicted drawing performance (Chamberlain et al., 2013; Cohen & Jones, 2008; Kozbelt, 2001; Ostrofsky et al., 2012). In contrast, when drawing ability has been assessed indirectly through degree of experience and training, the evidence generally suggests that there are no group-level expertise effects in general-level perceptual performance (Carson & Allard, 2013; Chamberlain et al., 2013; Cohen & Jones, 2008; Ostrofsky et al., in press; Perdreau & Canvanaugh, 2011). This may indicate that group-level comparisons between artists and non-artists are too indirect a measure of drawing ability, as some non-artists may be able to draw very well and some self-identified artists may not be able to draw well, despite their training. This claim is consistent with studies that have administered a single perceptual judgment task and found no difference in perceptual performance between groups of trained artists and non-artists while simultaneously finding reliable correlations between measures of drawing accuracy and perceptual performance across all participants (Chamberlain, et al. 2013, Cohen & Jones, 2008).

1.1.3 Summary.

Multiple sources of evidence generally support the claim that one major psychological factor that is related to drawing ability is the degree to which individuals accurately perceive the stimuli that they are drawing. Systematic patterns of error that are associated with the perception of a given set of visual stimuli have also been found in the drawings of the same stimuli (Mitchell et al., 2005; Ostrofsky et al., submitted), suggesting that perceptual transformations of visual information affect drawing performance. Further, drawing ability is positively correlated with multiple measures of perceptual performance accuracy, suggesting that stronger drawing ability is associated with more accurate perceptual encoding of visual stimuli at a general level. Thus, many adults may find it difficult to create accurate drawings because they misperceive the bottom-up visual information inherent in a visual model stimulus. Lastly, drawing skill and the ability to accurately encode veridical properties of visual stimuli appear to share a developmental trajectory.

1.2 The Memory-Based Theoretical Account of Drawing Ability

1.2.1 Theoretical Principles.

The memory-based theoretical account of adult drawing ability generally holds that drawing performance is influenced by the processing of information stored in long-term memory that has been acquired before a given drawing task begins (Cohn, 2012; Gombrich, 1960; Kozbelt & Seeley, 2008). Everyday experience strongly suggests the existence of stored long-term memories of graphic-based information that represents how to draw common objects. This is evident by the fact that normal adults are capable of drawing, to varying degrees of quality, common objects from memory without the guide of a directly perceivable model stimulus. Further evidence of the existence of specialized long-term memories that are specific to representing how to draw common objects (as opposed to mental imagery-related memories representing the appearance of common objects) comes from a study of a neurological patient who was severely impaired in his ability to draw common objects from memory. This impairment was accompanied by a normal ability to generate and operate on mental images and produce quality observational drawings of a directly perceivable model stimulus (Trojano & Grossi, 1992).

The sparing of the ability to observationally draw common objects in this patient suggest that observational drawing and memory-based drawing are supported by functionally specialized, independent mechanisms. However, the memory-based account of drawing accuracy proposes that in neurologically normal adults, mechanisms supporting memory-based and observation-based drawing performance interact with one another during the production of an observational drawing. Here, when attempting to reproduce a directly perceivable model stimulus, drawing performance is argued to be influenced by bottom-up visual information inherent in the model stimulus and top-down information inherent in stored long-term memories. Some theorists have argued that the processing of information stored in long-term memory is a major cause of drawing errors and something to be overcome in the development of drawing skill (e.g., Edwards, 1979; Glazek, 2012; Ruskin, 1857). According to this perspective, trained artists draw better than untrained non-artists because they have developed the ability to suppress the activation of graphic-based knowledge during observational drawing production, and thus, are primarily guided by the processing of the bottom-up information inherent in the model stimulus. In contrast, other theorists argue that skilled and unskilled drawers alike are equally influenced by the processing of information in long-term memory (e.g., Cohn, 2012; Gombrich, 1960; Kozbelt & Seeley, 2008). According to this perspective, trained artists produce more accurate observational drawings than non-artists because they have acquired through training long-term memories that are more sophisticated and accurate representations of the graphic-based properties of common objects. Despite the disagreement in the role of memory representations in the development of drawing skill, these two perspectives share the idea that, at least for unskilled non-artists, long-term memory representations are influential in the production of observational drawings.

1.2.2 Empirical Evidence Pertaining to Memory-Based Accounts.

If long-term memories influence drawing performance, then the appearance of observational drawings produced by non-artists should contain reflections of information that are not inherent in the model stimulus being reproduced but are rather inherent in the individual's schematic graphic-based memories of the object being drawn. Early sources of such evidence were generated by studies of drawings made by young children. A long lasting theoretical idea has been the conceptualization of drawing development as a shift from "intellectual realism" to "visual realism" (Ford & Rees, 2008; Luquet, 1927). *Intellectual realism* refers to the notion that young children's observational drawings of objects heavily reflect their knowledge about the viewpoint-invariant properties of objects, including features in their drawings that are known to exist in the object being drawn but are not present in the specific model they are reproducing. *Visual realism* refers to the idea that the drawings of older children more strongly emphasize the viewpoint-specific appearance of the model object being reproduced and are less influenced by their knowledge of features that are known to exist but are absent in the model produced.

Freeman and Janikoun (1972) tested the idea that drawing develops from a mode of intellectual realism to a mode of visual realism. In their study, children ranging in age from 5 to 9 years old viewed a mug with an image of a flower printed on the side. After inspection, the researchers placed the mug at a standardized distance and orientation relative to the participants, ensuring that the flower was visible but the mug's handle was occluded. The participants were asked to create a drawing of the mug exactly as it appeared to them from where they were sitting. Since mug handles are stereotypical features of mugs, but images of flowers are not, the role of memory on their observational drawings was assessed by measuring the frequency of commission errors where the invisible handle was included in the drawings and omission errors where the visible flower image was not included in the drawings. Children 5 to 7 years old had a strong bias to include the mug handle and omit the flower image. Their drawings were heavily influenced by long-term memory for graphical properties of mugs and less influenced by the mug's appearance. In contrast, none of the 9 year-old participants included the handle and every one included a depiction of flower image in their drawings. These results suggest a progression in the childhood development of drawing ability from an emphasis on representing memory-based information to an emphasis on representing the specific visual information inherent in a model stimulus being reproduced.

However, the influence of memory-based information on observational drawing is not something specific to early childhood, which simply vanishes through development into late childhood and adulthood. Rather, evidence suggests that even though memory-based information is less emphasized and model-specific information is more emphasized in the drawings of older children and adults, demonstrable influences of long-term memory information on observational drawing performance persist. For instance, Glazek (2012) asked both trained artists and untrained non-artists to draw reproductions of images of familiar, common objects (e.g., a human eye and a wine glass) and of unfamiliar objects (e.g., Chinese language characters), and the drawings were subjectively rated for perceived accuracy by a group of independent judges. Non-artists' drawings of the familiar objects were perceived to be less accurate reproductions than their drawings of the unfamiliar objects. In contrast, the perceived accuracy of the artists' drawings was not affected by the familiarity of the object being reproduced.

Since there are established long-term memories about the prototypical graphic-properties of familiar objects, the author concluded that the accuracy of non-artists' drawings of familiar objects suffered due to the influence of processing information stored in memory that was not inherent in the model stimulus being drawn. In contrast, since the participants were native English speakers with no familiarity with the Chinese language, they had no established long-term memory representations about the graphic-properties of Chinese language characters that could have potentially been activated while drawing. Thus, Glazek concluded that the drawings of the unfamiliar objects were primarily guided by the information inherent in the model stimulus and, consequently, more accurate. Further, the null effect of familiarity on the accuracy of artists' drawings was interpreted to suggest that trained artists experienced less interference from graphic-based long-term memory representations during the drawing of familiar objects than non-artists did. If this is the case, then the development of drawing skill can be partly conceptualized as developing the ability to inhibit the activation of graphic-based long-term memory representations of familiar objects and primarily process bottom-up visual information inherent in the model stimulus during drawing reproduction.

However, an alternative explanation for the finding that artists' drawings of familiar and unfamiliar model objects were equally accurate is that the long-term memories of artists, like non-artists, influence the process of observational depiction. For instance, perhaps the long-term memories of artists that are activated and that bias the processing of information supporting observational drawing are simply more accurate representations of the appearance of the model objects being reproduced. In this view, artists' drawing accuracy is not affected by model familiarity not because there is less influence of memory among artists, but rather because the memory representation influencing drawing more closely matches the appearance of the objects being drawn by artists. If this is the case, then the development of drawing skill can be partially conceptualized as the process of developing stronger long-term memory representations about objects' properties, which more accurately represent how these objects appear, rather than a developing an ability to suppress the activation and influence of memory representations altogether (Gombrich, 1960; Kozbelt & Seeley, 2008). Nevertheless, these results are consistent with the proposition that, with respect to the drawings of non-artists, a major source of drawing errors is the processing of information represented in long-term memory.

However, it is unlikely that the long-term memory representations of the graphic-properties of familiar objects are identical across individuals. Rather, prototypical representations of graphic properties of familiar objects likely vary substantially between individuals. If such memory representations influence drawing production, then one explanation of the variability in the appearance of observational drawings across individuals would be that variable memory representations, each specific to a given individual, are activated and influence the production of an observational drawing. In order to evaluate this idea, Matthews and Adams (2008) asked participants to create two drawings of a cylinder. First, participants drew a cylinder from memory without being previously provided a model to guide their drawings. Such drawings were used to probe how each individual in the sample prototypically represents the graphic-properties of a cylinder in memory. Second, participants were asked to draw a directly perceivable cylinder that was positioned in the upright orientation. Objective measurements of 6 different spatial relationships of the memory- and observation-based cylinder drawings were made (e.g., height-to-width ratio of the whole object; the degree of roundness of oval-shaped portion located on the top or bottom of the cylinder).

To test the idea that participants' observational drawings of the model cylinder was partially influenced by how the graphic-based properties of cylinders are represented in long-term memory, correlational analyses were conducted assessing the relationship between the spatial measurements of the two types of drawings. For the 68% of participants whose memory-based drawings depicted a cylinder in the upright orientation (the same orientation the model cylinder was positioned in during the observational drawing task), all 6 spatial measurements were associated with reliable positive correlations between the two types of drawings ranging in magnitude from 0.26 to 0.46. In contrast, for the 32% of participants whose memory-based drawings depicted a cylinder on its side (different in orientation from the model cylinder reproduced in the observation-based drawing task), the correlations for all 6 spatial relationship measures, while remaining positive, were smaller in magnitude relative to the group whose memory-based drawings depicted an upright cylinder (ranging from 0.06 to 0.28), and none were reliably different from 0. These results suggest that person-specific memories representing the spatial properties of cylinders was activated and biased the production of the cylinder drawing based on observation. Interestingly, the influence of memory representations on observational drawing performance seems to be orientation-specific.

1.2.3 Summary.

Although the memory-based account of adult drawing ability has not received the same degree of empirical evaluation as the perception-based account, evidence has been reported that suggests that adult observational drawing performance is partially biased by the activation and processing of long-term memory representations of the object being reproduced. For non-artists, this influence of memory seems to have a detrimental effect on observational drawing performance as the memory bias results in the drawing deviating from the actual appearance of the model object being reproduced. Thus, the evidence suggests that, in addition to perceptual transformations of model stimuli, long-term memory seems to be another major source of errors present in non-artists' observational drawings.

1.3 Moving Forward – The Current Studies

The studies reported in this dissertation continue the line of research that aims to understand the psychological mechanisms that are related to common errors in the observational drawings of non-artists. These studies focus on a very narrow aspect of observational drawing ability, namely, the ability to accurately reproduce the spatial relationships between the major features found in a face. The studies reported here have multiple aims. First, Study 1 developed an objective method of measuring non-artists' accuracy in reproducing the spatial relationships between facial features. As will be described in more detail in the Introduction of Study 1, the majority of drawing research has measured drawing accuracy using holistic, subjective accuracy ratings made by groups of independent judges. Although such a measurement allows one to determine the degree to which outside observers perceive the accuracy of a drawing, such measurements, due to their holistic nature, do not allow one to determine the nature of errors present in a drawing. Thus, a major aim of Study 1 was to determine the specific way that non-artists err in reproducing the spatial relationships of a model face and to see how such objectively measured errors are related to subjective accuracy ratings. Finally, since holistic accuracy ratings of drawings have been shown to be predicted by the degree to which non-artists experience perceptual constancy effects (Cohen & Jones, 2008; Ostrofsky, Kozbelt & Seidel, 2012), another major aim of Study 1 was to determine which specific types of spatial errors relating to face drawings are predicted by such perceptual performance measures. Presently, it is unclear as to whether perceptual constancies predict all aspects of drawing accuracy or only a subset of types of drawing errors.

Study 2, in evaluating the memory-based theoretical account of drawing performance, investigated whether long-term memories that represent the spatial properties of faces influence the production of observational drawings of a face. Study 2 aimed to determine whether the types of errors non-artists make in an observational drawing task and the biases present in their memory-based drawings of a face are related. Also, similar to the method of Matthews and Adams (2008), I evaluated whether the spatial relationships between facial features produced in a memory-based drawing task can predict how they are reproduced in an observation-based drawing task.

Finally, in evaluating the perception-based theoretical account of drawing ability, Study 3 investigated the effects that model face rotation has on the accuracy to which non-artists draw the spatial relationships between facial features. Model rotation effects on drawing performance have been tested before (Cohen & Earls, 2010). However, spatial drawing accuracy was measured using subjective holistic ratings, and thus, it is presently unclear what specific types of spatial face drawing errors are affected by model rotation and exactly how they are affected. As will be explained in the introduction to Study 3, the measurement of objective errors in reproducing the spatial relationships found in a face will allow a stronger test of the misperception hypothesis than is allowed by the use of subjective accuracy ratings.

2. Study 1

Throughout the history of visual art, faces have been a strong focus of drawers and painters. Depictions of faces are commonly found in almost every major period of known art-history ranging from at least the Ancient Egyptian period to the present day, and there is evidence that suggests human efforts to draw or paint faces go back to at least 27,000 years ago (Jones, 2006). The popularity of face-based art is further suggested by the observation that, according to the *Financial Times*, eight out of the 10 most expensive paintings ever sold include a depiction of a face or a group of faces (Sutherland, 2012). Perhaps reflecting the cultural popularity of face-based visual art, research studies on drawing have also frequently focused on understanding the psychological mechanisms associated with drawing faces from observation (Brodie, Wyatt & Waller, 2004; Cohen, 2005; Cohen & Bennett, 1997; Cohen & Earls, 2010; Cohen & Jones, 2008; Costa & Corazza, 2006; Freeman & Loschky, 2011; Hayes & Milne, 2011; Kozbelt, 2001; Kozbelt et al., 2010). As with the drawings of other categories of objects, these studies have demonstrated substantial individual variability in accuracy, with some reporting the unsurprising finding that trained artists draw faces more accurately than non-artists.

A major theme that relates many of these studies together is that the accuracy of face drawings is influenced by, or at least related to, perceptual processing. Specifically, research suggests that face drawing accuracy is: (1) predicted by the degree to which one experiences the shape constancy effect (Cohen & Jones, 2008); (2) increased when participants' gaze-shift frequency between the model stimulus and their emerging drawing increases (Cohen, 2005); (3) decreased when the face model is upside-down relative to when upright with respect to the spatial relations between the facial features (Cohen & Earls, 2010); and (4) increased when participants draw from face photographs where the low and high spatial frequencies have been isolated relative to when the middle spatial frequencies have been isolated (Freeman & Loschky, 2011).

A major limitation of this research concerns how face drawing accuracy has been measured. Potential errors in face drawing are heterogeneous: individuals could err in reproducing the shape or relative size of individual facial features, the spatial dimensions and relations between features, or other aspects of the face (such as cues to individual identity or emotional expression), and such errors may be largely independent of one another. Thus, the accuracy of face drawings is a complex multi-dimensional variable. However, the method of measurement of face drawing accuracy used in most past research has typically not reflected this complexity. Virtually all relevant studies have used subjective accuracy ratings where independent judges view the model stimulus and each face drawing together and provide a single Likert-scale holistic accuracy rating. Thus, it is unclear whether perceptual measures correlated with face drawing accuracy – like shape constancy errors (Cohen & Jones, 2008) – or experimental manipulations such as spatial frequency isolation (Freeman & Loschky, 2011), gaze-shift frequency (Cohen, 2005), or image inversion (Cohen & Earls, 2010; Kozbelt et al., 2010), affect all types of drawing errors or only a specific subset. Complementing the use of subjective ratings with more objective, multi-dimensional measurements of face drawing accuracy would improve on the limitations described above and provide a richer and more complete understanding of this topic.

Notably, two recent studies (Costa & Corazza, 2006; Hayes & Milne, 2011) have measured face drawing accuracy using objective measurements of the drawings themselves. Costa and Corazza (2006) asked trained art students to produce self-portraits by viewing themselves in a mirror. The drawings and photographic portraits of the participants were compared with respect to objective measurements of spatial elements such as eye, lip and face roundness. Systematic biases were observed that indicated artists reliably draw the eyes and lips rounder and with a larger relative height, and the lower face as rounder, than in the photograph. Importantly, this study is the first to my knowledge to attempt to objectively quantify face drawing errors and to report systematic (as opposed to random) patterns of errors.

More recently, Hayes and Milne (2011) reported a study where the two authors (at least one of whom was a skilled drawer with formal art training) produced portraits based on 30 photographs of male and female faces with a range of facial expressions seen at varying orientations. They measured drawing accuracy using both subjective ratings from independent judges and objective measurements. Comparisons of objective measurements between the drawings and photographs indicated a number of reliable errors that included the eyes being drawn too small, rounded, and positioned too close together, the mouth being wider with smaller lip height and positioned too close to the chin, and the upper face being too narrow. Further, the objectively measured errors were in considerable (though not perfect) agreement with the subjective accuracy ratings. This study complements the findings reported by Costa and Corazza (2006) by further demonstrating stereotyped patterns of face drawing biases in skilled trained artists.

To extend this effort, Study 1 objectively quantified errors present in face drawings produced by a sample of non-artists. Specifically, I focused on measuring drawing errors of different aspects of the spatial dimensions and relations between the features composing a face. These measures were chosen for the following reasons. First, even though there are other important aspects of face drawing ability other than the accuracy to which individuals successfully reproduce the relative spatial positioning of facial features (e.g., the accuracy to which individuals successfully reproduce the facial features themselves in isolation of any other feature), objective spatial measurements of spatial accuracy, unlike that of the isolated features themselves, are relatively easy to operationally define and measure. Second, the ability to perceptually recognize faces is heavily reliant on processing information about the relative spatial positioning of facial features (Rotshtein, Geng, Driver & Dolan, 2007; Tanaka & Sengco, 1997). This suggests that the perceived accuracy of face drawings might be partially reliant on the degree to which drawings accurately reproduce the spatial relationships between facial features found in the model that is being reproduced. Finally, some research shows that shape constancy errors have a stronger relationship with perceived spatial drawing accuracy than with perceived featural or overall drawing accuracy (Cohen & Jones, 2008). Further, perceived spatial drawing errors have been shown to be selectively affected by rotation of the model stimulus, whereas featural and overall drawing accuracy is not (Cohen & Earls, 2011). Thus, in the research on face drawing that has been published to date, reproduction of spatial relationships between facial features has emerged as an interesting element of face drawing accuracy which is related to individual differences in perceptual processing ability and affected by experimentally manipulating perceptual encoding of stimuli in ways that other elements of face drawing accuracy are not to the same degree.

In Study 1, participants created an observational drawing from a photographic model of a face. I employed two methods of measuring the accuracy of these drawings – by having judges provide traditional subjective accuracy ratings and by objectively measuring the degree to which the drawings deviate from the model with respect to the relative spatial positioning of facial features. Additionally, participants were administered perceptual judgment tasks that assess the degree to which they experience shape and size constancy effects. The analysis of performance in these drawing and perceptual judgment tasks aimed to address multiple questions. The first aim was to determine whether objectively measured spatial drawing errors made by non-artists are random or are directionally biased. A second aim was to determine how subjective accuracy ratings of face drawings are related to the degree of objective error in reproducing the relative spatial positioning of facial features. The final aim was to determine the degree of similarity in how subjective and objective measures of face drawing accuracy are related to the degree to which individuals experience shape and size constancy effects (which have been previously found to be correlated with subjective drawing accuracy ratings – Cohen & Jones, 2008; Ostrofsky et al., 2012). For the latter two aims, it is an open question as to what kinds of objectively measured spatial drawing errors predict subjective accuracy ratings and/or perceptual constancy errors.

2.1 Method – Study 1A.

2.1.1 Participants.

Forty-eight individuals (35 females, 13 males) participated in the drawing and perceptual constancy tasks, *M* (*SD*) age = 20.3 (1.5) years. Participants were recruited from the Brooklyn College Psychology Undergraduate Subject Pool and were provided course credit for compensation. All participants reported that they were not formally trained in drawing.

Twenty-four individuals (18 females, 6 males) participated as independent judges to rate the accuracy of the drawings produced by the participants described above, *M* (*SD*) age = 23.4 (5.9) years. These participants were recruited and compensated in the same way as the individuals who participated in the drawing and perceptual constancy tasks.

2.1.2 Materials and Procedures.

Participants were administered a free-hand drawing task, a shape constancy task, and a size constancy task, in that order.

Free-hand drawing task. Participants were asked to create a free-hand drawing of a grey-scale photograph of a woman's face, measuring approximately 6.8" × 10.1" and printed on an 8.5" × 11" piece of white paper in portrait orientation (see Figure 1). Participants were provided with an 8.5" × 11" piece of white paper and a sharpened pencil with eraser to create a drawing and were instructed to draw the photograph of the face as accurately as possible. They were told that they could use any drawing techniques they wished (except for tracing) and that their drawings would later be measured for accuracy. They were given a 15 minute time limit and were warned when they had five minutes and one minute remaining.

Figure 1. The model photograph participants reproduced in Study 1A and Study 3.

Shape Constancy Task. We used a modified version of the shape constancy task described in Cohen and Jones (2008). Participants were shown individual computerized presentations of images of target shapes, and asked to indicate the shape they perceived by pointing to a single option on a printed response sheet with 21 shape options (see Figure 2). Two conditions were tested. In the *depth cue condition*, participants were shown individual stimulus presentations of four photographs of a rectangular window embedded in a brick wall seen at different viewing points, which cause the projective shape of the window to deviate from rectangularity to varying degrees. These viewing points deviated from the frontoparallel view at approximately 26, 52, 65 and 78 degrees. In the *non-depth cue condition*, participants were shown individual presentations of quadrilaterals composed of four black lines presented on a uniform white background. The shape of the four quadrilaterals perfectly matched the shape of the four windows used in the depth cue condition.

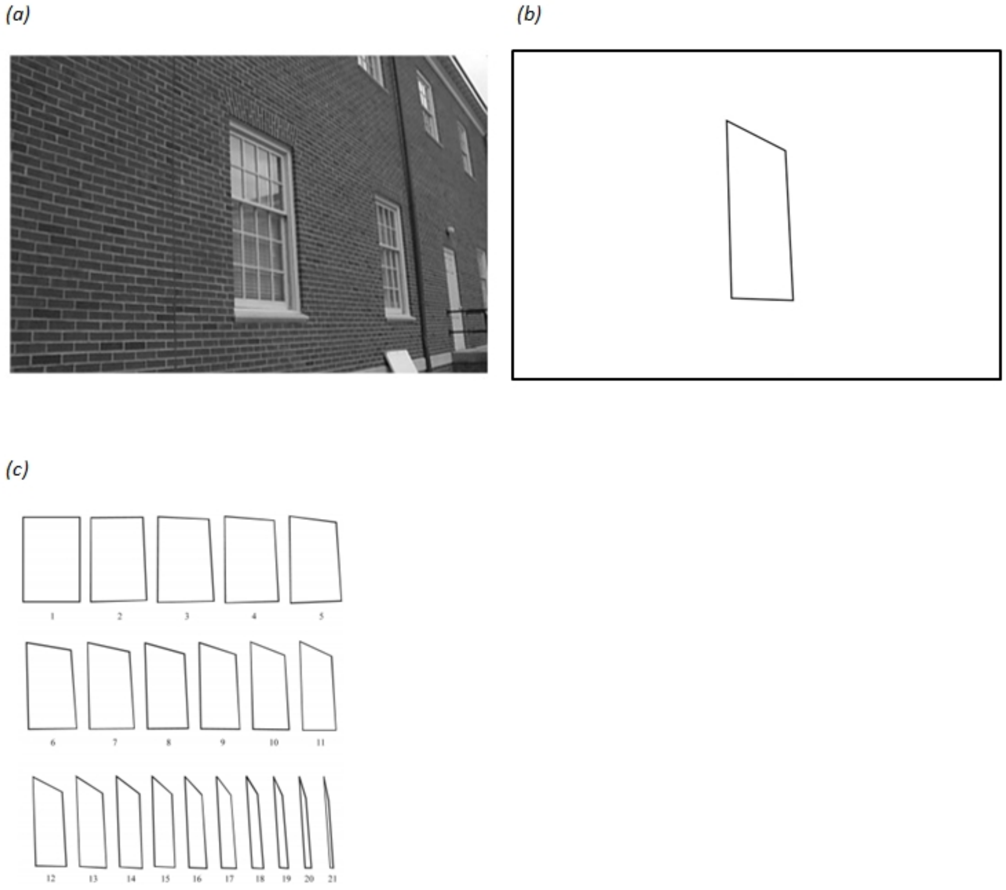

Figure 2. Stimuli presented during the Shape Matching Task of Study 1A. (a) Example of a stimulus presented in the depth cue condition. (b) Example of a stimulus presented in the non-depth cue condition. Note that the shapes of these examples in the depth and non-

depth cue stimuli are identical. (c) Illustration of the response options participants were provided (note that no numbers were presented on the response sheet given to subjects). Participants viewed a stimulus, and then were asked to point to the shape on the response sheet that perfectly matched the shape presented in the stimulus.

Participants used a response sheet to indicate their choice of the shape that matched each stimulus. The sheet consisted of 21 quadrilaterals composed of black lines printed on an 8.5” × 11” white piece of paper in portrait orientation. Four quadrilaterals perfectly matched the shape of the stimuli presented in the depth and non-depth cue conditions; an additional 17 quadrilaterals were also shown that were morphed in shape relative to the four target stimuli and which collectively subtended deviations from the frontoparallel view from 0 degrees (perfect rectangle) to approximately 91 degrees, and changed shape in approximately 4.3 degree intervals. The shapes were arranged from most rectangular to least rectangular in one version of the response sheet; this was reversed in the other version of the response sheet.

Participants were instructed to attend to and try to memorize the exact shape of the window or quadrilateral as it appeared on the screen. For window stimuli, instructions also emphasized that participants should memorize the window’s actual appearance on the screen, not its known rectangular shape. On each trial, participants viewed the stimulus for 15 seconds with the response sheet out of view before the image automatically disappeared. This was replaced by a blank white screen, at which time participants, working at their own pace, indicated the shape that best matched the target stimulus.

The depth cue and non-depth cue conditions each comprised four trials, with each stimulus presented once, in a random order. Stimuli were blocked within-condition. Condition order was counterbalanced across participants, as was the version of the response sheet used in each condition.

Error scores were computed by calculating the difference between the Correct Response and the Chosen Response Option, using the ordinal values of the response options on the response sheet. When calculated this way, an error score of 0 indicates a correct response. A positive error score indicates that the participant chose a shape that was more rectangular than the target, which is consistent with the classic shape constancy effect whereby the perceived shape of the stimulus is biased toward its known rectangular shape.

Size Constancy Task.[2] We administered the size constancy task used in Ostrofsky et al. (2012) which was originally adapted from the task used in Murray, Boyaci, and Kersten (2006). Participants saw two circles on the computer screen (see Figure 3). The upper circle was always the target, and participants were instructed to use arrow keys on the computer keyboard to manipulate the size of the lower circle to match the size of the target. Participants were explicitly instructed to focus on matching the actual size of the circles – that is, if they were measured on the computer screen – rather than their interpretation of their size.

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[2] Note that three participants did not complete the size constancy task.

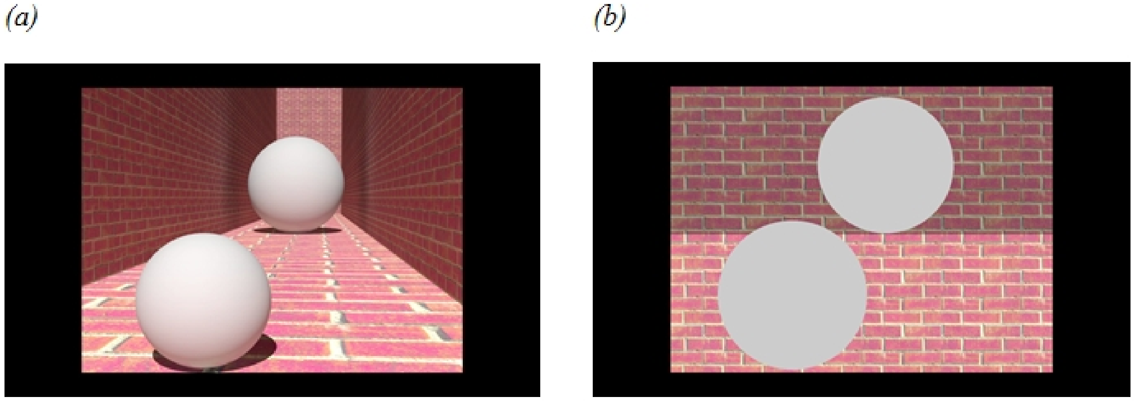


Figure 3. Stimuli presented to participants in the Size Matching Task of Study 1A. (a) Example of stimuli presented in the depth cue condition. (b) Example of stimuli presented in the non-depth cue condition. Participants were asked to adjust the size of the lower sphere/circle (Response Sphere/Circle) to perfectly match the size of the higher sphere or circle (Target Sphere/Circle) as it appeared on the screen.

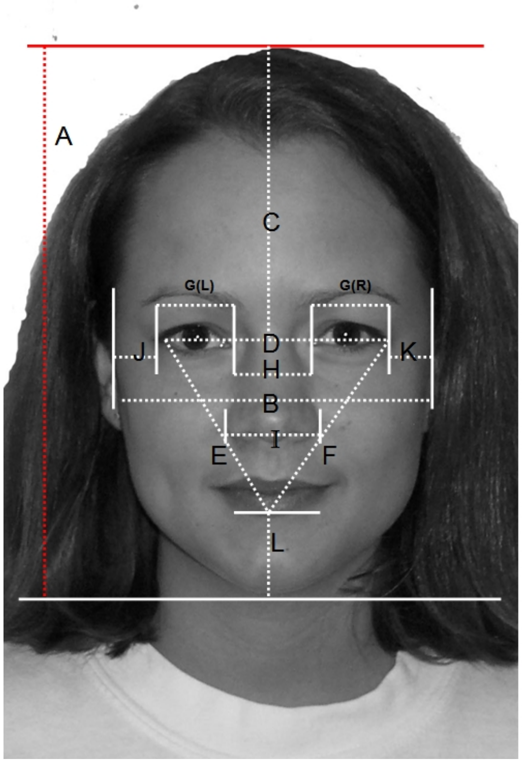
Two conditions were tested. In the *depth cue condition*, the circles were shaded to suggest spherical forms and were presented against a textured, converging perspective background to give the appearance that the upper target circle was more distant than the lower circle. In the *non-depth cue condition*, both circles were shown in a uniform shade of gray matching the overall value of the spheres in the depth condition. The background likewise maintained the same contrast of light and dark and included a similar texture as the depth condition; however, no depth cues were present.

Each condition was tested as a separate block: 50 trials in the depth cue condition and 25 trials in the non-depth cue condition, with condition order counterbalanced across participants. To facilitate analyses, in each condition, the target was always one of five standard sizes (156, 208, 260, 212 and 364 pixels in diameter – 10 trials each for depth condition and five trials each for non-depth condition – within each block, presented in a random order). On each trial, error scores were computed based on the diameter of the two circles using the number of pixels as the unit of measure – specifically, by dividing the diameter of the manipulated circle by the diameter of the target circle. A value of 1 indicates a perfect match in size between the two circles. An error greater than 1 indicates that the participants manipulated the size of the lower circle as larger than the target size of the upper circle, indicating that they perceived the size of the target upper circle to be larger than it actually was (reflecting the size constancy effect).

2.1.3 Measurements of Reproduced Spatial Relationships and Drawing Accuracy.

Subjective Measure of Drawing Accuracy in the Free-hand Drawing Task. I employed two methods of measuring accuracy of the face drawings. First, we used the traditional method of subjective accuracy ratings. Here, 24 independent judges viewed the model photograph of the face and each drawing individually and provided a single 20-point Likert-scale response indicating their assessment of the accuracy of each drawing, with 20 representing the highest accuracy. Each judge was instructed to provide this numerical rating with respect only to the realistic accuracy of the drawing and to not rate the drawings based on any other criteria, like aesthetic or creative factors. In order to control for any idiosyncratic biases in the judges' use of the 20 point scale, we transformed each judges' set of ratings into *z* scores. Inter-judge agreement was high (Cronbach's alpha = .972), so *z* scores were averaged across judges to create a single subjective accuracy rating score for each drawing.

Objective Measures of Drawing Accuracy in the Free-hand Drawing Task. Next, we made 12 spatial measurements (in cm) of the model face photograph and each drawing (see Figure 4 for a visual illustration of measurements A through L). We measured: (A) the length of the face from the top of the face (including hair) to the bottom of the chin, (B) The width of the face (with landmark points being at the point of the image where it appeared that the upper part of the ear connected to the side of the face), (C) the vertical distance from the top of the face to the middle of the eye-line (if the eye-line was not perfectly horizontal, the vertical distance between the top of the face and the midpoint between the two eyes was measured), (D) the distance between the two outer corner of the eyes, (E) the diagonal distance between the outer corner of the left eye (from the observer's perspective) and the center of the bottom of the bottom lip, (F) the diagonal distance between the outer corner of the right eye (from the observer's perspective) and the center of the bottom of the bottom lip, (G) the width of the eyes (the width of both eyes were measured and averaged to create one width measurement), (H) the inter-ocular distance between the two inner corners of the eyes, (I) width of the nose, (J) the horizontal distance between the outer corner of the left eye and the left side of the face (from the observer's perspective), (K) the horizontal distance between the outer corner of the right eye and the right side of the face (from the observer's perspective), and (L) the vertical distance between the center of the bottom of the bottom lip and the bottom of the chin.



Spatial Measurement Ratios of Model Stimulus

Measure	Description	Value
B/A	Width-to-Length Shape Ratio of Face	0.60
C/A	Vertical Position of Eye Line	0.53
E/D	Positioning of Eyes and Mouth Relative to One Another	0.96
F/D		0.96
E/F		1.00
G/B	Width of Eyes [G = Average of G(L) & G(R)]	0.23
H/B	Inter-ocular Distance	0.24
J/B	Distance from Outer Corner of Eyes to Side of Head	0.14
K/B		0.16
I/B	Width of Nose	0.27
L/A	Vertical Position of Mouth (Bottom of Bottom Lip)	0.13
[G(L) – G(R)] / G	Difference in Width of Left and Right Eyes	0.00
(J-K) / B	Horizontal Centering of Eyes	-0.02

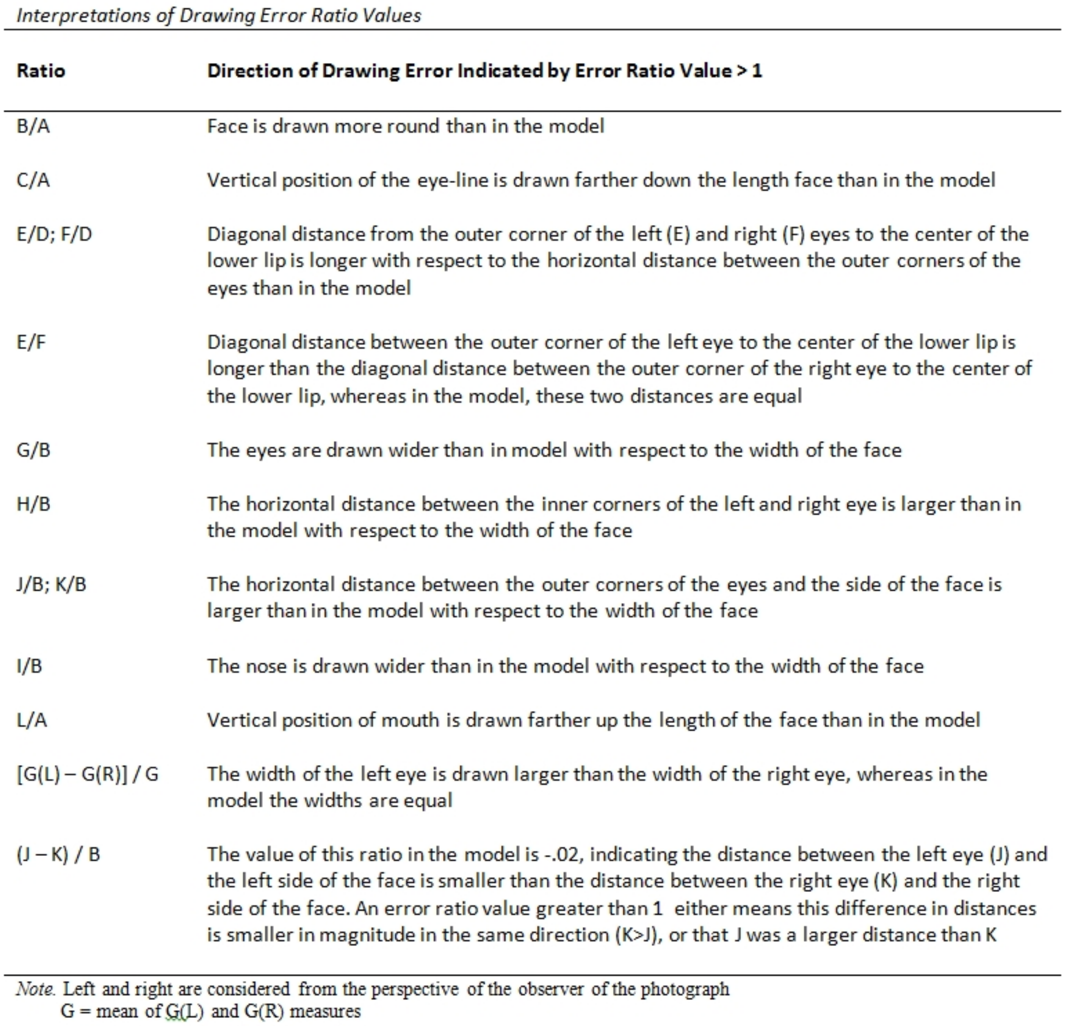
Figure 4. Illustration of the 12 measurements made and definitions of the 13 spatial relation ratios that were computed in Study 1. Values of the spatial relation ratios of the model face are presented.

We then calculated a number of ratios (defined and described in Figure 4, along with values of these ratios with respect to the model face photograph). Spatial drawing errors with respect to each ratio were defined as:

$$\text{Spatial Drawing Error Ratio} = \text{Drawing Ratio} / \text{Model Ratio}$$

Interpretations of the direction of error are specific to each ratio and are explained in Table 1. Because the model's value of the [G(L) – G(R)] / G was 0, the error values are undefined using this calculation. Therefore, the errors associated with this spatial relation ratio was computed as the difference between the Drawing Ratio and the Model Ratio, where a positive difference indicates that the left eye was drawn wider than the right eye, and a negative difference indicates the opposite.

Table 1.



Interpretations of Drawing Error Ratio Values

Ratio	**Direction of Drawing Error Indicated by Error Ratio Value > 1**
B/A	Face is drawn more round than in the model
C/A	Vertical position of the eye-line is drawn farther down the length face than in the model
E/D; F/D	Diagonal distance from the outer corner of the left (E) and right (F) eyes to the center of the lower lip is longer with respect to the horizontal distance between the outer corners of the eyes than in the model
E/F	Diagonal distance between the outer corner of the left eye to the center of the lower lip is longer than the diagonal distance between the outer corner of the right eye to the center of the lower lip, whereas in the model, these two distances are equal
G/B	The eyes are drawn wider than in model with respect to the width of the face
H/B	The horizontal distance between the inner corners of the left and right eye is larger than in the model with respect to the width of the face
J/B; K/B	The horizontal distance between the outer corners of the eyes and the side of the face is larger than in the model with respect to the width of the face
I/B	The nose is drawn wider than in the model with respect to the width of the face
L/A	Vertical position of mouth is drawn farther up the length of the face than in the model
[G(L) – G(R)] / G	The width of the left eye is drawn larger than the width of the right eye, whereas in the model the widths are equal
(J – K) / B	The value of this ratio in the model is -.02, indicating the distance between the left eye (J) and the left side of the face is smaller than the distance between the right eye (K) and the right side of the face. An error ratio value greater than 1 either means this difference in distances is smaller in magnitude in the same direction (K>J), or that J was a larger distance than K

Note. Left and right are considered from the perspective of the observer of the photograph
G = mean of G(L) and G(R) measures

2.2 Results – Study 1A.

Patterns of Spatial Errors in Face Drawings.[3] Average values for each spatial measurement ratio and the average spatial drawing errors are displayed in Table 2. The first

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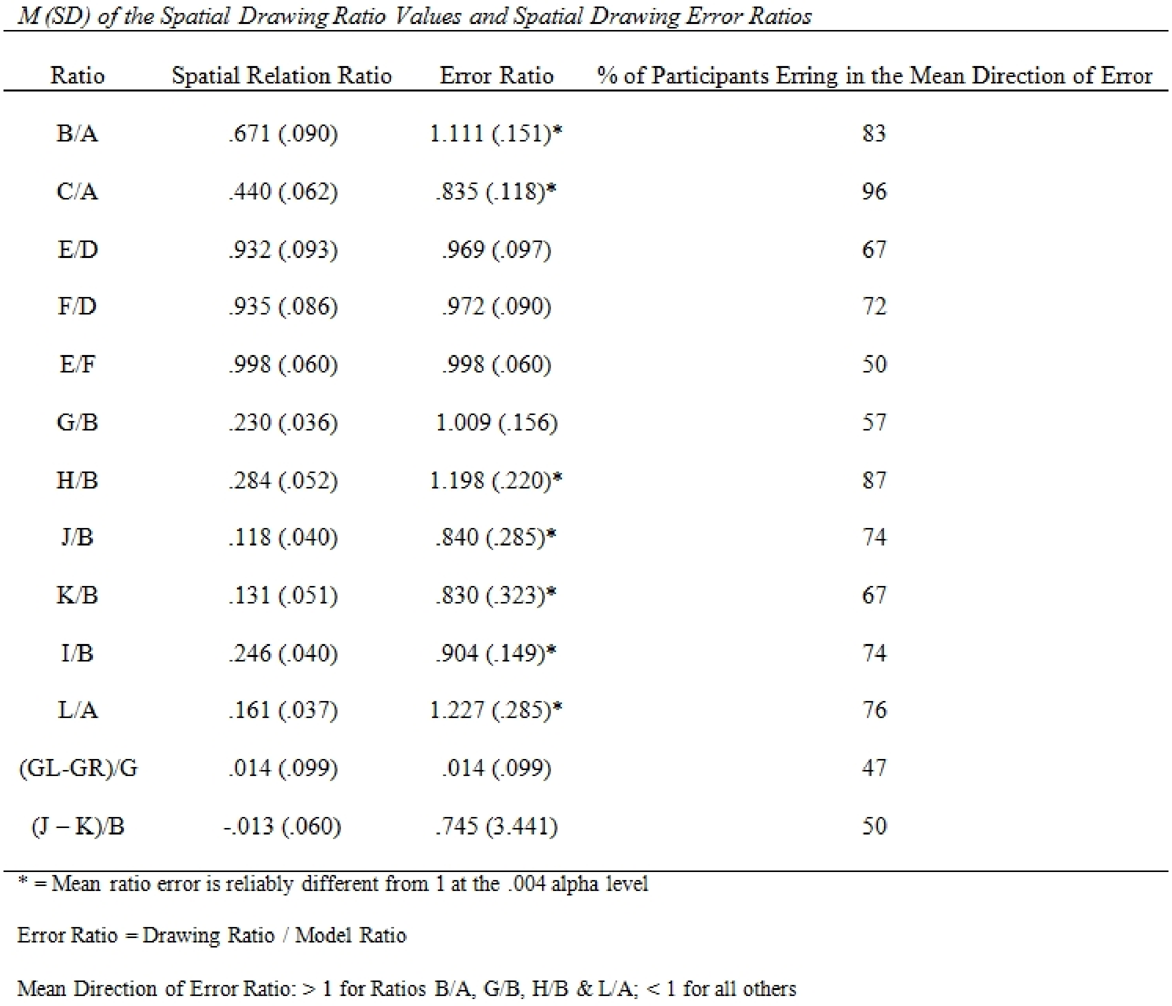
[3] Only drawings that included all facial features (both eyes, nose and mouth) were included in the analysis. This resulted in having to discard data from two participants.

question we addressed was whether the spatial errors participants made in their drawings were reliably biased in one direction or were randomly distributed in both directions. Thirteen single-sample *t* tests were conducted, comparing each average spatial drawing error against a value of 1.[4]

Table 2.



M (SD) of the Spatial Drawing Ratio Values and Spatial Drawing Error Ratios

Ratio	Spatial Relation Ratio	Error Ratio	% of Participants Erring in the Mean Direction of Error
B/A	.671 (.090)	1.111 (.151)*	83
C/A	.440 (.062)	.835 (.118)*	96
E/D	.932 (.093)	.969 (.097)	67
F/D	.935 (.086)	.972 (.090)	72
E/F	.998 (.060)	.998 (.060)	50
G/B	.230 (.036)	1.009 (.156)	57
H/B	.284 (.052)	1.198 (.220)*	87
J/B	.118 (.040)	.840 (.285)*	74
K/B	.131 (.051)	.830 (.323)*	67
I/B	.246 (.040)	.904 (.149)*	74
L/A	.161 (.037)	1.227 (.285)*	76
(GL-GR)/G	.014 (.099)	.014 (.099)	47
(J – K)/B	-.013 (.060)	.745 (3.441)	50

* = Mean ratio error is reliably different from 1 at the .004 alpha level

Error Ratio = Drawing Ratio / Model Ratio

Mean Direction of Error Ratio: > 1 for Ratios B/A, G/B, H/B & L/A; < 1 for all others

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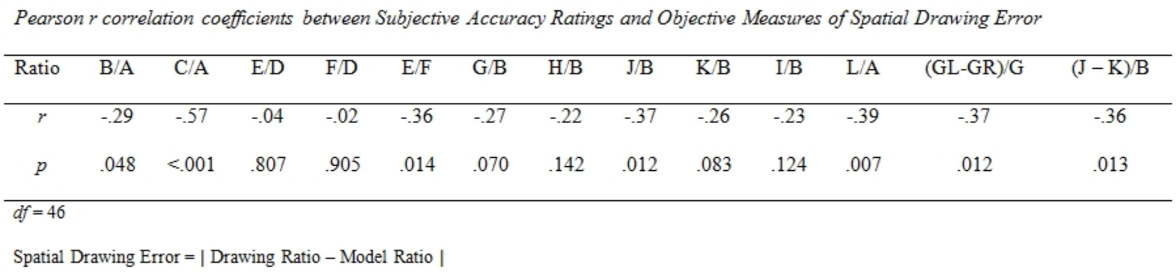
[4] The only exception being for the errors associated with the spatial relation ratio [G(L) – G(R)]/G, where the error differences were compared to a test value of 0.

These analyses provide evidence that non-artists are reliably biased to err in a single direction with respect to the reproduction of multiple spatial relationships in their face drawings. First, we found that participants systematically drew the face rounder than the model (B/A ratio), t (45) = 5.33, $p < .001$, Cohen's $d = .79$. There was also a bias to draw the eye line farther up the length of the face than in the model (C/A ratio), t (45) = -9.47, $p < .001$, Cohen's $d = 1.40$. We also observed a bias for participants to draw the inter-ocular distance as larger than in the model with respect to the width of the face (H/B ratio), t (45) = 6.11, $p < .001$, Cohen's $d = .90$. Participants also drew both eyes closer to the sides of the face than in the model with respect to the width of the face (J/B ratio), t (45) = -3.80, $p < .001$, Cohen's $d = .56$; (K/B ratio), t (45) = -3.57, $p < .004$, Cohen's $d = .53$. There was also a reliable bias to draw the nose as more narrow than in the model with respect to the width of the face (I/B ratio), t (45) = -4.39, $p < .001$, Cohen's d =.65. Finally, participants drew the bottom of the lower lip farther up the length face than in the model (L/A ratio), t (45) = 5.42, $p < .001$, Cohen's d =.80. The remaining average spatial drawing error ratios were not reliably different from 1 (all $p > .01$).

Relationship Between Objective and Subjective Measures of Drawing Accuracy. Next, we determined whether the objective measures of spatial drawing accuracy were related to the independent judges' subjective ratings of drawing accuracy. We re-calculated the objective spatial drawing errors as the absolute difference between the spatial relation ratio value of the drawing and the model for each of the 13 spatial relation ratios. Then, we computed the Pearson r correlation coefficient between the subjective accuracy ratings and each of the spatial relation ratios. Table 3 displays the results of these analyses.

Table 3.



Pearson r correlation coefficients between Subjective Accuracy Ratings and Objective Measures of Spatial Drawing Error

Ratio	B/A	C/A	E/D	F/D	E/F	G/B	H/B	J/B	K/B	I/B	L/A	(GL-GR)/G	(J – K)/B
r	-.29	-.57	-.04	-.02	-.36	-.27	-.22	-.37	-.26	-.23	-.39	-.37	-.36
p	.048	<.001	.807	.905	.014	.070	.142	.012	.083	.124	.007	.012	.013

df = 46

Spatial Drawing Error = | Drawing Ratio – Model Ratio |

All 13 spatial relation ratio errors were related to the subjective accuracy ratings in the negative direction to varying degrees of strength, indicating that as each spatial relation error grew larger in magnitude, the independent judges tended to rate the drawing lower in accuracy. This is what we would expect if the judges' subjective accuracy ratings were partially influenced by the degree of objective spatial error present in a drawing. The objectively measured spatial relationships that were reliably associated to the subjective accuracy ratings[5] were the ones relating to: (1) the vertical position of the eyes on the length of the face (C/A ratio), (2) the vertical position of the mouth on the length of the face (L/A ratio), (3) the roundness of the face (B/A ratio), (4) the difference between the outer corners of the left and right eyes' diagonal distance to the bottom of the lower lip (E/D & F/D ratios, respectively), (5) the distance between the left eye and the left side of the face (J/B ratio), (6) the difference in width between the left and right eye ([G(L) – G(R)] / G ratio), and (7) the difference in left and right eyes' distance from the side of the face ([J – K]/B ratio). Thus, the evidence indicates that the multiple objective measurements of spatial drawing error made here are related to the factors that determine the subjective accuracy ratings of the drawings.

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[5] Here, a reliable correlation is defined as one whose $p < .05$.

Shape Constancy. Average errors in the shape constancy task are displayed in Figure 5a. We wished to determine whether participants reliably experienced the shape constancy effect. To determine this, we conducted a 2 (Stimulus Condition: Depth vs. Non-Depth cue conditions) × 4 (Target Shape: 26 vs. 52 vs. 65 vs. 78 degree frontal view deviation) repeated-measures ANOVA testing for effects on shape matching errors. Due to a violation of the assumption of sphericity, we corrected the degrees of freedom using the Huynh-Feldt procedure to reduce potential alpha inflation. We observed a reliable main effect of Target Shape, F (2.03, 95.57) = 36.06, $p < .001$, partial $\eta^2 = .43$, indicating differences in the size of error across target shapes. We also found a reliable main effect of Stimulus Condition, F (1, 47) = 77.28, $p < .001$, partial $\eta^2 = .62$, indicating that errors were larger in the depth cue condition relative to the non-depth cue condition. Analysis of condition means indicated that participants perceived the shape of the window to be more rectangular than the projective shape, reflecting participants' experience of shape constancy. We also observed a reliable interaction between stimulus condition and target shape, F (3, 141) = 8.95, $p < .001$, partial $\eta^2 = .16$. This interaction was explored by quasi-*F* tests, comparing errors between the depth and non-depth cue conditions at each target shape[6]. Results indicated that errors in the depth cue condition were reliably larger than errors in the non-depth cue condition for each target shape (all $p < .001$). However, the degree of the shape constancy effects reliably differed across target shapes, being greatest for the 65 degree target shape and smallest for the 26 degree target shape.

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[6] Each quasi-*F* test comparison for the shape constancy task was evaluated with 1 between-condition *df* and 105.41 within-condition *df.*

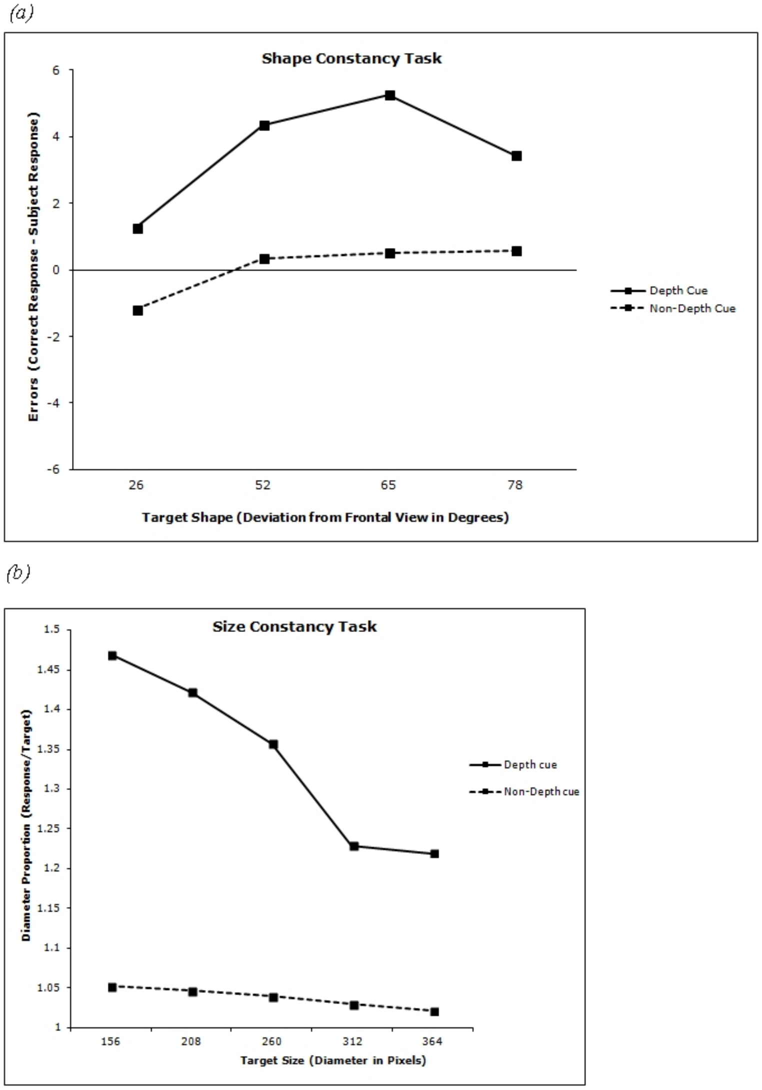

Figure 5. Performance in the Perceptual Matching Tasks in Study 1A. (a) Performance in the shape matching task. Errors were computed as the difference in ordinal rank between the correct response and the chosen response on the response option sheet. Errors greater than 0 indicate the shape constancy effect (e.g., the chosen shape was more rectangular than the shape of the target). (b) Performance in the size matching task. Errors were computed as the ratio between the size of the Response Sphere and the size of the Target Sphere. Error ratios greater than 1 indicate the size constancy effect (e.g., the Response Sphere/Circle was adjusted to be larger than the Target, indicating that the Target Sphere/Circle was perceived to be larger than it actually appeared).

Size Constancy. Average errors in the size constancy task are shown in Figure 5b. We wished to determine whether participants reliably experienced the size constancy effect. In order to determine this, we conducted a 2 (Stimulus Condition: Depth vs. Non-Depth cue conditions) × 5 (Target Size: 156 vs. 208 vs. 260 vs. 312 vs. 360 pixel diameter) repeated-measures ANOVA testing for effects on size matching proportion errors. Due to a violation of the assumption of sphericity, we again corrected the degrees of freedom using the Huynh-Feldt procedure. We observed a reliable main effect of Target Size, F (2.75, 115.68) = 255.69, $p < .001$, partial $\eta^2 = .86$, indicating differences in error size as a function of target size. We also found a reliable main effect of Stimulus Condition, F (1, 42) = 425.26, $p < .001$, partial $\eta^2 = .91$, indicating that participants' errors were reliably larger in the depth cue condition compared to the non-depth cue condition. Participants manipulated the size of the bottom sphere to be larger than the target sphere, indicating they perceived the target sphere, which was set at a greater perceived distance, as larger than it appeared on the screen, reflecting participants' experience of size constancy. Additionally, a reliable interaction was observed, F (3.17, 133.15) = 164.62, $p < .001$, partial $\eta^2 =.80$. This interaction was explored by conducting quasi-F tests, comparing the errors between the depth and non-depth cue condition for each target size[7]. Results indicated that errors in the depth cue condition were reliably larger than in the non-depth cue condition for all target sizes (all $p < .001$). However, the degree to which participants experienced size constancy differed across target sizes, being largest for the 156-pixel diameter target and progressively decreasing (in a non-linear fashion) as the target increased in size.

Relationship between Drawing Accuracy and Perceptual Constancies. Finally we wished to determine whether size and shape constancy effects predicted subjective and objective

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[7] Each quasi-F test comparison for the size constancy task was evaluated using 1 between condition df and 62.73 within-condition df.

drawing accuracy measures. For each participant, we calculated the absolute value of the average shape and size matching errors separately for the depth and non-depth cue conditions of the task.

With respect to the subjective accuracy ratings, drawing accuracy was reliably correlated with errors made in the depth cue version of the shape matching task, *r* (46) = -.370, *p* = .01, but not with errors made in the non-depth cue version, *r* (46) = -.117, *p* > .05. Similarly, drawing accuracy was reliably correlated with errors made in the depth cue version of the size matching task, *r* (43) = -.488, *p* = .001, but not with errors made in the non-depth cue version of the size matching task, *r* (43) = -.089, *p* > .05. In other words, for the depth cue conditions of the shape and size matching tasks, participants who made larger perceptual constancy errors tended to produce drawings that were rated lower in accuracy. However, there was a lack of a reliable relationship between the degree of perceptual errors made in the non-depth cue versions of the shape and size matching tasks and the rated accuracy of drawings.

With respect to the objectively measured spatial drawing errors, errors made in the depth-cue version of the shape matching task were reliably correlated with the C/A ratio errors (vertical position of the eye line), *r* (46) = .340, *p* = .02, the E/F ratio errors (representing the difference in outer corner of eye-bottom of bottom lip distances between the left and right eyes), *r* (46) = .309, *p* = .03, the L/A ratio errors (the vertical position of the bottom lip), *r* (46) = .306, *p* = .04, and the I/B ratio errors (the width of the nose), *r* (46) = .423, *p* = .003. Errors made in the non-depth cue version of the shape matching task were reliably correlated with H/B ratio errors (inter-ocular distance), *r* (46) = .316, *p* = .03, and curiously, were negatively correlated with the [J – K] / B ratio errors (the difference in distance between the outer-corner of the eyes and the side of face between the left and right sides), *r* (46) = -.316, *p* = .03. Additionally, errors made in depth cue version of the size matching task was reliably correlated with the E/F ratio errors, *r* (43) =

.314, *p* = .04, and with the J/B ratio errors (the distance between the outer-corner of the left eye and the left side of the face), *r* (43) = .424, *p* = .005. Finally, errors made in the non-depth cue version of the size matching task was only reliably correlated with the B/A ratio errors (the shape of the face as measured by the face width-to-length ratio), *r* (43) = .415, *p* = .006. No other correlations were reliable at the .05 level.

2.3 Discussion – Study 1A.

To the best of my knowledge, this is the first study to demonstrate that non-artists, when drawing the spatial positioning of facial features, are systematically biased to err in a single direction with respect to multiple spatial relationships. It was found that most non-artists err in drawing a face as too circular, with the eyes too high and too far apart (and too close to the sides of the face), the nose too narrow, and the mouth too high. Interestingly, although trained artists' face drawings also contain stereotyped errors (Costa & Corazza, 2006; Hayes & Milne, 2011), some of the patterns of artists' errors were different in direction than those we observed in non-artists – for instance, Hayes and Milne's (2011) findings of the upper region of the face being drawn too narrow, the two eyes being positioned too close together, and the mouth being positioned too close to the chin. Such expert-novice comparisons might be a fruitful future direction, especially since expert-novice drawing comparisons have typically been based on holistic accuracy ratings, which do not inform specific expert-novice differences other than the common finding that artists' drawings are perceived by judges to be more accurate than non-artists' drawings.

Following this point more generally, the spatial relations objective measurement scheme employed in this study complements the traditional method of measuring drawing accuracy through subjective ratings as the two methods of measurement assess drawing accuracy at different levels of analysis. While the objective measurement scheme used in this study to assess spatial drawing accuracy allows precise quantification of how the spatial positioning of features in the drawings deviate from the model being copied, subjective accuracy ratings allow one to quantify the degree to which independent observers perceive how accurately a drawing reproduces the visual information in the model. Thus, one measurement method provides information that the other does not, and vice versa.

A question that arises from the complementary nature of these two measurement methods is the relationship between the two with respect to face drawing. Subjective judgments about the perceived quality of a face drawing are highly likely to be influenced by many different factors, where errors in reproducing the spatial positioning of features are just one set of multiple related variables. Indeed, it was found that, to varying degrees of magnitude, errors in reproducing all of the spatial relations measured in this study were negatively correlated to the subjective accuracy ratings (with an average r = -.29),[8] suggesting that the degree to which participants err in reproducing multiple spatial relationships among facial features influences judgments of the perceived accuracy of the face drawings. Some of the spatial relationships were related more to the subjective ratings than others, with the vertical position of the eye-line and mouth on the length of the face being most strongly associated with subjective ratings (C/A ratio errors accounting for 32.5% and L/A ratio errors accounting for 15% of the variance of the subjective ratings) and the diagonal distance between the outer corners of the eyes and the bottom of the center lip relative to the horizontal distance between the outer corners of the two eyes being most

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[8] This average correlation was calculated by converting the 13 *r* correlation coefficients to *z*' values, taking the average of the *z*' values, and then re-converting the average *z*' to a *r* correlation coefficient to avoid biases due to the relatively small sample size (see Silver, Clayton & Dunlap, 1987).

weakly associated with subjective ratings (E/D ratio errors accounting for 0.1% and F/D ratio errors accounting for 0.04% of the variance of subjective ratings). Due to the observation that spatial drawing errors did not account for the majority of variance in the perceived accuracy of the drawings, it is important to acknowledge that the measurement of spatial positioning errors of facial features is a relatively narrow assessment of face drawing accuracy, providing no information on other presumably important aspects of face drawing accuracy, such as the accuracy to which participants reproduce the facial features themselves (e.g., how accurately the eyes, nose and mouth were drawn in isolation). Future research should aim to adopt measurement methods to objectively quantify the errors of reproducing the facial features themselves in order to achieve a more complete analysis of how a face drawing objectively deviates from the model being reproduced.

Another issue that arises when considering the relationship between objective and subjective measures of drawing accuracy is the degree of similarity in how these two classes of drawing accuracy measurement relate to performance in non-drawing tasks. In many studies (e.g., Cohen & Jones, 2008; Kozbelt, 2001; Ostrofsky et al., 2012), it has been found that subjective ratings of the perceived accuracy of drawings reliably predicts performance in a number of non-drawing tasks, such as the degree to which individuals experience perceptual constancy effects. But since subjective ratings holistically measure accuracy, it is impossible to determine which particular aspects of drawing accuracy are related to such non-drawing performance measures. In this study, we replicated findings that subjective ratings are negatively associated with shape and size constancy errors caused by the processing of depth cues (Cohen & Jones, 2008 and Ostrofsky et al., 2012, respectively) but are not associated with shape and size matching errors when all depth cues were removed from the target stimuli. However, upon analysis of the relationship between the objective measures of spatial drawing accuracy and perceptual constancy measures, it was evident that not all spatial drawing errors were associated with perceptual constancy errors and not all spatial drawing errors were uncorrelated with perceptual matching errors when no depth cues are present in the stimuli. Thus, these findings highlight a need for future research aiming to assess the relationship between drawing accuracy and non-drawing task performance to be more specific as to the precise elements of drawing accuracy that are related and unrelated to non-drawing performance measures.

As subjective ratings of drawing accuracy do not directly inform us of the specific drawing errors that are related to non-drawing task performance, they additionally do not inform us of the specific drawing errors that are affected by experimental manipulations such as model rotation (Cohen & Earls, 2010), model spatial frequency isolation (Freeman & Loschky, 2011) and model-to-drawing gaze shift frequency (Cohen, 2005), affect drawing accuracy when measured using holistic subjective ratings. This theme will be re-visited later, as Study 3 of my dissertation re-assesses the effect that model rotation has on drawing accuracy (Cohen & Earls, 2010) by analyzing objectively measured spatial drawing errors as opposed to the previously used subjective accuracy ratings.

Finally, by revisiting the particular patterns of spatial error that were observed, one must question the reliability and generalizability of the systematic error biases that were found. Since this was the first study that I am aware of testing for such effects in non-artists, it is important to acknowledge (1) the possibility of Type I errors being made in reporting a systematic direction of error in reproducing facial features, and (2) the possibility that some systematic error biases were specific to drawings of the single adult Caucasian female face used as the model stimulus. Needless to say, there is substantial individual variability in the relative spatial positioning of facial features across different individuals' faces and previous research has demonstrated group-based differences in the average relative spatial positioning of facial features. For example, on average, males have larger inter-ocular and mouth-to-chin distances and wider upper faces than females (Bishara, Jorgensen & Jakobsen, 1995; Dodgson, 2004). Further, on average, Caucasians have smaller inter-ocular distances than African Americans, Hispanics, Pacific Islanders and Native Americans (Dodgson, 2004). It is an open question whether the biases observed presently would generalize to (1) drawings made of other adult Caucasian female faces, and (2) drawings of male faces or faces of different races. Examining which types of spatial drawing biases of faces are universal, versus specific to a particular individual face or groups of faces, is an empirical question worth evaluation.

So, efforts were made to probe the reliability and generalizability of the findings that errors in reproducing some spatial relationships among facial features were associated with reliable directional biases. In Study 1B, a different sample of participants drew from observation one of three photographs of an adult Caucasian female face (one of the three being the same photograph used in the previously described study). These drawings were collected in the context of a larger study, but only the analysis of the objective measures of spatial drawing errors will be discussed in the following section. In Study 2, we further probed the generalizability of the effects observed in Study 1A by having participants draw a photograph of an adult Caucasian male face.

2.4 Method – Study 1B.

2.4.1 Participants.

One hundred and five individuals participated in this study. Participants were undergraduate Introduction to Psychology students recruited from the University of North Carolina in Wilmington and were compensated with course credit. Twenty four participants did not produce a complete face drawing, where the eyes, nose, mouth and/or hair were not reproduced. These drawings were not included in the analysis to follow, and therefore, we will only consider the drawings of the 81 participants who reproduced all major facial features and the hair of the model.

2.4.2 Materials.

Each participant was asked to draw one of three photographs depicting an adult Caucasian female's face in the frontoparallel with a neutral emotional expression (see Figure 6). The model photographs were printed on an 8.5'' × 11'' sheet of white paper in the portrait orientation. This was presented by being mounted on a 24'' × 36'' board positioned in front of the participants. Participants were provided a pencil, eraser and 8.5'' × 11'' sheet of white paper to create their drawing.

Figure 6. The model face stimuli reproduced in Study 1B. (a) Face 1. (b) Face 2. (c) Face 3.

2.4.3 Procedure.

Participants were randomly assigned one of the three model photographs to draw. Of the drawings that will be included in the data analysis, this resulted in 37 participants drawing *Face 1*, 25 participants drawing *Face 2* and 19 participants drawing *Face 3*. After providing informed consent, participants were instructed to pay close attention to the details of the model photograph and draw as accurate a copy of the face as they can. It was emphasized that creativity, aesthetic value or style was not important. Participants were given a 10-minute time limit to complete their drawing.

2.4.4 Measurements of Drawn Spatial Relations and Errors.

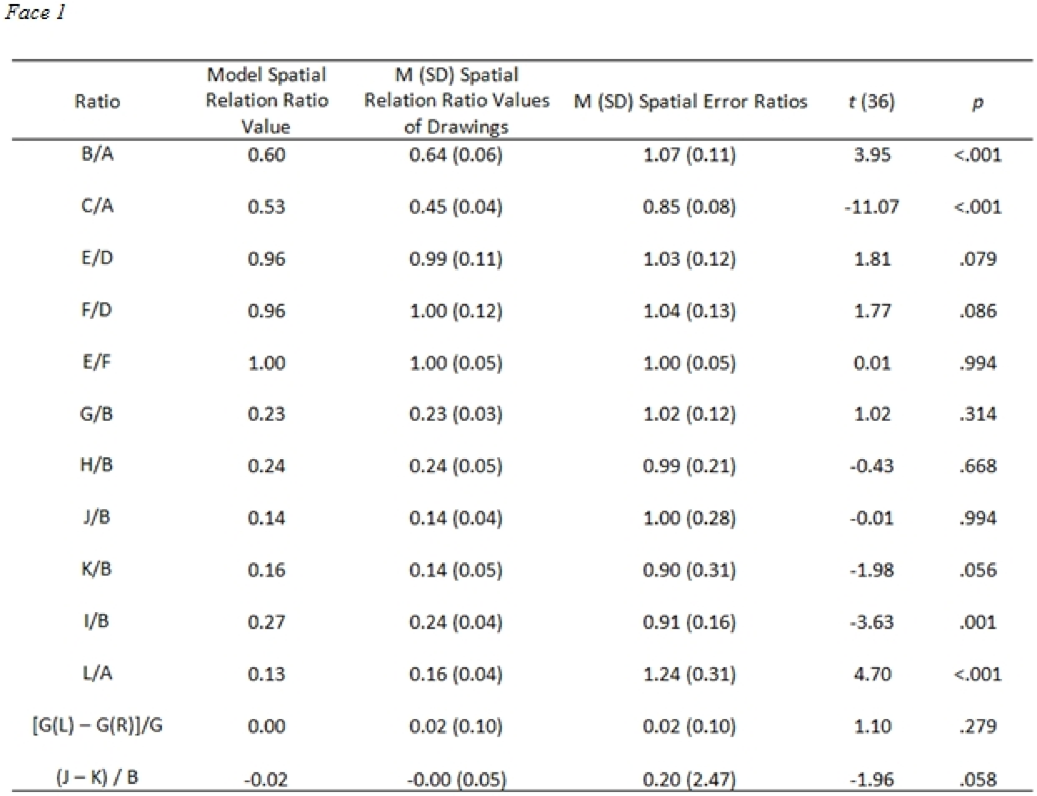
The twelve measurements, the 13 spatial relation ratios, and the ratio errors of the drawings were measured in the same way as described in Study 1A (see Figure 4 for a description of each spatial relation ratio and Table 1 for how to interpret the ratio error values).

2.5 Results – Study 1B.

As a reminder of the results of Study 1A, participants' drawings of an adult female face (Face 1 in this study) reliably drew the face too round (B/A ratio), the eyes and mouth too far up the length of the face (C/A & L/A ratios), the eyes too far apart (H/B ratio) and too close to the sides of the face (J/B & K/B ratios) and the nose too narrow (I/B ratio). Here, the goal of the following analysis is to determine whether these effects can be replicated (by analyzing errors associated with drawings of Face 1) and whether they generalize to drawings of other adult Caucasian female faces (by analyzing errors associated with drawings of Faces 2 and 3). The means and standard deviations of the spatial relation ratio values and error ratio values of the drawings are presented along with the spatial relation ratio values of the three model photographs in Tables 4, 5 and 6. As with Study 1A, 13 single sample t tests (one for each of the spatial relation ratios) were conducted comparing the error ratio values against a test value of 1 in order to determine whether errors are reliably biased in one direction. This was performed separately for the three groups of drawings based on the three different model photographs.

Model Face 1 Since this model was the same one used in Study 1A, I analyzed whether the spatial drawing error effects previously described can be directly replicated. Four of the seven reliable spatial error effects that were observed in Study 1A were also observed here. First, participants were observed to draw the face rounder than the model face (B/A ratio), t (36) = 3.95, $p < .001$, Cohen's $d = 0.65$. Second, participants reliably drew the eyes farther up the length of the face than they were in the model (C/A ratio), t (36) = -11.07, $p < .001$, Cohen's $d = 1.82$. Third, the mouth was reliably drawn farther up the length of the face than it was in the model (L/A ratio), t (36) = 4.70, $p < .001$, Cohen's $d = 0.77$. Finally, the nose was drawn more narrow than it was in the model with respect to the width of the face (I/B ratio), *t* (36) = -3.63, *p* = .001, Cohen's *d* = 0.60.

Table 4.



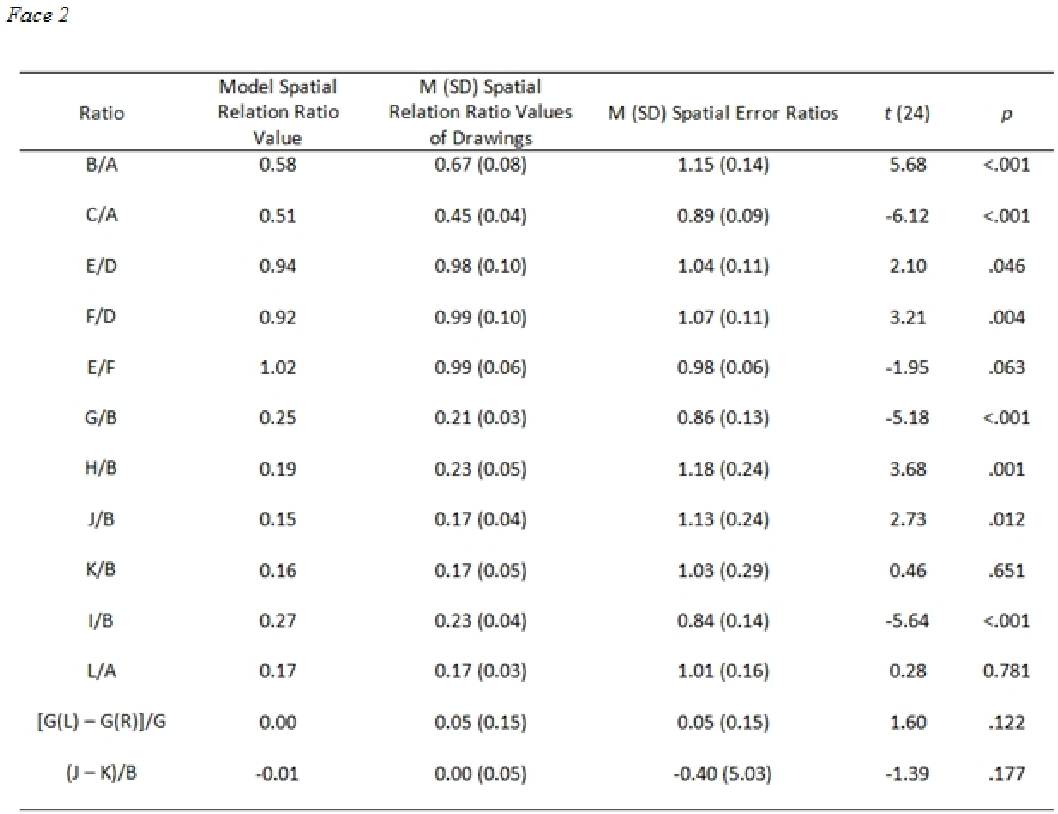
Face 1

Ratio	Model Spatial Relation Ratio Value	M (SD) Spatial Relation Ratio Values of Drawings	M (SD) Spatial Error Ratios	*t* (36)	*p*
B/A	0.60	0.64 (0.06)	1.07 (0.11)	3.95	<.001
C/A	0.53	0.45 (0.04)	0.85 (0.08)	-11.07	<.001
E/D	0.96	0.99 (0.11)	1.03 (0.12)	1.81	.079
F/D	0.96	1.00 (0.12)	1.04 (0.13)	1.77	.086
E/F	1.00	1.00 (0.05)	1.00 (0.05)	0.01	.994
G/B	0.23	0.23 (0.03)	1.02 (0.12)	1.02	.314
H/B	0.24	0.24 (0.05)	0.99 (0.21)	-0.43	.668
J/B	0.14	0.14 (0.04)	1.00 (0.28)	-0.01	.994
K/B	0.16	0.14 (0.05)	0.90 (0.31)	-1.98	.056
I/B	0.27	0.24 (0.04)	0.91 (0.16)	-3.63	.001
L/A	0.13	0.16 (0.04)	1.24 (0.31)	4.70	<.001
[G(L) – G(R)]/G	0.00	0.02 (0.10)	0.02 (0.10)	1.10	.279
(J – K) / B	-0.02	-0.00 (0.05)	0.20 (2.47)	-1.96	.058

In contrast to what was observed in Study 1A, the eyes were not reliably drawn farther apart than they were in the model with respect to the width of the face (H/B ratio), *t* (36) = -0.43, *p* = .668, Cohen's *d* = 0.07. Further, even though there was a marginally reliable trend to draw the right eye closer to the right side of the face than it was in the model with respect to width of the face (K/B ratio), *t* (36) = -1.98, *p* =.056, Cohen's *d* = 0.33, the left eye was not reliably drawn closer to the left side of the face than it was in the model with respect to the width of the face (J/B ratio), *t* (36) = -0.01, *p* = .994, Cohen's *d* < 0.01. The error ratios for the remaining spatial relation ratios were not reliably different from 1 (p > .004) as was the case in Study 1A.

Model Face 2 Similar to the drawings of Face 1 in this study and in Study 1A, participants reliably drew the face rounder than it was in the model (B/A ratio), *t* (24) = 5.68, *p* < .001, Cohen's *d* = 1.14. Additionally similar was the observation that participants reliably drew the eyes farther up the length of the face than it was in the model (C/A ratio), *t* (24) = -6.12, *p* < .001, Cohen's *d* = 1.22. A final similarity in errors shared with Face 1, drawings of Face 2 reliably reproduced the nose more narrow than it was in the model with respect to the width of the face (I/B ratio), *t* (24) = -5.64, *p* < .001, Cohen's *d* = 1.13.

Table 5.



Face 2

Ratio	Model Spatial Relation Ratio Value	M (SD) Spatial Relation Ratio Values of Drawings	M (SD) Spatial Error Ratios	*t* (24)	*p*
B/A	0.58	0.67 (0.08)	1.15 (0.14)	5.68	<.001
C/A	0.51	0.45 (0.04)	0.89 (0.09)	-6.12	<.001
E/D	0.94	0.98 (0.10)	1.04 (0.11)	2.10	.046
F/D	0.92	0.99 (0.10)	1.07 (0.11)	3.21	.004
E/F	1.02	0.99 (0.06)	0.98 (0.06)	-1.95	.063
G/B	0.25	0.21 (0.03)	0.86 (0.13)	-5.18	<.001
H/B	0.19	0.23 (0.05)	1.18 (0.24)	3.68	.001
J/B	0.15	0.17 (0.04)	1.13 (0.24)	2.73	.012
K/B	0.16	0.17 (0.05)	1.03 (0.29)	0.46	.651
I/B	0.27	0.23 (0.04)	0.84 (0.14)	-5.64	<.001
L/A	0.17	0.17 (0.03)	1.01 (0.16)	0.28	0.781
[G(L) – G(R)]/G	0.00	0.05 (0.15)	0.05 (0.15)	1.60	.122
(J – K)/B	-0.01	0.00 (0.05)	-0.40 (5.03)	-1.39	.177

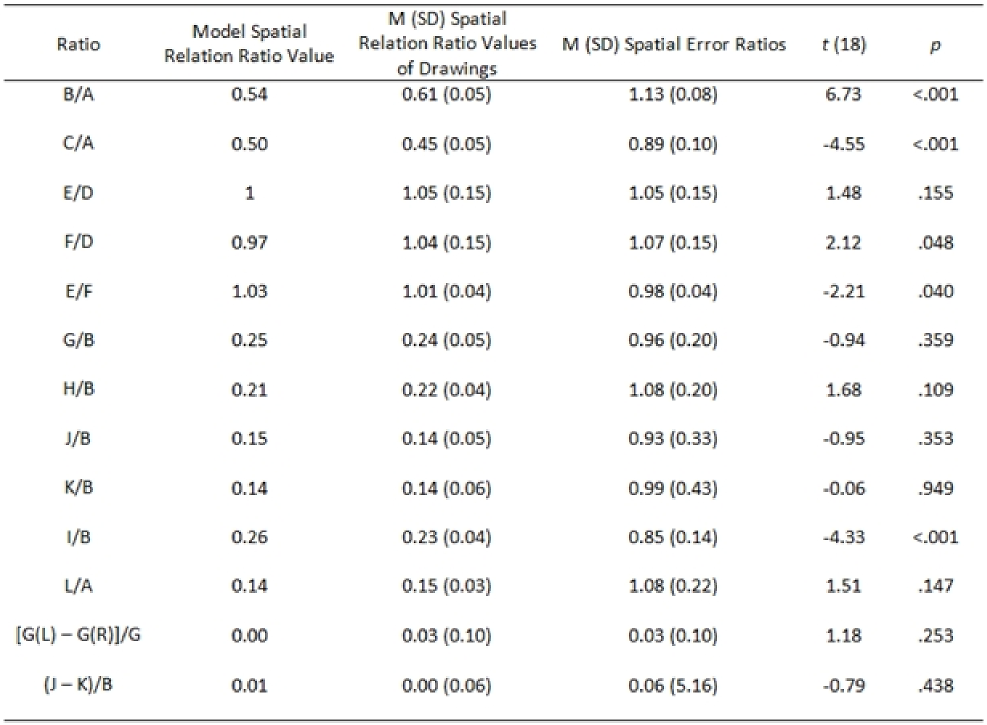
Similar to drawings of Face 1 in Study 1A but not Study 1B, drawings of Face 2 reliably reproduced the eyes farther apart than they were in the model with respect to the width of the face (H/B ratio), t (24) = 3.68, p = .001, Cohen's d = 0.74.

Unlike drawings of Face 1 in both Studies 1A and 1B, participants reliably drew the eyes narrower than they were in Face 2 with respect to the width of the face (G/B ratio), t (24) = -5.18, p < .001, Cohen's d = 1.04. An additional dissimilarity between drawings of Faces 1 and 2 were that there were marginally reliable trends to draw the diagonal distances between the outer corners of the eyes and the bottom of the lower lip longer than they were in the model relative to the distance between the outer corners of the left and right eye (E/D ratio: t (24) = 2.10, p = .046, Cohen's d = 0.42; F/D ratio: t (24) = 3.21, p = .004, Cohen's d = 0.64). A final dissimilarity between drawings of Faces 1 and 2 was the finding that there was a marginally reliable trend for participants to draw the left eye farther away from the side of the face than it was in Face 2 with respect to the width of the face (J/B ratio), t (24) = 2.73, p = .012, Cohen's d = 0.54. The error ratios for the remaining spatial relation ratios were not reliably different from 1 (p > .004).

Model Face 3 Similar to drawings made of Faces 1 and 2, the participants drew the face rounder than it was in Face 3 (B/A ratio), t (18) = 6.73, p < .001, Cohen's d = 1.54. Also similar to the drawings of Faces 1 and 2, participants reliably drew the eyes farther up the length of the face than it was in Face 3 (C/A ratio), t (18) = -4.55, p < .001, Cohen's d = 1.04. A final similarity to drawings of both Faces 1 and 2, participants reliably drew the nose narrower than it was in Face 3 with respect to the width of the face (I/B ratio), t (18) = -4.33, p < .001, Cohen's d = 1.02.

Table 6.

Face 3



Ratio	Model Spatial Relation Ratio Value	M (SD) Spatial Relation Ratio Values of Drawings	M (SD) Spatial Error Ratios	*t* (18)	*p*
B/A	0.54	0.61 (0.05)	1.13 (0.08)	6.73	<.001
C/A	0.50	0.45 (0.05)	0.89 (0.10)	-4.55	<.001
E/D	1	1.05 (0.15)	1.05 (0.15)	1.48	.155
F/D	0.97	1.04 (0.15)	1.07 (0.15)	2.12	.048
E/F	1.03	1.01 (0.04)	0.98 (0.04)	-2.21	.040
G/B	0.25	0.24 (0.05)	0.96 (0.20)	-0.94	.359
H/B	0.21	0.22 (0.04)	1.08 (0.20)	1.68	.109
J/B	0.15	0.14 (0.05)	0.93 (0.33)	-0.95	.353
K/B	0.14	0.14 (0.06)	0.99 (0.43)	-0.06	.949
I/B	0.26	0.23 (0.04)	0.85 (0.14)	-4.33	<.001
L/A	0.14	0.15 (0.03)	1.08 (0.22)	1.51	.147
[G(L) – G(R)]/G	0.00	0.03 (0.10)	0.03 (0.10)	1.18	.253
(J – K)/B	0.01	0.00 (0.06)	0.06 (5.16)	-0.79	.438

Similar to the drawings of Face 2 but not Face 1, there was a marginally reliable trend for participants to draw the diagonal distance between the outer corner of the right eye and the bottom of the lower lip longer than it was in Face 3 relative to the distance between the outer corners of the two eyes (F/D ratio), t (18) = 2.12, p =.048, Cohen's d = 0.49. This was not the case for the similar diagonal distance from the outer corner of the left eye (E/D ratio), t (18) = 1.48, p =.155, Cohen's d = 0.34. All other error ratios from the remaining spatial relation ratios were not reliably different from a test value of 1 (p > .004).

2.6 Discussion – Study 1B.

In assessing the reliability of the effects observed in Study 1A in the drawings made of Face 1, it was found that some of the directional error bias effects replicated and others did not. Stable across Studies 1A and 1B were the findings that the face was drawn too round (B/A ratio), the eyes and mouth were drawn too far up the length of the face (C/A and L/A ratios, respectively), and the nose was drawn too narrow (I/B ratio). Findings in Study 1A that the inter-ocular distance is systematically drawn too large and that both eyes are systematically drawn too close to the sides of the face were effects that failed to replicate in Study 1B with respect to drawings of Face 1.

Further, in assessing the generalizability of these directional error biases, there was evidence that suggests that some biases are universal across faces of different individual females and some are specific to a particular female faces. Across the drawings of all three model female faces, reliable biases to draw the face too round, the eyes too far up the face and the nose too narrow were observed, indicating that these three biases are potentially universal when most non-artists draw any adult Caucasian female face. In contrast, there was one directional error bias that seems to be relatively stable but specific to drawings of Face 1. In both Studies 1A and 1B (and as will be seen later in Study 3), participants reliably drew the mouth farther up the length of the face than it was in the Face 1 model (L/A ratio). In contrast to this strong reliability, this effect did not generalize to the drawings of female Faces 2 and 3 (and as will be seen later in Study 2, did not generalize to drawings of an adult Caucasian male face). This could potentially be due to the observation that, out of the three female faces used as models in Study 1B and the 1 male face used as a model in Study 2, the lower lip-to-chin distance relative to the length of the face was smallest in Face 1. Thus, there might be an overall tendency to draw the vertical position of the mouth at a given range of values that is higher than it appears in Face 1 but not in Faces 2 and 3.

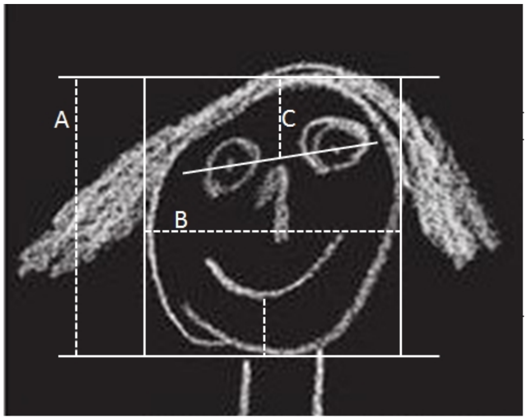
In support of the above claim, if one averages the values of L/A ratio values across all 81 drawings, the resulting mean is 0.16 (+/- 0.03). The greater the L/A ratio values of the models diverged from 0.16, the greater the mean error in reproducing this was in the drawings. For instance, Face 2's L/A ratio value was very close to this, being 0.17, and the mean error ratio value in reproducing Face 2's L/A ratio was 1.01, indicating that the participants, on average, drew the vertical position of the mouth on the length of the face 1% higher than it was in Face 2. Face 3's L/A ratio value of 0.14 was at a greater distance from the 0.16 average of the L/A ratio of all the drawings, and the mean error ratio of drawings of Face 2 was 1.07, indicating an average bias to draw the mouth 7% higher on the length of the face than it was in Face 2. Face 1's L/A ratio value of 0.13 was at an even greater distance from the 0.16 average of all the drawings' L/A ratio values, and the mean error ratio of the drawings of Face 1 was 1.24, indicating that, on average, participants drew the mouth 24% higher up the length of the face than it was in the model. Thus, for some spatial relationships like the one quantified by the L/A ratio, there might be a central tendency around which most non-artists relatively position facial features irrespective of how they are spatially positioned in the model, and the greater the model diverges from this central drawing tendency, the greater the measured errors will be. Such an idea can be evaluated in the future by measuring drawings of a larger set of models and evaluating how the degree of drawing error is influenced by the degree of difference between the models' relative spatial positioning of target features and the central tendency of drawings of that spatial relationship.

2.7 General Discussion

An important question raised by the results of Studies 1A and 1B relate to the possible sources of the biases we found to be reliable across the drawings of all three model faces (face drawn too round (B/A ratio), eyes drawn too far up the face (C/A ratio) and the nose drawn too narrow (I/B ratio)). The results here do not provide any conclusive information on what drives these biases in the observed directions, but we can offer speculations based on previous research. One possible mechanism could be related to biases in how attention is deployed during face perception. Consider our finding that of the 127 drawings analyzed in Studies 1A and 1B, 117 (92%) of the drawings positioned the vertical position of the eye-line farther up the length of the face than it was in the model being reproduced, and, thus, attenuated the length of the forehead in the drawings. Previous research has revealed that, when perceiving a face, attention is deployed more frequently and for longer periods of time to the eyes than to the forehead region (Heisz & Shore, 2008; Nguyen, Isaacowitz & Rubin, 2009). If such an attentional bias is present while drawing, then the attenuation of the forehead and the up-shift of the vertical eye-position could be explained by participants ignoring the spatial properties of the forehead and thus not fully attending to the task of accurately reproducing this region. Eye-tracking could be a valuable tool to inform this issue across facial features, as could interventions where participants are instructed to attend to particular spatial relationships, to see if this improves drawing accuracy (cf. Sutton & Rose, 1998). Such a hypothesis is consistent with the advice of "how-to" drawing manuals, which commonly provide schematic guides highlighting the important spatial relations of faces that should be attended to (e.g., Hamm, 1963, pgs. 1-5).

Another possible source of the observed biases relates to how individuals canonically represent the spatial relations among facial features in memory. Matthews and Adams (2008) reported that the spatial relations in observation-based drawings of cylinders are correlated with those produced in imagination-based drawings of cylinders. Since the latter category of drawings were produced without any directly perceivably model to guide drawing, the spatial relations produced in imagination-based drawings were assumed to reflect a long-term memory representation of the spatial relationships of cylinders, which influence drawing production even in an ostensibly observation-based drawing task. A similar mechanism could explain the observed biases in face drawing, suggesting that some of the systematic patterns of error observed in the present study at least partly originate in the processing of information inherent in long-term memory representations of faces. This hypothesis was tested in Study 2 of this dissertation.

Yet another potentially fruitful approach to drawing biases concerns the developmental trajectory of how spatial relations of a face are drawn. When do such biases emerge, and how do they change or stay the same during lifespan development? Do the processes contributing to systematic biases made by adult non-artists reflect processes occurring early in childhood? This is a difficult set of questions to address since, to my knowledge, no formal quantitative analysis of children's spatial face drawing biases has yet been conducted. To better inform speculations on this topic, I conducted a preliminary analysis computing the B/A and C/A spatial relation ratio values (two of the three spatial relation ratios found to have a single reliably biased direction of error across drawings of all three model faces in Study 1B) of 140 five- and six-year olds' self-portraits (see Figure 7 and its caption for details). Although a direct quantitative comparison between the children's drawings and those produced by our adult sample would not be valid, informal comparisons of the children's average spatial relation ratio values and the direction of adults' deviations from the model photograph provide some useful information. For instance, the average shape of the face drawn by children is almost a circle (the width-to-length ratio is on average 99.7%). Whereas the non-artists in our sample did not draw the shape of the face as a circle, 103 out of 127 drawings (81%) in Studies 1A and 1B drew the shape of the face rounder than the shape of the model face. Further, children draw the vertical position of the eye-line on average 31.9% down from the top of the face, indicating a bias to draw the vertical position of the eye-line farther up the face than it is for most faces, which on average approximates 50% (Hamm, 1963). This same bias was present among adult non-artists, as 117 out of 127 drawings (92%) positioned the vertical position of the eye-line farther up the length of the face than in the model being drawn. Such informal comparisons suggest that childhood face drawing biases may persist into adulthood for non-artist individuals. In order to more conclusively support this claim, future research should adopt a developmental approach and study how the spatial relations of a face are drawn from childhood to adulthood under standardized drawing task conditions.



	B/A	C/A
Model Face	.735	.419
Observational Drawings	.765 (.085)	.361 (.062)
5- and 6-year old children's drawings	.997 (.220)	.319 (.090)

Figure 7. A sample of face drawings produced by 140 five and six year old children from 36 different countries was taken from the "Portrait/Self Portrait: Early Pictures in Different Cultural Contexts" collection (Porte, Maurer & Gujer, 2012). These drawings were made by children who were asked to produce a self-portrait from memory. Drawings were measured for spatial-relation ratios B/A and C/A (two of the spatial relationships that were found to be drawn with reliable single directional error biases). There were important differences between how "A" was measured for children's drawings and how they were measured as described in Figure 4. Since most children's drawings did not include hair, "A" was measured as the longest vertical distance between the *top of the head* if there was no hair or *the hairline* if there was hair and *the bottom of the head*. This figure illustrates this measurement scheme for a drawing that was relatively average with respect to the two

spatial-relation ratio values of the full sample of drawings. The model photograph in Study 1 (Figure 1) and our participants' drawings in Study 1A were re-measured according these guidelines. The mean (standard deviation) of the children's and participants' updated spatial-relation ratio values and the updated spatial-relation values of the model photograph are shown here. Updating the spatial-relation values of the observational drawings and model photograph still resulted in the same reliable systematic patterns of error found using the original measurement scheme (testing error ratios against a test value of 1 - B/A: $p < .05$; C/A: $p < .001$).

In any case, the results of Studies 1A and 1B suggest that the accuracy of face drawings need not only be measured by subjective ratings, the method that has dominated empirical studies to date. Rather, objectively measuring specific spatial aspects of drawing errors has the potential to allow precise, clearly defined analyses of specific aspects of face drawing accuracy. Indeed, our analysis uncovered previously undocumented findings on biases in non-artists' drawings of faces. Such results highlight the importance of objective measures in the study of drawing accuracy.

In conclusion, the development of objective measures in drawing accuracy promises to further our understanding of the cognition of drawing. The challenge of future research will be to devise methods on how to objectively measure other aspects of drawing accuracy, whether featural for face drawings or other aspects for other categories of objects. To date, there have been cases of other drawing studies using other categories of objects as the model stimulus, such as plain angles (Carson & Allard, 2013) and line drawings of bodies (Tchalenko, 2009), that have successfully utilized objective measures of drawing accuracy to understand the psychological processes associated with drawing behavior. We hope that this effort continues to further our understanding of this all-too-poorly understood topic.

3. Study 2

In Study 1, we found evidence that the observational drawings of multiple spatial relationships between facial features are associated with systematic errors that are reliably biased in particular directions. Specifically, evidence generated by Study 1B suggested that some of these biases tend to be robust over the drawings of multiple face models (e.g., face drawn too round, eyes drawn too far up the length of the face and the nose drawn too narrow) and one of these biases are specific to the face being drawn (e.g., the mouth drawn too far up the length of the face in model Face 1 only). One question that emerges from such findings concerns the potential sources of such error biases. What psychological processes might contribute to the production of such reliable and robust spatial drawing errors?

Study 2 evaluated the idea that face-based information represented in long-term memory might be an influential factor in the production of such spatial errors in the drawings made by non-artists. In the General Introduction of this dissertation, multiple sources of evidence were described that suggest the top-down processing of information represented in long-term memory influence the production of observational drawings, such as those of cylinders and other familiar objects (Glazek, 2012; Matthews & Adams, 2008). However, no previous research to my knowledge has attempted to determine whether such evidence can be found with respect to the drawings of faces. Thus, in Study 2, I evaluated whether there is an association between observational drawing errors and biases inherent in long-term memory representations with respect to the relative spatial positioning of facial features. Two methodological strategies were employed to determine whether such an association exists. First, the nature of biases inherent in the long-term memory representations of the spatial relationship between facial features was determined by comparing imagination-based drawings to an estimated “average face”. Namely, participants were asked to produce an imagination-based drawing of an adult Caucasian male face in the frontal view without the guide of a directly perceivable model, and multiple spatial relationships were measured by computing the same 13 spatial relation ratios that were calculated in Study 1. In order to determine any potential biases inherent in the memory representations guiding these drawings, the spatial relation ratios were compared between the drawings and the mean values of a set of 50 photographs depicting the frontal-view faces of adult Caucasian males. If one assumes that the average of the spatial relation ratios of the photograph collection closely estimates the spatial relationships between facial features of the "average adult Caucasian male face", then any reliable deviations of the spatial relation ratios of the imagination-based drawings from the average of these ratios of the "average adult Caucasian male face" can be considered as reliable biases inherent in the long-term memory representations of faces in non-artists.

In order to determine whether such potential long-term memory biases are congruent with any systematic directional error biases in the production of observational-based drawings, participants were asked to reproduce through drawing a directly perceivable model image of a single adult Caucasian male's face. As in Study 1, I determined whether participants are reliably biased to err in reproducing spatial relationships between facial features in a single direction. If systematic observational drawing errors are partially influenced by long-term memory biases, then any reliable directional error biases found in the observational drawings (e.g., participants drawing the face rounder than the model face) should also be evident as biases in the imagination-based drawings in the same direction (e.g., the shape of the face in the participants' imagination-based drawings should be, on average, rounder than the average shape of the faces in the photograph collection).

In order to further probe the possible influence of long-term memory representations on non-artist performance in the observational drawing of faces, I attempted to determine whether how the spatial relationships produced in the imagination-based drawings were depicted are able to reliably predict how the spatial relationships are reproduced in the observation-based drawings. Namely, correlational analyses were conducted testing for a relationship between the spatial relation ratio values of the two types of drawings. If observational drawings of the spatial relationships between facial features are partially influenced by information inherent in long-term memory, one should expect the spatial relation ratio values to be positively correlated between the imagination- and observation-based drawings. These predictions were tested by the study described below.

3.1 Method.

3.1.1 Participants.

Thirty-eight individuals (32 females and 6 males; *M* (*SD*) age = 22.84 (3.44) years) participated in this study. Participants were recruited from the Brooklyn College Psychology Undergraduate Subject Pool and were compensated by receiving course credit.

3.1.2 Materials

One task participants were asked to complete was to create a drawing of a face based on observation of a photograph. The photograph that served as the model of these observation-based drawings was taken from the Psychological Image Collection at Stirling (PICS) Utrecht ECVP Database[9] (image “m4001”) (see Figure 8). The photograph depicts a frontal view image of an adult male Caucasian face with neutral emotional expression. The photograph was presented to

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[9] The face image databases of PICS can be accessed at: http://pics.stir.ac.uk

participants in grayscale and printed on an 8.5 × 11 in. sheet of paper. The image of the photograph measured 8 × 10.75 in. on the printed sheet of paper.

Figure 8. The model photograph participants reproduced in Study 2.

Participants were asked to create the observation-based drawing of the photograph described above in addition to creating a drawing of a face based on their imagination without any external referent stimulus. Participants were provided with an 8.5 × 11 in. sheet of blank white paper to draw on for each of the two drawing tasks. Further, participants were provided with a sharpened No. 2 pencil, an eraser and a manual pencil sharpener to use in creating their drawings.

For the purpose of determining average values of the spatial-relations ratios of adult Caucasian male faces, 50 photographs depicting such individuals were obtained from 4 online face photograph databases: (1) PICS Utrecht ECVP database[1], (2) PICS Aberdeen database[1], (3) The Informatics and Mathematical Modeling (IMM) Frontal Face Database[10] (Fagertun & Stegmann, 2005) and (4) The Investigative Interviewing Research Laboratory (IIRL) Face Database[11] (Meissner, Brigham & Butz, 2005). Photographs that were chosen from these databases always depicted an adult male Caucasian face shown in the full frontal view and with a neutral emotional expression and no facial hair.

3.1.3 Procedure

After providing informed consent, an explanation was provided to participants that they would be creating two drawings of faces. All participants first created the *imagination-based drawing*. Participants were instructed to create a drawing of the face of a typical adult male Caucasian. More detailed instructions were given that asked participants to (1) only draw a head, neck and shoulder line, (2) to draw all important facial features including the eyes, nose and mouth, (3) to draw the face with a neutral facial expression and (4) to not draw any facial hair. Participants were told that they could use the eraser and pencil sharpener if they needed. Participants were given a 15-minute time limit to create the drawing and were provided with a 5- and 1-minute warning.

After participants completed the imagination-based drawing, the *observation-based drawing* task was administered. Participants were provided with the model stimulus photograph and were asked to draw as accurate a copy of the photograph as possible. They were instructed that their goal is not to produce a highly creative drawing and were specifically told that they should not add any details not present in the photograph or eliminate any important details that are present in the photograph. Participants were told that they could use the eraser and pencil

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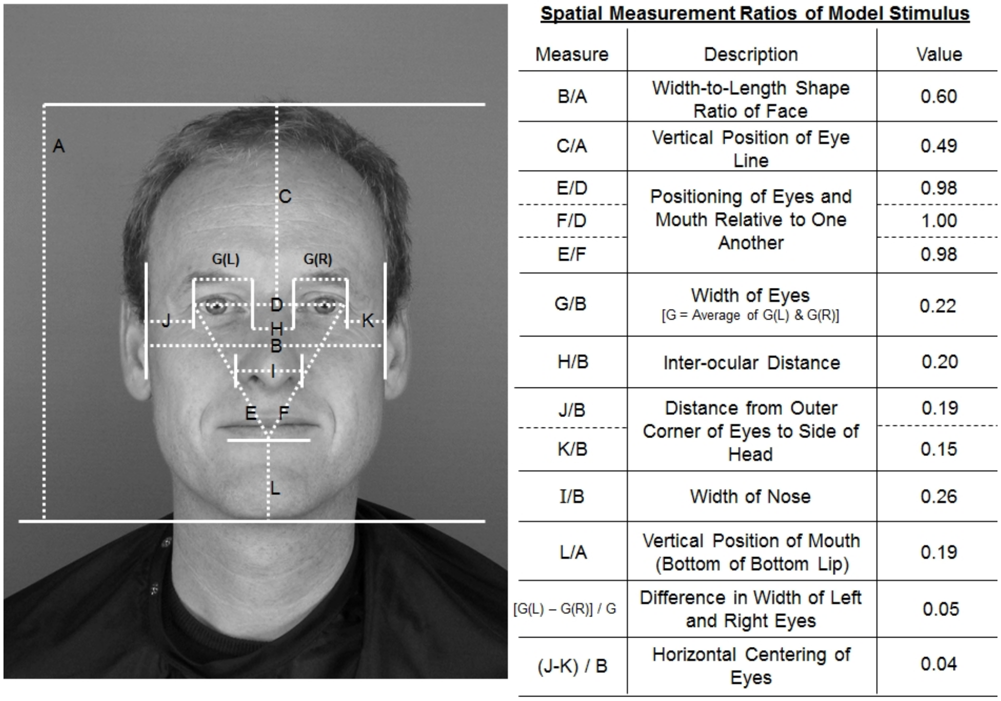
[10] The IMM Frontal Face Database can be accessed at: http://www2.imm.dtu.dk/pubdb/views/publication_details.php?id=3943

[11] The IIRL Face Database can be accessed at: http://iilab.utep.edu/stimuli.htm

sharpener if they needed and that they could use any drawing technique they wanted except for tracing (participants were monitored to ensure that they did not trace any element of the photograph). A 15-minute time limit was imposed on this task, and participants were provided with 5- and 1-minute warnings.

3.1.4 Measurements of Drawn Spatial Relations and Errors.

Twelve spatial measurements (in cm), Al through L, were made of the observation- and imagination-based drawings, the model photograph used for the observational drawing task and the 50 photographs of adult male Caucasian faces (see Figure 9). Measurements A through L were defined in the same way as they were in Study 1.



Spatial Measurement Ratios of Model Stimulus

Measure	Description	Value
B/A	Width-to-Length Shape Ratio of Face	0.60
C/A	Vertical Position of Eye Line	0.49
E/D	Positioning of Eyes and Mouth Relative to One Another	0.98
F/D		1.00
E/F		0.98
G/B	Width of Eyes [G = Average of G(L) & G(R)]	0.22
H/B	Inter-ocular Distance	0.20
J/B	Distance from Outer Corner of Eyes to Side of Head	0.19
K/B		0.15
I/B	Width of Nose	0.26
L/A	Vertical Position of Mouth (Bottom of Bottom Lip)	0.19
[G(L) – G(R)] / G	Difference in Width of Left and Right Eyes	0.05
(J-K) / B	Horizontal Centering of Eyes	0.04

Figure 9. Illustration of the 12 measurements made and definitions of the 13 spatial relation ratios that were computed in Study 2. Values of the spatial relation ratios of the model face are presented.

Based on these measurements, a number of ratios were calculated (defined and described in Figure 9, along with values of these ratios of the model face photograph). For the drawings created in the observation-based drawing task, spatial drawing errors for each ratio were calculated that were defined as:

Spatial Drawing Error Ratio = Drawing Ratio / Model Ratio

Interpretations of the direction of error are specific to each ratio and are defined for each ratio in Table 1.

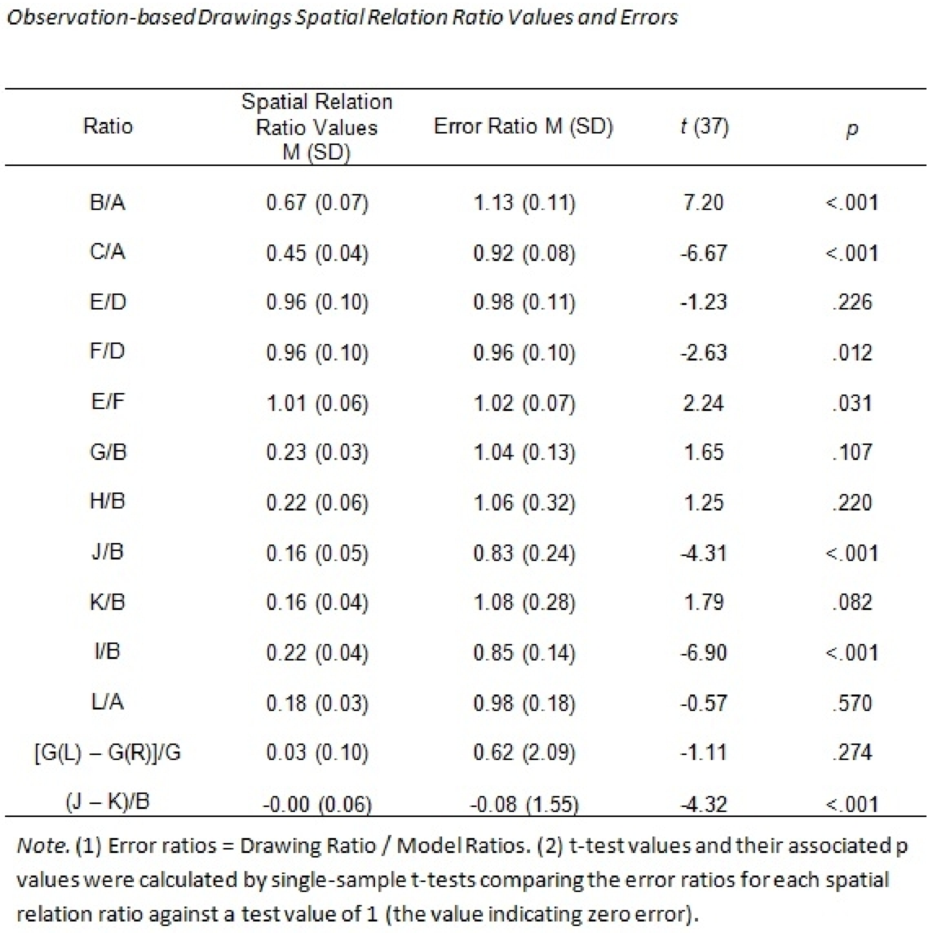
3.2. Results

Three sets of questions will be addressed by the data analysis of this study. First, the observation-based drawings will be analyzed to determine the whether errors in reproducing the spatial relationships between facial features are random or directionally biased in a particular direction. Second, I will analyze whether the imagination-based drawings contain any systematic biases that are similar to the systematic errors observed in the observation-based drawing task by comparing the average spatial relation ratio values between the imagination-based drawings and the collection of face photographs described above. Finally, it will be determined if there is a predictive relationship between the values of the spatial relation ratio values of the imagination- and observation-based drawings.

In order to determine the nature of errors present in the observation-based drawings, thirteen single-sample *t* tests were performed comparing the average of each spatial relation error ratio to a test value of 1. Table 7 displays *t* test and *p* value statistics for each error ratio. Five moderate-to-strong reliable effects were observed from these analyses. Participants were observed to reliably draw the face rounder than it was in the model (B/A ratio error), *t* (37) =

7.20, $p < .001$, Cohen's $d = 1.17$. There was a reliable bias to draw the eyes too far up the length of the face relative to the model (C/A ratio error), t (37) = -6.67, $p < .001$, Cohen's $d = 1.08$. Participants reliably drew the nose more narrow than it was in the model (I/B ratio error), t (37) = -6.90, $p < .001$, Cohen's $d = 1.12$. The left eye (from the observer's perspective) was found to be drawn closer to the left side of the face than it was in the model, t (37) = -4.31, $p < .001$, Cohen's $d = 0.70$. Finally, in the model photograph, the horizontal placement of the eyes with respect to the width of the face was slightly shifted to the right side of the face (from the observer's perspective) as indicated by the model value of the (J – K) / B ratio equaling +0.04. The drawings reliably deviated from this right horizontal shift in the opposite direction, t (37) = -4.32, $p < .001$, Cohen's $d = 0.70$, resulting in, on average, a more symmetrical placement that was minimally shifted to the left side of the face (mean value of (J – K) / B = -0.003).

Table 7.



Observation-based Drawings Spatial Relation Ratio Values and Errors

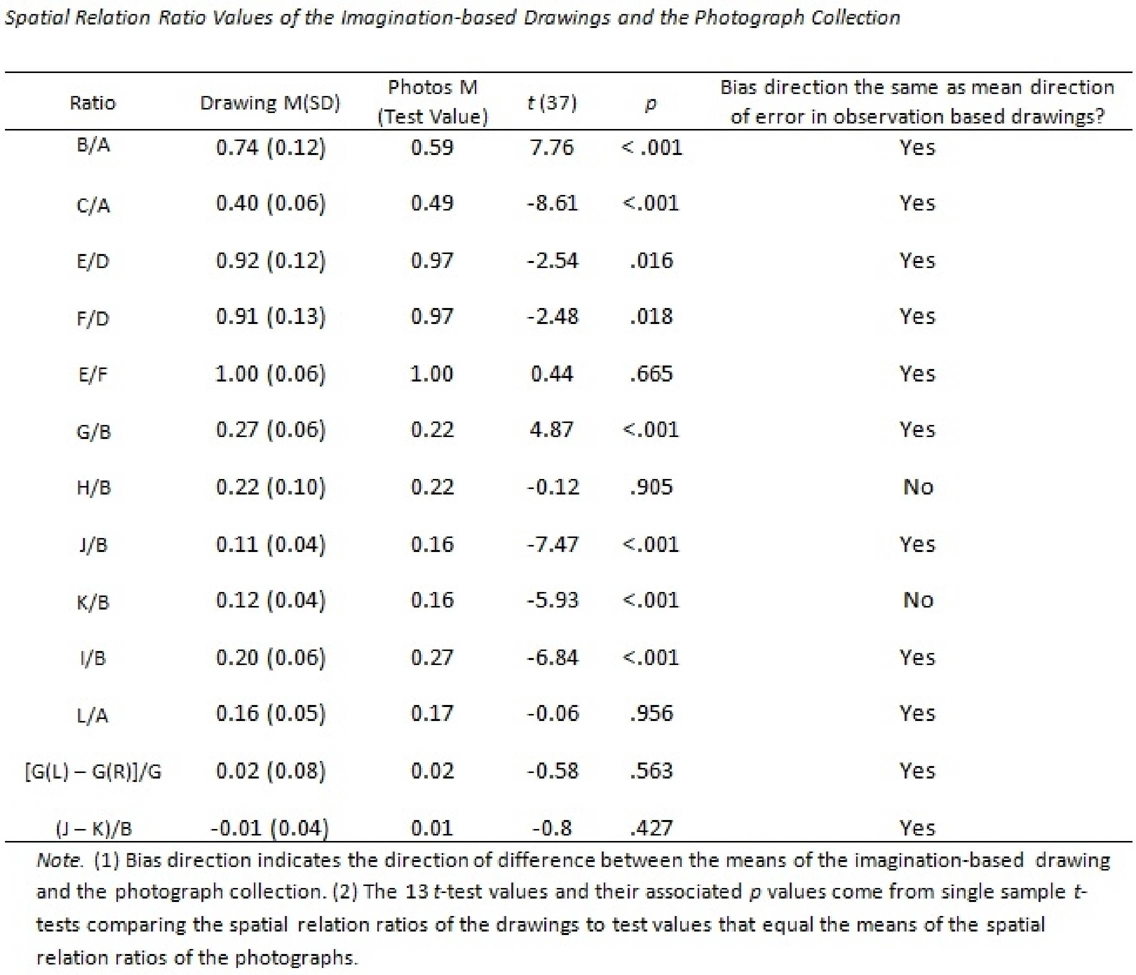
Ratio	Spatial Relation Ratio Values M (SD)	Error Ratio M (SD)	*t* (37)	*p*
B/A	0.67 (0.07)	1.13 (0.11)	7.20	<.001
C/A	0.45 (0.04)	0.92 (0.08)	-6.67	<.001
E/D	0.96 (0.10)	0.98 (0.11)	-1.23	.226
F/D	0.96 (0.10)	0.96 (0.10)	-2.63	.012
E/F	1.01 (0.06)	1.02 (0.07)	2.24	.031
G/B	0.23 (0.03)	1.04 (0.13)	1.65	.107
H/B	0.22 (0.06)	1.06 (0.32)	1.25	.220
J/B	0.16 (0.05)	0.83 (0.24)	-4.31	<.001
K/B	0.16 (0.04)	1.08 (0.28)	1.79	.082
I/B	0.22 (0.04)	0.85 (0.14)	-6.90	<.001
L/A	0.18 (0.03)	0.98 (0.18)	-0.57	.570
[G(L) – G(R)]/G	0.03 (0.10)	0.62 (2.09)	-1.11	.274
(J – K)/B	-0.00 (0.06)	-0.08 (1.55)	-4.32	<.001

Note. (1) Error ratios = Drawing Ratio / Model Ratios. (2) t-test values and their associated p values were calculated by single-sample t-tests comparing the error ratios for each spatial relation ratio against a test value of 1 (the value indicating zero error).

Having found a number of systematic spatial errors in the observation-based drawing task, one question that arises is whether these stereotyped errors are reflective of biases inherent in production-based representations stored in memory. In order to inform an answer to this question, the imagination-based drawings and a collection of 50 photographs of males were measured according to the 13 spatial relation ratios defined in Figure 9. If we assume that the mean of the photo-based spatial relation ratios approximates the central tendency of these relationships of the population of adult Caucasian male faces, then we can probe spatial memory biases by comparing the means between the imagination-based drawings and the photograph collection. This was done by conducting 13 single sample *t* tests where the spatial relation ratio values of the imagination-based drawings were compared to a test value defined as the mean of the spatial relation ratio values of the photograph collection.

Table 8 displays the results of these analyses in addition to the means and standard deviations of the spatial relation ratio values of the imagination-based drawings and the means of the spatial relation ratios of the photograph collection. In comparison to the mean spatial relation ratio values of the photograph collection, the imagination-based drawings reliably deviated, for the most part, in the same direction as the participants erred, on average, in the observation-drawing task. Indeed, the mean direction in which the imagination-based drawings deviated from the photograph collection means was the same as the mean direction of error of the observation-based drawings for 11 out of the 13 spatial relation ratios. Further, out of the 5 spatial relation ratios that were associated with a reliable direction of error in the observation-based drawings, 4 of these spatial relation ratios in the imagination-based drawings were associated with a reliable bias with respect to the photograph collection in the same direction (and were, coincidentally, the 4 spatial relation ratios associated with the 4 strongest effect sizes in these analyses). Specifically, in comparison to the photograph collection, the participants' imagination-based drawings were biased to: (1) draw the face as too round (B/A ratio), t (37) = 7.76, $p < .001$, Cohen's d = 1.26, (2) to draw the eyes too far up the length of the face (C/A ratio), t (37) = -8.61, $p < .001$, Cohen's d = 1.40, (3) to draw the left eye too close to the side of the face (J/B ratio), t (37) = -7.47, $p < .001$, Cohen's d = 1.21, and (4) to draw the nose too narrow with respect to the width of the face (I/B ratio), t (37) = -6.84, $p < .001$, Cohen's d = 1.11. Thus, these results indicate that there are spatial relation biases inherent in the long-term memory that are directionally congruent with respect to the spatial relationships that are associated with the strongest directional error biases present in observational drawings, suggesting that these memory biases might be related to the production of observational drawing errors.

Table 8.



Spatial Relation Ratio Values of the Imagination-based Drawings and the Photograph Collection

Ratio	Drawing M(SD)	Photos M (Test Value)	*t* (37)	*p*	Bias direction the same as mean direction of error in observation based drawings?
B/A	0.74 (0.12)	0.59	7.76	< .001	Yes
C/A	0.40 (0.06)	0.49	-8.61	<.001	Yes
E/D	0.92 (0.12)	0.97	-2.54	.016	Yes
F/D	0.91 (0.13)	0.97	-2.48	.018	Yes
E/F	1.00 (0.06)	1.00	0.44	.665	Yes
G/B	0.27 (0.06)	0.22	4.87	<.001	Yes
H/B	0.22 (0.10)	0.22	-0.12	.905	No
J/B	0.11 (0.04)	0.16	-7.47	<.001	Yes
K/B	0.12 (0.04)	0.16	-5.93	<.001	No
I/B	0.20 (0.06)	0.27	-6.84	<.001	Yes
L/A	0.16 (0.05)	0.17	-0.06	.956	Yes
[G(L) – G(R)]/G	0.02 (0.08)	0.02	-0.58	.563	Yes
(J – K)/B	-0.01 (0.04)	0.01	-0.8	.427	Yes

Note. (1) Bias direction indicates the direction of difference between the means of the imagination-based drawing and the photograph collection. (2) The 13 *t*-test values and their associated *p* values come from single sample *t*-tests comparing the spatial relation ratios of the drawings to test values that equal the means of the spatial relation ratios of the photographs.

There were other spatial relations that reliably deviated from the photograph collection means that were not associated with a reliable direction of error in the observation-based drawings. Namely, participants were biased to draw the eyes too wide with respect to the width of the face (G/B ratio), *t* (37) = 4.87, *p* < .001, Cohen's *d* = 0.79, and to draw the right eye too close to the side of the face, *t* (37) = -5.93, *p* < .001, Cohen's *d* = 0.96. All other comparisons of the imagination-based drawing spatial relation ratios to the photograph collection were not associated with reliable directions of bias (*p* > .004).

Thus, at this point, the evidence suggests that most of the systematic errors individuals make when creating observation-based drawing s are additionally inherent in the graphic-based representations stored in memory that guide the production of imagination-based drawings. Indeed, out of the 5 spatial relation ratios that were associated with a reliable direction of error across the observation-based drawings (B/A, C/A, J/B, I/B and [J – K] / B), four of these were additionally associated with the same reliable direction of bias across the imagination-based drawings (the only exception being the [J – K] / B ratio). This suggests that these biases stored in memory might contribute to the presence of similar errors made when individuals draw a directly perceivable face.

However, there are limitations in considering this evidence alone to evaluate the claim that a source of systematic observational drawing errors in reproducing spatial relations between facial features are how these spatial relationships are stored in memory. These limitations relate to the fact that drawing errors and biases analyzed thus far were treated on the level of the sample and not on the level of individuals. The mean values of the spatial relation ratios in both the imagination-based and observation-based drawings do not reflect the individual variability of these ratios across participants. Thus, it is not known whether an individual's direction and degree of bias in the imagination-based drawings is similar to that of the errors in the observation-based drawings. Consider the finding that participants draw the face too round in the observation-based drawings relative to the reproduced model and in the imagination-based drawings relative to the collection of male face photographs (B/A ratio). Even though most participants are biased in this direction in the two different drawings tasks (84% of participants in the observation-based drawings and 97% of participants in the imagination-based drawings), does this mean that the degree of roundness that the face is drawn is similar across the two types of drawings for individual participants? It is not known because a similar degree of bias between the two types of drawings across the sample does not necessarily indicate a similar degree of bias within specific individuals.

This is also the case for the spatial relation ratios that were not associated with a single reliable direction of error and bias in either of the two drawing tasks across the sample. Take for example the spatial relation ratios H/B (reflecting inter-ocular distance) and L/A (reflecting the vertical position of the mouth on the length on the face) in the observation-based drawing task. Even though these two ratios were not associated with a single reliable direction of error, this is not indicative of the fact that most participants were particularly accurate in reproducing these spatial relationships. Rather, it is indicative that some participants were biased to err in one direction and other participants were biased to err in the opposite direction. With respect to the H/B ratio, 58% of participants drew the eyes, on average, 28% (+/- 19%) farther apart from each other than they were in the model photograph with respect to the width of the face. Alternatively, 42% of participants drew the eyes, on average, 22% (+/- 19%) closer together than they were in the model photograph with respect to the width of the face. As one more example and relating to the L/A ratio, 53% of participants drew the mouth, on average, 12% (+/- 8%) farther up the length of the face than it was in the model and 45% of participants drew the mouth, on average, 18% (+/- 13%) farther down the length than it was in the model. Thus, even though there were no reliable average direction of observational drawing errors for these and other spatial relation ratios to be similar or dissimilar to the directions of bias in the imagination-based drawings across on the level of the sample, this does not mean that there are no substantial idiosyncratic directions of error and bias that can be found to be similar across imagination- and observation-based drawings for specific individuals.

So, in order to generate more evidence that bears on the claim that memory representations bias observation-based drawing performance, it is important to assess the relationship between these types of drawings with respect to the spatial relation ratios on the individual level. If the way spatial relationships between facial features are represented in memory influence how these relationships are reproduced when drawing a directly perceivable model face, it would need to be shown that the individual variability of the spatial relation ratio values produced in the imagination-based drawings predict the values of the spatial relation ratios reproduced in the observation-based drawings[12]. Thus, 13 Pearson *r* correlation coefficients were calculated assessing the direction and magnitude of the relationship between the imagination- and observation-based drawings for each spatial relation ratio and are displayed in Table 9.

Upon inspection of Table 9, one can see that 11 out of the 13 spatial relation ratios are associated with positive correlations between the imagination- and observation-based drawings, ranging in magnitude from 0.22 to 0.65, indicating that, of these, the variance in the spatial relation ratio values of the observation-based drawings is shared with 5% – 42% of the variance in the imagination-based drawings depending on the spatial relation ratio value considered. To determine an average correlation, all positive *r* values were converted to *z*' values, whose average was computed and then re-transformed back to a *r* value (Silver, Clayton & Dunlap,

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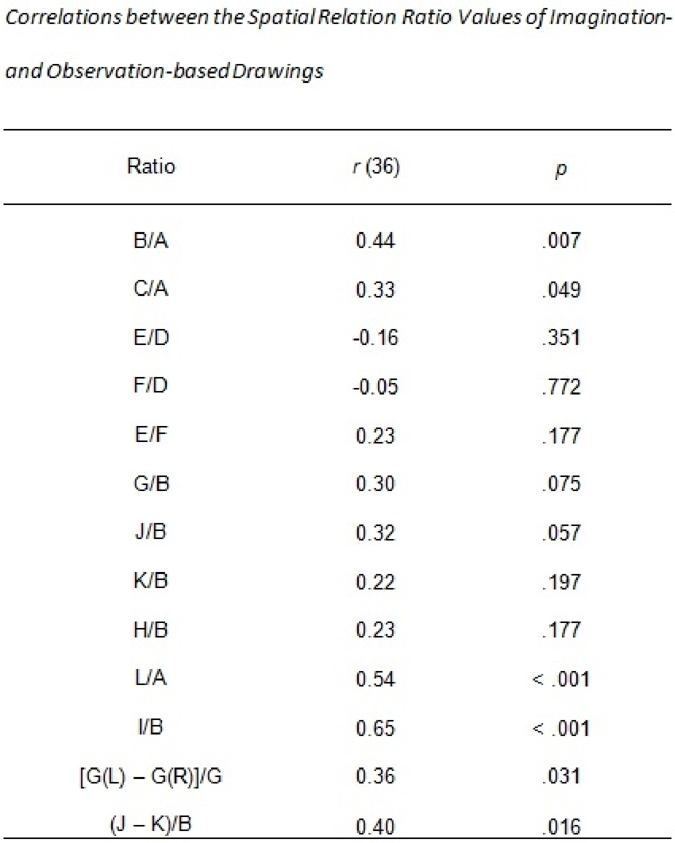
[12] It is acknowledged that even though reliable positive correlations between the spatial relation ratio values of the imagination- and observation-based drawings would have to be evident if memory representations bias observation-based drawing performance, this does not mean that the presence of such reliable correlations is direct evidence that this is so.

1987). From this method, the average correlation for the spatial relation ratios between the two drawing tasks was 0.39.

Table 9.



Correlations between the Spatial Relation Ratio Values of Imagination- and Observation-based Drawings

Ratio	*r* (36)	*p*
B/A	0.44	.007
C/A	0.33	.049
E/D	-0.16	.351
F/D	-0.05	.772
E/F	0.23	.177
G/B	0.30	.075
J/B	0.32	.057
K/B	0.22	.197
H/B	0.23	.177
L/A	0.54	< .001
I/B	0.65	< .001
[G(L) – G(R)]/G	0.36	.031
(J – K)/B	0.40	.016

All four of the spatial relation ratios that were associated with a common reliable direction of error/bias in the imagination- and observation-based drawings were associated with reliable positive correlations in the spatial relation ratio values between the two types of drawings. The degree of roundness of the face was positively correlated between the two types of drawings (B/A ratio), *r* (36) = .44, *p* = .007. The degree to which the eyes were vertically positioned on the length of the face was also positively correlated between imagination- and observation-based drawings (C/A ratio), *r* (36) = .33, *p* = .049. The width of the nose relative to the width of the face was also found to be positively related between the two types of drawings (I/B ratio), r (36) = .65, $p < .001$. Finally, the degree of distance between the left eye and the left side of the face was positively correlated between the two types of drawings (J/B ratio), r (36) = .32, $p = .057$.

Relating to the one spatial relation ratio that was observed to have a reliable direction of error in the observation drawing task that was not observed to have a reliable direction of bias in the imagination drawings, the degree of symmetry relating to the distances between the left and right's eyes distance from the sides of the face ([J – K] / B ratio) was positively correlated between the two drawing tasks, r (36) = .40, $p = .016$.

Relating to the spatial relation ratios that were associated with a reliable direction of bias in the imagination-based drawings but not a reliable direction of error in the observation-based drawings, the degree of width of the eyes relative to the width of the face was positively correlated between the two drawing tasks (G/B ratio), r (36) = .30, $p = .075$.

Finally, relating to the spatial relation ratios that were not associated with reliable directions of error or bias in the two drawing tasks, the degree to which the mouth was vertically positioned on the length of the face was positively correlated between the two drawings (L/A ratio), r (36) = .54, $p < .001$. Also, the degree to which the widths of the left and right eye differed relative to the average width of the eyes was positively correlated between the imagination- and observation-based drawing tasks ([GL – GR] / G ratio), r (36) = .36, p = .031. All remaining spatial relation ratios were not associated with reliable correlation coefficients at the 0.10 alpha level, five of whose correlation coefficients were positive (E/F, K/B and H/B ratios) and two of which were negative (E/D and F/D ratios).

3.3 Discussion

In Study 1B, it was found that three spatial relationships were associated with single reliable directions of error that generalized across the observational drawings of three different female faces. Namely, participants drew the face too round (B/A ratio), the eyes too far up the length of the face (C/A ratio), and the nose too narrow with respect to the width of the face (I/B ratio). Further evidence that these are robust error biases was observed here, as the observational drawings of the male face model also reliably contained these three systematic directional errors. Thus, one can tentatively conclude that these three biases are universally present in most non-artists' observational drawings of faces, although further testing with drawings of a larger set of model faces should be made in the future to strengthen this claim.

The idea that how some spatial relationships of facial features are represented in long-term memory influence how these relationships are reproduced in observational drawings is supported by the evidence generated in this study. To summarize, there was a congruency in the direction of the spatial relation ratio errors/biases between imagination- and observation-based drawings for the four spatial relation ratios that were associated with the strongest directional error biases in the observational drawings. Further, on the individual-level of analysis, the ratio values that quantified these four spatial relationships in the imagination-based drawings reliably predicted those values reproduced in the observation-based drawing task. Additionally, there were positive correlations between the two types of drawings in how other spatial relationships not associated with a single reliable direction of error or bias were produced in the observation- and/or imagination-based drawings.

Thus, the evidence suggests that the observational drawing of the spatial relationships in a face is guided by both bottom-up processing of the visual information inherent in the model face being reproduced and top-down processing of information representing the spatial relationships of a face stored in long-term memory. Evidence that bottom-up processing of model-based information is guiding drawings is had by considering the degree of variability in the spatial relation ratio values across the observation- and imagination-based drawings. For 8 out of the 13 spatial relationships measured, the degree of variability in spatial relation ratio values is smaller in the observation-based drawings than in the imagination-based drawings. The finding that, for the most part, the produced spatial relations were more similar across participants in their observation-based as opposed to imagination-based drawings can be understood by the fact that all the observational drawings were based on a single standard stimulus whereas the imagination-based drawings were based on the participants' idiosyncratic memory representations of how a face is drawn. Thus, the lower variability in observation-based drawings suggests that the bottom-up processing of the standardized information inherent in the model face was guiding the production of observation-based drawings to some degree.

However, the observation that the way most of spatial relationships produced in the imagination-based drawings reliably predicted how they were reproduced in the observation-based drawings suggests that the top-down processing of spatial information in memory additionally guides, to some degree, the production of observational drawings. The evidence suggests that when non-artists are attempting to draw a face based on a directly perceivable model, the canonical representations of the spatial relationships in a face stored in memory that guide imagination-based drawings are activated and partially bias how certain spatial relationships are drawn.

This would result in the observational drawings of the spatial relations of a face being guided by the mixed influence of processing information inherent in the model and in long-term memory. This mixed-influence perspective of observational drawing is consistent with evidence presented in Table 10. Here, for the 8 spatial relation ratios that were associated with a reliable positive correlation between the imagination-based and observation-based drawings (at a liberal $\alpha = .10$ level), the means of these ratio values for the two drawing tasks and the value of the model stimulus reproduced in the observation-drawing tasks are presented. As one can see, the mean values of all 8 of these spatial relation ratios produced in the observation-drawing task fall between the mean values of the spatial relation ratios of the imagination-based drawings and the value of the model stimulus that was being reproduced in the observation-based drawing task. This was particularly the case for the B/A, C/A, I/B and J/B ratios, as when identifying this pattern on the individual-level, most participants' observational drawing values of these ratios fell between the values of the imagination-based drawing and the model face. Thus, these results suggest the observational reproduction of some spatial relationships between facial features is biased by both model-based and memory-based information.

Table 10.

Mean Values of Imagination- and Observation-Based Drawings & Model Values of the Spatial Relation Ratio Values that were Reliably Correlated across the Two Types of Drawings

Ratio	Imagination Based Drawing Mean	Observation-Based Drawing Mean	Model Value	% of Participants Whose Observation-Drawing Value is In-Between Imagination-Drawing & Model Values
B/A	0.74	0.67	0.60	63
C/A	0.40	0.45	0.49	61
G/B	0.27	0.23	0.22	58
J/B	0.11	0.16	0.19	55
I/B	0.20	0.22	0.26	68
L/A	0.16	0.18	0.19	45
[G(L) – G(R)]/G	0.02	0.03	0.05	24
(J-K)/B	-0.01	-0.00	0.04	32

Note. If the ordinal rank pattern of the spatial relation ratio values between the imagination-based drawings, the observation-based drawing and the model face was random, then one would expect a baseline rate of 33% of participants whose spatial relation ratio values of their observational drawings fell in between the spatial relation ratio values of the imagination-based drawings and the model face (since this pattern fits 2 out of the 6 possible ordinal rank patterns). Binomial tests indicate that the percentage of participants whose spatial relation ratio values of the observation-based drawing fell in between the spatial relation ratio values of the imagination-based drawing and the model face was reliably greater than chance with respect to the B/A ($p < .001$), C/A ($p < .001$), G/B ($p = .001$), J/B ($p = .004$) and I/B ratios ($p < .001$).

The evidence presented in this study is consistent with other findings that suggest an influence of memory-based representations in the creation of observational drawings. As discussed in the Introduction to this study, Matthews and Adams (2008) reported that spatial relation ratio values of imagination-based drawings of a cylinder reliably predicted the spatial relation ratio values of observation-based cylinder drawings. Thus, the relationship spatial relationship reproduction between imagination- and observation-based drawings does not appear to be specific to the category of familiar objects being drawn.

The theoretical influence of memory-based information on observational drawing performance may also be able to partially explain findings reported by Cohen (2005), who reported that faster and more frequent eye-gaze shifts between a face model being reproduced and the emerging drawing resulted in the production of drawings subjectively rated to be more accurate than drawings produced under conditions of relatively slower and less frequent model-to-drawing eye-gaze shifts. It may be the case that relatively slower and less frequent shifts result in short-term perceptual memories of the model-based information quickly degrading and thus being more largely influenced by how these properties are canonically stored in long-term memory. Consequently, faster eye-gaze shifts between the model and emerging drawing may reduce the amount of perceptual short-term memory degradation while viewing and working on the emerging drawing and thus attenuate the influence of long-term memory information. This hypothesis would lead to the prediction that the correlation between the spatial relationships of imagination- and observation-based drawings would be weaker when the observation-based drawings were produced under conditions of fast eye-gaze shifts compared to relatively slower eye-gaze shifts between the model and emerging drawing. This is clearly a prediction that should be tested by future research as currently no evidence to date has been produced to satisfactorily explain the cause of this interesting effect.

Finally, the results of this study raise two interesting sets of questions that could be addressed with future research. The first set of questions pertains to the influence of long-term memory representations on observational drawings over the course of development of drawing ability. Is observational drawing ability related to (1) the degree to which long-term memories influence observational drawing performance, or (2) the content of the long-term memories that influence observational drawing performance? The former possibility would suggest that memory-based influences generally interfere with accurate copy drawing, and the development of drawing skill would be partly conceptualized as a process of gradually reducing the influence memory representations have on drawing performance and increasing the influence of perceptual-based information inherent in the stimulus. In contrast, the latter possibility would argue that both unskilled and skilled drawers alike rely on and are influenced by memory-based information when producing an observational drawing. Here, the development of drawing skill would partly be characterized as developing richer, more complex long-term memories that more accurately represents the graphical properties of the objects being drawn. This perspective would be consistent with the use of "how-to" drawing manuals that are widely used and referenced in drawing instruction. Here, these manuals teach students prototypical properties of common objects, with the desired result that individuals will develop a stronger knowledge of how common objects are drawn realistically. Thus, skilled drawers may not rely on long-term memories less than unskilled non-artists, but rather, may have more accurate knowledge about prototypical appearances of objects and how to reproduce those in the drawing medium.

Testing between these two possibilities would be a relatively straightforward process. One could potentially replicate Study 2 sampling both artist and non-artist participants and comparing the degree to which imagination- and observation-based drawings are correlated between these groups. If memory-based information exclusively interferes with observational drawing ability, then artist participants should show significantly weaker correlations between the spatial-relation measurements between these two types of drawings compared to non-artist participants. However, if memory-based information similarly affects both artists and non-artists, and artists just have more accurate graphical knowledge of the structure of faces than non-s, then the degree to which imagination-based and observation-based drawings are correlated should not reliably differ between these two groups.

Another question that the results of Study 2 raise concern the influence of long-term memories on other aspects of observational drawing performance other than the reproduction of the spatial relationships between facial features. One aspect of observational drawing accuracy that has been completely neglected in this dissertation is that related to the drawing of the isolated facial features. Do the long-term memory representations of isolated facial features that guide imagination-based drawings influence the reproduction of isolated facial features when individuals attempt to reproduce a model face from observation? Currently, this is a difficult question to address as there are no established ways in the literature to my knowledge that allow a quantification of the accuracy and appearance of drawn isolated facial features.

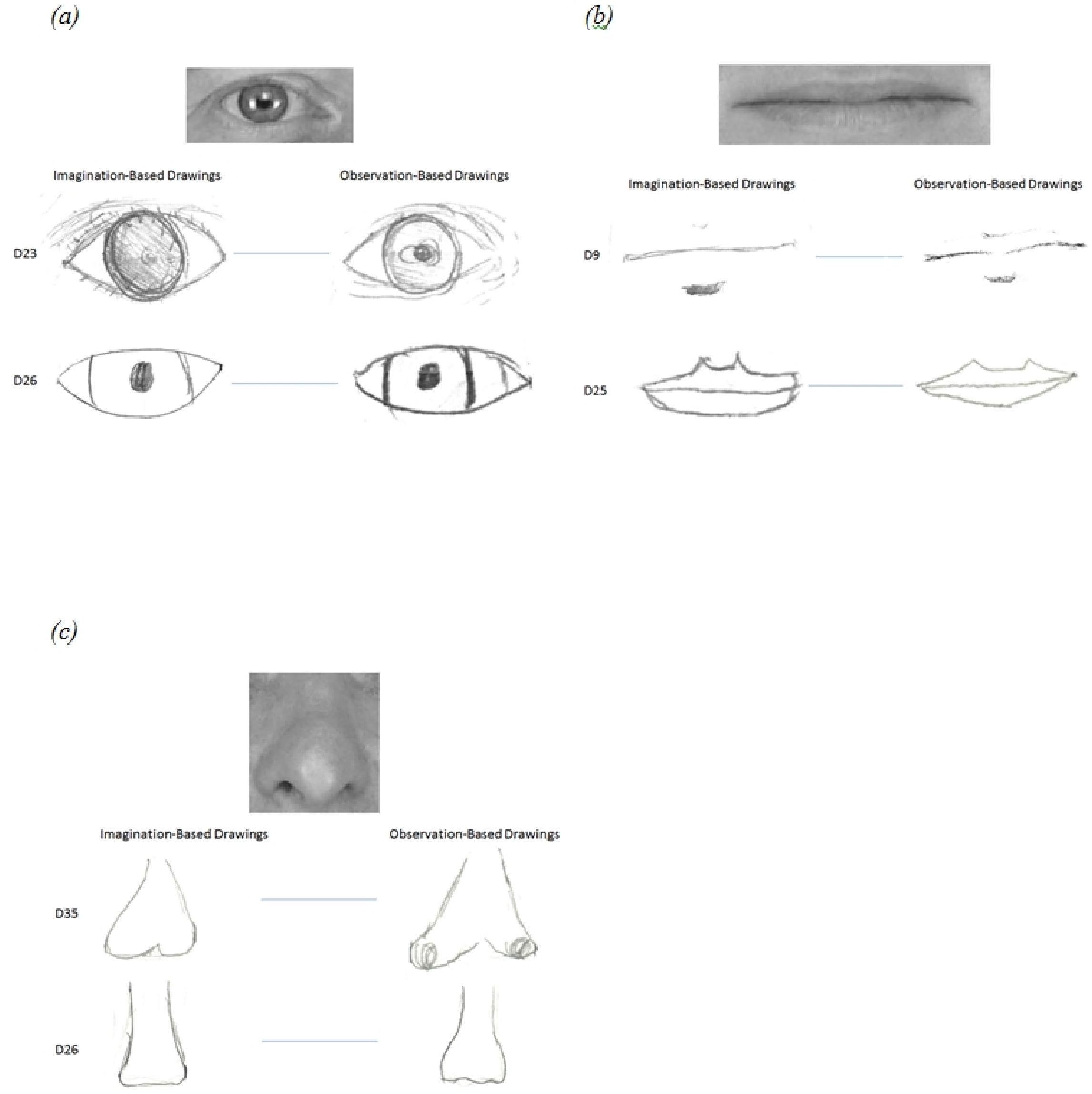


Figure 10. Illustrations of some participants' drawings of isolated facial features ((a) eyes, (b) mouth and (c) nose) in the imagination-based and observation-based drawings produced in Study 2 presented alongside the appearance of these features in the model face.

However, informal qualitative observations of participants' imagination- and observation-based drawings produced in this study's sample suggest an influence of long-term memories on observational drawings of facial features for at least some participants. Figure 10 presents isolated segments of selected participants' imagination- and observation-based drawings of the eyes, mouth and nose. It is my impression that there is a strong similarity between how these participants reproduced the target facial features in the observation-based drawings of the model face and how they represented the same features in their drawings based on memory. With respect to drawings of the eyes, if one looks at drawing 23 (D23), for instance, this participant drew the left eye's iris as a full circle in their imagination-based drawing. Later, when they attempted to reproduce the eye of the model face, they persisted in drawing the iris of the eye as a full circle despite the fact that this is not how the iris appears in the model. Similarly, if one looks at D26's eye drawings, one can see that the eye is represented as a football shape containing two vertical, out-ward curving lines composing the iris in both the imagination-based and observation-based drawings. This way of composing the eye in the observation-based drawing deviates from the model's eye, particularly with respect to failing to reproduce the appearance of the bottom curvature of the iris.

Similar observations were made with respect to drawings of the mouth. For instance, D9's representation of the mouth in both types of drawings are extremely similar in that the mouth is simply represented by a single horizontal line representing the concave region in-between the upper and lower lips, with two smaller horizontal lines representing the center of the top portion of the upper lip and bottom portion of the lower lip. D25's imagination- and observation-based drawings of the mouth included two sharp-angled peaks in the top center of the upper lip, features that are not apparent in the model face's mouth.

Finally, with respect to drawings of the nose, we can once again see strong similarities between the imagination- and observation-based drawings. D35's imagination-based representation of the lower nose is composed of two downwardly curved regions that are separated by a sharp-angled upward curve in the middle. The nose is represented in observation-based drawing in almost the exact same way (with the addition of two shaded regions to indicate the nostrils) despite the fact that an upwardly curved region in the middle of the lower nose does not exist in the model face. It is my impression that D26's representations of the nose are very similar between the imagination- and observation-based drawings, both in terms of the shape and the lack of the production of shaded regions indicating nostrils that are clearly apparent in the model face. Thus, with consideration of the examples qualitatively described above, it seems that in some cases, participants observation-based drawings of isolated facial features are more similar to how these features are represented in long-term memory (as reflected in their imagination-based drawings) than how they appear in the model face that is being reproduced, suggesting further the role of memory in non-artists' observational drawing. Hopefully in the future, more formal, quantitative techniques will be developed that can lend themselves to stronger analyses of isolated facial feature drawings in order to more strongly test the idea that long-term memory representations influence the observational drawings of these features as they appear to influence the observational drawings of spatial relationships between facial features.

4. Study 3

In Study 1A, it was found that subjective ratings of perceived accuracy of face drawings were reliably associated with shape and size constancy errors caused by the processing of depth cues but were not associated with errors in perceiving the shape and size of stimuli that contained no depth cues. In contrast, it was found that not all objective measures of spatial drawing accuracy of faces were related to depth-cue induced perceptual errors and not all measures of spatial drawing accuracy were unrelated to non-depth cue induced perceptual errors. Thus, it was judged to be the case that subjective measures of overall drawing accuracy oversimplified the relationship (or lack thereof) between face drawing and perceptual accuracy.

As stated in the Discussion of Study 1, this raises the possibility that the use of subjective accuracy ratings may additionally oversimplify the effects that certain experimental manipulations have on face drawing accuracy. Is it the case that the experimental manipulations used in the past affect all elements or only a select subset of elements of face drawing accuracy? This is one of the general issues to be addressed in Study 3, where I will specifically focus on the effects that model rotation has on drawing accuracy. Studying this effect is important due to the relevance it has with respect to evaluating both perceptual theories of drawing accuracy and the validity of common art instruction practices.

Edwards (1979, 1999) famously advocated for the practice of drawing models upside-down to increase novices' drawing accuracy. The theoretical foundation of the practice was based on the idea that, "[novices] do not perceive in the special way required for drawing. They take note of what's there, and quickly translate the perception into words and symbols mainly based on the symbol system developed throughout childhood and on what they know about the perceived object" (Edwards, 1999, p. 82). Thus, most novices' drawings were said to contain reproductions of graphic symbols stored in memory that stand for elements of an object (e.g., a smile as a U-shaped line; the eyes as isolated circles or ovals; the shape of the head as a circle) rather than the apparent visual information contained in the model stimulus. Further, she theorizes that perceiving objects in non-canonical orientations (e.g., upside-down) inhibits the activation of such symbolic representations and therefore facilitates the ability for individuals to perceptually encode, and therefore draw, the visual information actually present in the model stimulus. This theoretical foundation and the resulting practice became very well-known in the art-instruction field, as evident by the widespread advocating of this technique on many online drawing tutorials (Google search "upside-down drawing") and in many print-based drawing manuals.

Even though there is much anecdotal and testimonial evidence that suggests this technique is effective, this claim did not receive any formal scientific test of its effectiveness for over 30 years until very recently by Cohen and Earls (2010). They assessed the effects of model rotation on face drawing accuracy because the misperception theory of drawing accuracy predicted that certain elements of drawing accuracy should be impaired when drawing an upside-down face.

It has long been known that upside-down faces are more difficult to recognize than upright faces (Carey & Diamond, 1977; Yin, 1969). This impairment is not related to the processing of all information in a face. Rather, it has been demonstrated that while the recognition of individual facial features themselves is not impaired by face inversion, individuals are less sensitive in perceiving the spatial relationships between facial features while the face is upside-down compared to when it is upright (Leder & Bruce, 1998; Leder & Bruce, 2000). The misperception hypothesis of drawing accuracy proposes that any process that results in perceptual error of a stimulus should additionally result in a similar drawing error of that stimulus. Thus, Cohen and Earls (2010) evaluated the misperception hypothesis by testing the prediction that drawing upside-down faces should result in worse accuracy in drawing the relative spatial positioning of facial features relative to when drawing upright faces, but that there should be no difference in the accuracy of reproduction of the local facial features themselves between drawings of upright and upside-down models. This was tested in an experiment where participants were randomly assigned to draw an upright or upside-down face. The drawings were later rated for perceived accuracy by independent judges in two ways. Namely, each judge provided separate ratings for the perceived accuracy of the drawings' reproduction of the local facial features and the relative spatial positioning of the facial features. They reported that spatial accuracy ratings were lower for drawings of upside-down faces compared to upright faces, but that there was no difference in the local-feature accuracy ratings between drawings of upright and upside-down faces. Thus, the results provided empirical support of the misperception hypothesis while simultaneously disconfirming the anecdotally reported effectiveness of the practice of drawing faces upside-down.

Since both spatial and local-feature drawing accuracy was measured subjectively by Cohen and Earls (2010), one could question whether all or only some of the spatial relationships within a face were drawn worse when drawing an upside-down model. If the misperception hypothesis proposal that cognitive processes that result in perceptual inaccuracies result in similar drawing inaccuracies is true, then one would predict that the drawing accuracy of some spatial relationships within a face should be affected by face inversion more than others because it has been shown the magnitude of the perceptual effects of face rotation reliably differ across different types of spatial relationships between facial features. Namely, it has been recently demonstrated that perceptual sensitivity of vertical spatial relationships (specifically, the vertical position of the eyes on the length of the face) is detrimentally affected by face rotation to a reliably greater degree than the perceptual sensitivity of horizontal spatial relationships (specifically, the inter-ocular distance) (Crookes & Hayward, 2012; Goffaux, 2008; Goffaux & Rossion, 2007; Goffaux et al., 2009; Sekunova & Barton, 2008). Further, this pattern of effects has been observed for both 180-degree rotations of a face (upside-down faces) and 90 degree counter-clockwise rotations of a face (Goffaux & Rossion, 2007). Thus, the misperception hypothesis predicts that the deleterious effect of drawing rotated faces (180 and 90 degrees) relative to drawing upright faces should be larger for reproductions of vertical spatial relationships than for horizontal spatial relationships between facial features.

This prediction was not able to be tested by Cohen and Earls (2010) because by using a single subjective rating to quantify the perceived spatial accuracy of a drawing, accuracy of reproducing vertical vs. horizontal spatial relationships are not able to be discriminated. Fortunately, the use of a subset of the objective measurements described in Studies 1 and 2 allow one to test this specific prediction derived from the misperception hypothesis. The goal of studies 3A and 3B was to test this prediction. Here, the accuracy of drawing two vertical spatial relationships (the vertical position of the eyes and mouth on the length of the face) and one horizontal spatial relationship (the inter-ocular distance) was measured in drawings participants made of upright vs. 180 degree rotated faces (Study 3A) and upright vs. 90 degree rotated faces (Study 3B). Note that throughout the remainder of discussion of these two experiments, *vertical and horizontal orientations are not defined with respect to gravity. Rather, they are defined relative to the canonical orientation of the face.* For example, references to the "vertical position of the eyes on the length of the face" refers to the ratio of the distance between the eyes and the canonical top of the head to the distance between the top of the head and the bottom of the chin across the 0, 90 and 180 degree model/drawing conditions.

4.1 Method – Study 3A.

4.1.1 Participants.

Thirty individuals (23 females and 7 males; *M* (*SD*) age = 20.23 (3.30) years) participated in this experiment and were recruited from the Brooklyn College Psychology Undergraduate Subject Pool. Participants were compensated by receiving course credit.

4.1.2 Materials.

Participants were asked to draw a single photograph of a frontal view of a woman's face (see Figure 1) that was presented in two different orientations. The photograph was presented on a 17 in. computer monitor (Dell Model: 1704FPVt) using the Microsoft Powerpoint 2003 software program. When presented on the computer monitor, the image of the photograph measured 7 × 9.5 in. In one condition (*Upright Condition*), the photograph was presented in the upright orientation. In the second condition (*Inverted Condition*), the photograph was presented as a 180 degree rotation of the upright photograph.

Participants were provided with an 8.5 × 11 in. sheet of white paper, a sharpened No. 2 pencil with an eraser and a manual pencil sharpener to use to create the drawing.

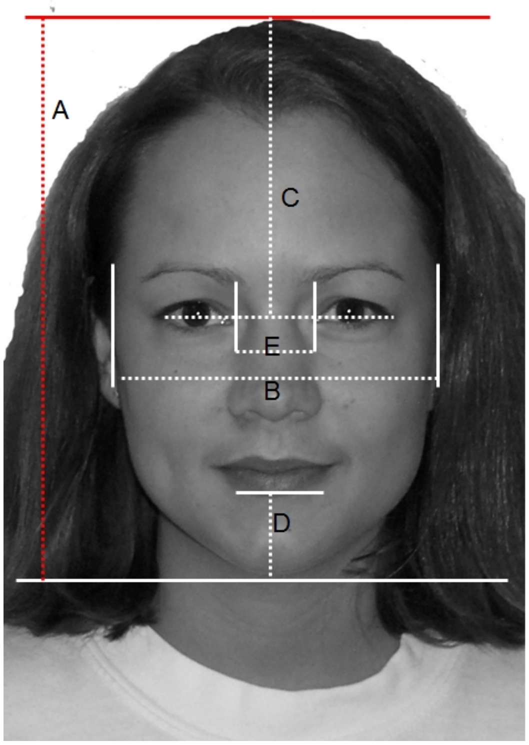
4.1.3 Procedure.

After providing informed consent, the participants received an explanation that they would be producing two drawings of face photographs. Participants were instructed that their goal in creating the drawings is to copy the photograph as accurately as possible. They were further instructed that they should not add any details that are not present in the photograph and that they should not eliminate any important details that are present in the photograph. Furthermore, participants were instructed to draw the face as they see it presented on the computer monitor. Specifically, when drawing the inverted photograph, they were asked to draw an upside-down face as opposed to trying to draw an upright face mentally rotated from the inverted photograph. Finally, they were told that they could use the eraser and pencil sharpener if they needed. Participants were given a 15 minute time limit to create the drawing, and the experimenter provided 5- and 1-minute warnings.

A repeated-measures experimental design was employed, in which participants drew the face in both orientation conditions. The order in which the upright and inverted drawings were produced was counterbalanced across participants.

4.1.4 Measurements of Drawn Spatial Relations and Errors.

For the model photograph and the two drawings produced by each participant, 5 measurements (A – E) were be made (see Figure 11). "A" is a measurement of the length of the face between the top of the face (including the hair) and the bottom of the chin. "B" is a measurement of the width of the face between the left and right top intersections of the ear and the face. "C" is a measurement of the vertical distance between the top of the face (including the hair) and the horizontal eye-line. "D" is a measurement of the vertical distance between the bottom of the lower lip and the bottom of the chin. "E" is a measurement of the inter-ocular distance between the inner corners of the two eyes.



Spatial Measurement Ratios

Vertical Spatial Relations

Ratio	Description	Model Value
C/A	Vertical Position of Eye-Line	0.53
D/A	Vertical Position of Mouth (Bottom of Lower-Lip)	0.13

Horizontal Spatial Relation

Ratio	Description	Model Value
E/B	Inter-ocular distance (between inner corners of eyes)	0.24

Figure 11. Illustration of the 5 measurements made and definitions of the three spatial relation ratios that were computed in Study 3. Values of the spatial relation ratios of the model face are presented.

Based on these measurements, two vertical-spatial and one horizontal-spatial relation ratios were calculated to determine the relative positioning of target facial features (see Figure 11). Ratios C/A (vertical positioning of the eyes relative to the length of the face) and D/A (vertical positioning of the mouth relative to the length of the face) are ratios measuring vertical spatial relations of facial features, and ratio E/B (inter-ocular distance relative to the width of the face) is a ratio measuring a horizontal spatial relation of facial features.

Drawing errors were calculated for each of the three ratios as follows:

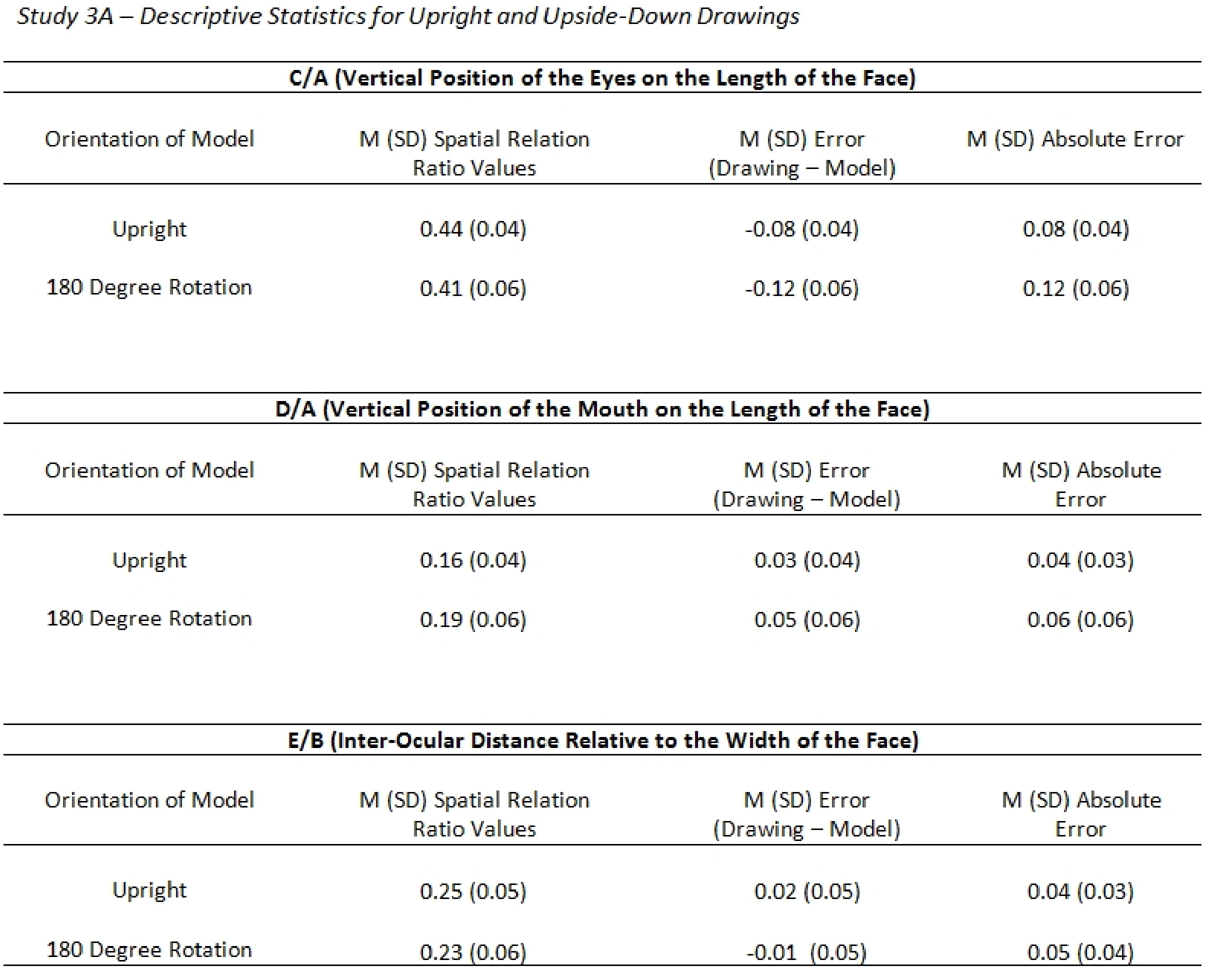
Drawing Error = Drawing Ratio Value – Model Ratio Value

Positive drawing errors are interpreted as follows: (1) for the C/A ratio, the vertical position of the eyes were drawn too far down the length of the face, (2) for the D/A ratio, the vertical position of the mouth was drawn too far up the length of the face, and (3) for the E/B ratio, the eyes were drawn too far apart.

4.2 Results – Study 3A

Table 11 displays the means and standard deviations of the three computed spatial relation ratios and drawing errors for both the upright and inverted drawings. The data analysis to be performed for this experiment will be conducted to address two sets of questions. First, it will be determined whether some of the systematic patterns of spatial drawing error observed in Study 1 replicate in a different sample of participants when the drawings are produced from an upright and rotated model. Second, an evaluation of the misperception hypothesis of drawing accuracy will be conducted by testing the prediction that model rotations cause a greater detrimental effect on the drawing accuracy of vertical spatial relationships than of horizontal spatial relationships.

Table 11.



Study 3A – Descriptive Statistics for Upright and Upside-Down Drawings

C/A (Vertical Position of the Eyes on the Length of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright	0.44 (0.04)	-0.08 (0.04)	0.08 (0.04)
180 Degree Rotation	0.41 (0.06)	-0.12 (0.06)	0.12 (0.06)

D/A (Vertical Position of the Mouth on the Length of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright	0.16 (0.04)	0.03 (0.04)	0.04 (0.03)
180 Degree Rotation	0.19 (0.06)	0.05 (0.06)	0.06 (0.06)

E/B (Inter-Ocular Distance Relative to the Width of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright	0.25 (0.05)	0.02 (0.05)	0.04 (0.03)
180 Degree Rotation	0.23 (0.06)	-0.01 (0.05)	0.05 (0.04)

Did the drawing error effects observed in Study 1 (eyes and mouth drawn too far up the face in both Studies 1A and 1B; the eyes drawn too far apart in Study 1A but not 1B) replicate in both upright and inverted drawings? In order to determine this, three single-sample *t* tests were computed for each model orientation condition, comparing the mean errors against a test value of 0 (no error). As in Study 1, the eyes were reliably drawn farther up the face with respect to the length of the face than they were in the model (C/A error) in both drawings of the upright, *t* (29) = -10.68, *p* < .001, Cohen's *d* = 1.95, and rotated models, *t* (29) = -10.31, *p* < .001, Cohen's *d* = 1.88. Another effect that was replicated from Study 1 was the finding that the mouth was reliably drawn farther up the face with respect to the length of the face than it was in the model (D/A error) in both drawings of the upright, t (29) = 4.96, p < .001, Cohen's d = 0.91, and rotated models, t (29) = 4.70, p < .001, Cohen's d = 0.86. However, replication of the effect from Study 1 concerning the error of reproducing the inter-ocular distance from the model (E/B error) was somewhat mixed at best. When drawing the upright model, there was a marginally reliable tendency to draw the eyes farther apart with respect to the width of the face than they were in the model, t (29) = 1.99, p = .056, Cohen's d = 0.36. When drawing the rotated model, the reproduction of the inter-ocular distance was not reliably biased to be too far apart or too close together, t (29) = -0.93, p = .360, Cohen's d = 0.17.

The second and most important question with respect to testing this experiment's hypothesis relates to comparing errors between the drawings of the upright and rotated models. Since previous perceptual research and the misperception hypothesis being tested here only predict that spatial drawing errors (of vertical spatial relations in particular) should be larger in drawings of the rotated as compared to upright model, but offer no predictions as to the direction of increased error, all drawing errors were converted to absolute values for the purposes of the following analyses. Additionally, since all participants drew the same face twice under two different orientation conditions, it is possible that the order in which upright and upside-down faces were drawn has an effect on the accuracy in drawing the spatial relationships of interest here. So, for each of the three computed spatial relation ratios, a 2 (Orientation: Upright vs. Rotated) × 2 (Order: Upright Drawn First vs. Rotated Drawn First) mixed ANOVA was conducted testing for effects on absolute drawing errors.

With respect to the vertical spatial relation C/A, there was a reliable main effect of Orientation, F (1, 28) = 10.06, p = .004, indicating that the vertical position of the eyes on the length of the face was drawn with reliably greater errors in the upside-down drawings than in the upright drawings. This effect did not appear to be dependent on which of the two drawings was produced first, as evident by a lack of reliable Orientation × Order interaction, F (1, 28) = 2.37, *p* = .135. Further, there was no reliable main effect of the order in which the upright and upside-down drawings on degree of error in drawing this spatial relationship, F (1, 28) = 0.49, *p* = .489.

With respect to the vertical spatial relation D/A, there was a marginally reliable main effect of Orientation, F (1, 28) = 3.14, *p* = .082, indicating that, similar to what was found with respect to the C/A ratio, errors in reproducing the vertical position of the mouth on the length of the face were reliably greater in the upside-down drawings than in the upright drawings. There was no evidence of this effect being dependent on whether the upright drawing was produced before or after the production of the upside-down drawing, as evident by a lack of reliable Orientation × Order interaction, F (1, 28) = 0.08, *p* = .785. Additionally, there was no reliable main effect of order on absolute drawing errors, F (1, 28) = 0.48, *p* = .496.

Finally, with respect to the horizontal spatial relation E/B, the degree of error in reproducing the inter-ocular distance did not reliably differ between the upright and upside-down drawings, F (1, 28) = 0.20, *p* = .660. This was similar between participants who produced the upright drawing first and participants who produced it second, as evident by a lack of reliable Orientation × Order interaction, F (1, 28) = 0.53, *p* = .472. Further, the order in which upright and upside-down drawings were produced did not have a reliable effect on the absolute drawing errors of the inter-ocular distance (F, 1, 28) = 0.11, *p* = .747.

Collapsing across participants in the two different Order conditions, the size of the effects (Cohen's *d*) that orientation rotation had on absolute errors in drawing the C/A, D/A and E/B spatial relationships were 0.57, 0.33 and 0.08, respectively.

4.3 Discussion – Study 3A

Two major set of findings emerged from the results of Study 3A. First, concerning drawings of the particular face that served as the model in this study (Study 1A's model and Study 1B's Face 1 model), the observation that participants reliably draw the eyes and mouth farther up the length of the face than it is in the model was replicated (C/A & D/A ratios, respectively). Interestingly, not only were these effects directly replicated when participants drew an upright version of the face, but were also replicated under conditions where the participants drew the upside-down face. Thus, these two spatial relation biases are not characterized as gravitational biases to reproduce these features too far up the length of the drawing (as they drew an upside-down face when presented with the upside-down model). Rather, they are characterized as a relative bias to reproduce these features too far up the length of the canonically oriented face, resulting in opposite gravitational biases between upright and upside-down drawings where the features are drawn too far up the drawing in the upright condition and too far down the drawing in the upside-down condition.

In contrast, with regards to the horizontal spatial relation of the inter-ocular distance (E/B ratio), there was partial replication of the effects observed in Study 1. When drawing the upright faces, there was a trend for participants to draw the eyes too far apart, as was observed in Study 1A. However, when drawing the upside-down face, there was no single reliable direction of error in the reproduction of the distance between the eyes, as was observed in the upright drawings made in Study 1B. Thus, in consideration of all the evidence presented in Studies 1 – 3A, it is safest to assume that there is no stable single directional bias of error in the reproduction of the inter-ocular distance. Rather, the evidence suggests that some individuals are biased to draw the eyes too close together whereas other individuals are biased to draw the eyes too far apart. Further, this direction of bias for a given individual may remain stable across multiple drawings, as 73% of participants erred in reproducing the inter-ocular distance in the same direction between upright and upside-down drawings, and there was a reliable relationship in the directional errors in reproducing the inter-ocular distance between the two drawings, r (28) = 0.42, p = .02. Thus, even though there isn't strong evidence of a single reliable direction of error in reproducing the inter-ocular distance that is characteristic of most non-artists' drawings of faces, there still might be stable reliable errors that are individually specific with respect to whether the eyes are drawn too close together or too far apart. However, future research where participants reproduce a larger set of models that are in a single standard orientation should be conducted to more soundly test this idea.

The second major set of findings concern the testing of the misperception hypothesis' prediction that the reproduction of vertical spatial relationships should be affected by model rotation to a greater degree than the reproduction of horizontal spatial relationships. The results of Study 3A confirm this prediction. Participants' absolute errors in reproducing the vertical position of the eyes and mouth were larger when drawing the upside-down face compared to when drawing the upright face. In contrast, even though the mean absolute error of drawing the inter-ocular distance in the rotated face was larger than that for drawings of the upright face, this was not a statistically reliable difference. Further, if one compares the effect sizes associated with the comparisons of drawing accuracy between the upright and upside-down drawings across the three different spatial relationships, the effects that model rotation had on drawing accuracy for the vertical spatial relationships were much larger than they were for the horizontal spatial relationship. These results suggest that the mechanism(s) that result in the larger effects of model rotation on the perception of vertical than horizontal spatial relationships between facial features (Crookes & Hayward, 2012; Goffaux, 2008; Goffaux & Rossion, 2007; Goffaux et al., 2009; Sekunova & Barton, 2008) additionally results in a congruent pattern of error in drawing these spatial relations in a face. More generally, these results are consistent with the proposition that there are shared processes that operate on the visual information guiding both perceptual judgments and drawing behaviors, and thus, that a major source of drawing errors are inaccuracies in the perceptual encoding of stimuli (Cohen & Bennett, 1997).

One consideration to make is that the larger effects of face rotation on the perception and drawing vertical spatial relationships compared to horizontal spatial relationships may be due to the fact that the change in orientation was in the vertical direction. However, at least with regard to findings relating to perceptual judgments, this does not appear to be the case. Goffaux and Rossion (2007) reported that the pattern of effects noted for 0 vs. 180 degree rotations of a face were very similar to those observed for 0 vs. 90 degree rotations of a face. Thus, the misperception hypothesis predicts that the pattern of drawing effects observed here should be the same when the degree of rotation from an upright face is 90 degrees. This prediction was tested in Study 3B.

4.4 Method – Study 3B

4.4.1 Participants.

Thirty-two individuals (24 females and 8 males; *M* (*SD*) age = 20.13 (3.75) years) participated and were recruited from the Brooklyn College Psychology Undergraduate Subject Pool. Participants were compensated by receiving course credit.

4.4.2 Materials.

The face model stimulus, method of computerized presentation and materials provided to participants to create the drawings was identical to that of Study 3A. The only difference between Study 3A and this experiment was the degree of rotation in the Rotated Condition. In one condition (*Upright Condition*), the photograph was presented in the upright orientation, identical to the Upright Condition of Study 3A. In the second condition (*Rotated Condition*), the photograph was presented as either as a clock-wise or counter-clockwise 90 degree rotation of the upright photograph.

4.4.3 Procedure.

After providing informed consent, the explanation of the task and instructions participants received was identical to that provided in Study 3A. When drawing the upright photograph, the sheet of paper the participants created their drawings on was provided in the portrait orientation, and when drawing the rotated photograph, the sheet of paper the participants created their drawing on was provided in the landscape orientation. Participants were told not to change the orientation of the sheet of paper they are drawing from how it was provided to them.

All participants drew the face in both the upright orientation and one of the two rotated orientations. Half of the participants drew the 90-degree clockwise rotated model and the other half of participants drew the 90-degree counter-clockwise rotated model. The order in which the upright and rotated drawings were produced was counterbalanced across all participants.

4.4.4 Measurements of Drawn Spatial Relations and Errors

The measurements and spatial-relation ratios of the model photograph and drawings made in Study 3A were identically made in this experiment (see Figure 11). Further, the calculations of drawing error (and the interpretations of the sign of the error) in this experiment were identical to how they were calculated in Study 3A.

4.5 Results – Study 3B

Table 12 displays the means and standard deviations of the three computed spatial relation ratios and drawing errors for both the upright and inverted drawings. As was done for Study 3A, two sets of questions will be evaluated here. The first set of questions concerns whether the errors in reproducing the spatial relations computed by the C/A, D/A, and E/B ratios were systematically biased in a single direction or whether the direction of error was random. As in Study 3A, three single sample t tests were calculated for drawings produced in each of the 2 model orientation conditions (upright vs. rotated), and this was done separately for participants in the two rotation conditions (clock-wise vs. counter-clockwise rotation). *With respect to the vertical spatial relation C/A*, participants reliably drew the eyes farther up the length of the face than they were in the model when drawing the upright model (Clockwise Rotation Group: t (15) = -6.56, $p < .001$, Cohen's $d = 1.64$; Counter-Clockwise Rotation Group: t (15) = -4.74, $p < .001$, Cohen's $d = 1.19$) and the rotated model (Clockwise Rotation Group: t (15) = -5.12, $p < .001$, Cohen's $d = 1.28$; Counter-Clockwise Rotation Group: t (15) = -5.39, $p < .001$, Cohen's $d = 1.34$). *With respect to the vertical spatial relation D/A*, participants in the Counter-Clockwise Rotation Group reliably drew the mouth farther up the length of the face than it was in the model when drawing the upright model, t (15) = 3.34, $p = .004$, Cohen's $d = 0.84$, and the rotated model, *t* (15) = 5.85, *p* < .001, Cohen's *d* = 1.46. For the participants in the Clock-wise Rotation Group, this effect was marginally reliable in the same direction of error when drawing the upright model, *t* (15) = 1.86, *p* = .083, Cohen's *d* = 0.47, and when drawing the rotated model, *t* (15) = 1.81, *p* = .090, Cohen's *d* = 0.45. Finally, *for the horizontal spatial relation E/B*, participants in the Counter-Clockwise Rotation Group did not err in a reliable single direction when reproducing the inter-ocular distance relative to the width of the face when drawing the upright model, *t* (15) = 0.29, *p* = .774, Cohen's *d* = 0.07, and when drawing the rotated model, *t* (15) = 0.22, *p* = .828, Cohen's *d* = 0.05. For participants in the Clockwise Rotation Group, there was a marginally reliable trend to draw the eyes farther apart with respect to the width of the face than in model when drawing the upright model, *t* (15) = 2.03, *p* = .060, Cohen's *d* = 0.51, but there was no systematic direction of error when drawing the rotated model, *t* (15) = 0.71, *p* = .945, Cohen's *d* = 0.02.

Table 12.

Study 3B - Descriptive Statistics for Upright and 90 Degree Rotated Drawings

C/A (Vertical Position of the Eyes on the Length of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright – CW	0.45 (0.05)	-0.08 (0.05)	0.08 (0.05)
90 Degree Rotation – CW	0.44 (0.07)	-0.09 (0.07)	0.09 (0.06)
Upright – CCW	0.46 (0.05)	-0.06 (0.05)	0.07 (0.05)
90 Degree Rotation - CCW	0.42 (0.08)	-0.11 (0.08)	0.11 (0.07)

D/A (Vertical Position of the Mouth on the Length of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright – CW	0.14 (0.03)	0.01 (0.03)	0.02 (0.02)
90 Degree Rotation – CW	0.15 (0.04)	0.02 (0.04)	0.03 (0.03)
Upright – CCW	0.18 (0.06)	0.05 (0.06)	0.06 (0.05)
90 Degree Rotation - CCW	0.19 (0.04)	0.06 (0.04)	0.06 (0.04)

E/B (Inter-Ocular Distance Relative to the Width of the Face)

Orientation of Model	M (SD) Spatial Relation Ratio Values	M (SD) Error (Drawing – Model)	M (SD) Absolute Error
Upright – CW	0.26 (0.05)	0.03 (0.05)	0.05 (0.04)
90 Degree Rotation – CW	0.24 (0.05)	0.00 (0.05)	0.04 (0.03)
Upright – CCW	0.24 (0.07)	0.01 (0.07)	0.06 (0.04)
90 Degree Rotation - CCW	0.24 (0.05)	0.00 (0.05)	0.03 (0.03)

Note. CW = Clockwise Rotation Group; CCW = Counter-Clockwise Rotation Group

The second set of questions that will be evaluated with respect to this experiment pertains to evaluating the hypothesis, derived from previous perceptual research and the misperception hypothesis, that the pattern of drawing error effects due to face rotation that were observed for 0 vs. 180 degree rotation comparisons in Study 3A should be similarly observed for comparisons of drawing error between 0 vs. 90 degree model rotations. As with Study 3A, errors were transformed to absolute values. For each of the target spatial relation ratios, a 2 (Model Orientation: Upright vs. Inverted) × 2 (Rotation: Clockwise vs. Counter-Clockwise) × 2 (Order: Upright Drawn First vs. Rotated Drawn First) mixed ANOVA was computed testing for differences and interactions in absolute drawing errors.

With respect to the vertical spatial relation C/A, there was a reliable main effect of Orientation, indicating that the degree of absolute error in reproducing the vertical position of the eyes on the length of the face was reliably greater in the rotated drawings than in the upright drawings, F (1, 28) = 11.46, *p* = .002. This pattern was observed in the drawings of participants in both Order and Rotation conditions, as evident by the lack of a reliable Orientation × Order interaction, F (1, 28) = 0.00, *p* = .994, and the lack of a reliable Orientation × Rotation interaction, F (1, 28) = 2.30, *p* = .140. There was no reliable main effect of Order Condition, F (1, 28) = 2.13, *p* = .156 or Rotation Condition, F (1, 28) = 0.02, *p* = .901. Additionally, a reliable Orientation × Order × Rotation interaction was not observed, F (1, 28) = 0.89, *p* = .353.

With respect to the vertical spatial relation D/A, errors in reproducing the vertical position of the mouth with respect to the length of the face were not reliably different between drawings of the upright and rotated models, F (1, 28) = 0.80, *p* = .380. This lack of orientation effect on absolute drawing errors was observed in participants in both Order and Rotation conditions, as evident by the lack of a reliable Orientation × Order interaction, F (1, 28) = 0.39, *p* = .536, and the lack of a reliable Orientation × Rotation interaction, F (1, 28) = 0.24, *p* = .629. Further, there was no reliable main effect of Order Condition, F (1, 28) = 0.43, *p* = .519.

However, there was a reliable main effect of Rotation group, F (1, 28) = 6.74, *p* = .015, indicating that participants in the Counter-Clockwise Rotation group reproduced the vertical position of the mouth on the length of the face with greater error than the participants in the Clockwise Rotation group. Finally, there was no evidence of there being a reliable Orientation × Order × Rotation interaction, F (1, 28) = 1.50, *p* = .231.

Finally, with respect to the horizontal spatial relation E/B, there was a marginally reliable main effect of Model Orientation, F (1, 28) = 3.41, *p* = .076. In contrast to the directions of effect caused by model rotation reported here and in Study 3A, this reliable main effect indicated that model rotation facilitated drawing performance. There were smaller errors in reproducing the inter-ocular distance with respect to the width of the face when participants drew the rotated model compared to when they drew the upright model. This effect was similar for participants in both Order and Rotation conditions, as evident by the lack of a reliable Orientation × Order interaction, F (1, 28) = 0.07, *p* = .801, and the lack of a reliable Orientation × Rotation interaction, F (1, 28) = 0.87, *p* = .358. There was no reliable main effect of Rotation Group, F (1, 28) = 0.03, *p* = .868, or of Order Condition, F (1, 28) = 0.09, *p* = .765. Finally, there was no reliable Orientation × Order × Rotation interaction, F (1, 28) = 0.06, *p* = .816.

4.6 Discussion – Study 3B

As with Study 3A, this study produced two major sets of results. The first set of results concerns the directional patterns of error in reproducing the three spatial relationships measured. As with all analyses reported across Studies 1 – 3A, participants reliably drew the eyes farther up the length of the face in both upright and rotated drawings. Further, participants were biased to draw the mouth farther up the length of the face in both upright and rotated drawings, with the effect being stronger and more reliable in the counter-clockwise rotation group than in the clockwise rotation group. Finally, for the most part, there was no single reliable direction of error in reproducing the inter-ocular distance for upright or rotated models, with the single exception being that the clockwise rotation group had a trend to draw the eyes too far apart when reproducing the upright face but not when reproducing the rotated face. As in Study 3A, the directional errors in reproducing the inter-ocular distance were reliably correlated across upright and rotated drawings, r (30) = .45, p = .01, suggesting that there might be stable directional biases on the individual level where some participants are biased to draw the eyes too far apart whereas other participants are reliably biased to draw the eyes too close together. Thus, it was confirmed that the directional error biases relating to the vertical positioning of the eyes and mouth on the length of the face are highly consistent when drawing this model face (as additionally seen in the results of Study 1 and 3A) and are not dependent on the orientation of the model being drawn, as these biases has now been observed to exist when drawing upright, upside-down and 90 degree rotated models.

The second major set of results served to further evaluate the predictions of the misperception hypothesis. Unlike the set of results for Study 3A, the evidence produced here is not entirely consistent with the predictions of the misperception hypothesis. On the one hand, participants produced larger absolute errors in drawing the vertical position of the eyes when reproducing the rotated model compared to when drawing the upright model, with stronger effects being observed in the counter-clockwise rotation group than in the clockwise rotation group. This is similar to what Goffaux and Rossion (2007) observed in that participants were found to be less perceptually sensitive to changes in the vertical positioning of the eyes for 90 degree counter-clockwise rotated faces than for upright faces (they did not present clockwise-rotated face stimuli to participants). Thus, for this particular vertical spatial relationship of faces, there is a congruency of effects of face rotation on individuals' perception and drawing of the vertical positioning of the eyes, as the pattern of perceptual and drawing errors due to rotation does not depend on the degree of rotation, being similarly found for both 90 and 180 degree rotations.

One dissimilarity found between Studies 3A and 3B was that, here, absolute errors in reproducing the vertical position of the mouth on the length of the face did not differ between drawings of upright versus 90 degree rotated faces. How this particular result bears on the evaluation of the misperception hypothesis is presently unclear. On the one hand, Goffaux and Rossion (2007) proposed that the perception of vertical spatial relations is selectively disrupted by face rotation, irrespective of the degree of rotation. This leads one to identify a prediction of the misperception hypothesis that the vertical position of the mouth on the length of the face should be reproduced with worse accuracy when drawing rotated (both 180 and 90 degrees) as opposed to upright faces. Even though this was observed for comparisons between drawings of upright and 180 degree rotated faces, the result that this effect was not observed between drawings of upright and 90 degree rotated faces may lead one to conclude that this result is not consistent with the misperception hypothesis as the evidence suggests that this effect is dependent on the degree of rotation.

However, Goffaux and Rossion (2007) operationally defined vertical spatial relations in their experiments solely as the vertical positioning of the eyes on the length of the face. Thus, they provided no evidence of the consequences of face rotation on the perception of the vertical position of the mouth on the length of the face. So, it is presently unclear as to whether the lack of effect concerning the vertical position of the mouth due to 90 degree face rotation indicates a specific dissociation between perceptual and drawing processes or whether the perception of the vertical position of the mouth is not affected by face rotation in the same way that the perception of the vertical position of the eyes is (especially for 90 degree rotations). This highlights a gap in the perceptual research literature, and future studies should aim to determine whether different vertical spatial relationships of a face are processed differently from one another just as vertical and horizontal spatial relationships pertaining to the eyes are processed in qualitatively different ways.

Finally, another potential disconfirmation of the misperception hypothesis was evident by the observation that 90 degree rotations of the face model resulted in improvements in the drawing accuracy of the inter-ocular distance relative to drawings of the upright face. This appears to be inconsistent with the prediction of the misperception hypothesis as it has been shown that 90 degree counter-clockwise face rotations result in a small detrimental effect on the perceptual processing of the distance between the eyes (Goffaux & Rossion, 2007). On the one hand, the evidence provided here may indicate a dissociation between the perception and drawing of the inter-ocular distance in two ways. First, whereas the effect of model rotation on the perception of the inter-ocular distance has been shown not to differ between 180 and 90 degree rotations (Goffaux & Rossion, 2007), the effect of model rotation on drawing the distance between the eyes differed between 180 and 90 degree rotations. Second, whereas individuals tend to perceptually encode the inter-ocular distance less accurately in 90 degree rotated faces than in upright faces, participants in Study 3B reproduced the inter-ocular distance more accurately when drawing the 90 degree rotated face compared to when drawing the upright face. This result cannot be explained by the misperception hypothesis based on the evidence published to date in the perceptual research literature. However, this disconfirmation should be considered with caution. Unlike the repeated demonstrations that 180 degree face rotations cause small impairments in the perceptual sensitivity of the inter-ocular distance (Crookes & Hayward, 2012; Goffaux, 2008; Goffaux & Rossion, 2007; Goffaux et al., 2009), the observation that 90 degree face rotations detrimentally affect the perceptual sensitivity of the inter-ocular distance has only been demonstrated in one experiment to my knowledge (Goffaux & Rossion, 2007, Experiment 3). Thus, it is presently unclear whether the 90 degree face rotation effect on the perception of the inter-ocular distance is a reliable enough finding to serve as a strong foundation to test predictions of the misperception hypothesis.

4.7 General Discussion

The approach taken by Study 3 highlights the utility of using objective measurements of drawing error in testing theories relating to drawing performance, the misperception hypothesis being just one example. Quantifying specific elements of drawing error objectively allowed a stronger test of the misperception hypothesis and allowed the discovery of novel findings that was not possible with the use of subjective accuracy measurements.

Recall that Cohen and Earls (2010) reported that drawings of an upside-down model face were subjectively perceived to be less accurate than drawings of upright faces with respect to reproducing the spatial relationships between facial features. Such a subjective method of measurement did not allow one to determine if all or just some of the elements of spatial drawing accuracy were affected by rotating the drawing model, due to the holistic nature of the ratings. However, analysis of objective measurements of spatial drawing errors indicated that the detrimental effects of model rotation on spatial drawing accuracy is not universal across all reproduced spatial relationships. Reproduction of some spatial relationships are negatively impacted by model rotation (vertical position of the eyes on the length of the face) whereas others are either not affected at all by model rotation (no reliable difference of errors in reproducing the inter-ocular distance between upright vs. upside-down models) or are positively affected by model rotations (reproductions of the inter-ocular distance contained less errors in drawings of 90 degree rotated faces relative to drawings of upright faces).

Thus, subjective accuracy ratings do not provide complete accounts of the effects that experimental manipulations have on drawing accuracy in some cases. This suggests that it might be fruitful to re-visit other findings that have, through the use of subjective accuracy ratings, indicated influences of perceptual manipulations on drawing accuracy using objective measurements of drawing error to determine whether such effects universally affect all or only some aspects of drawing accuracy. For instance, consider findings reported by Freeman and Loschky (2011). Here, participants drew faces from observation under conditions where the model stimuli were filtered to isolate either the high-, middle- and low-spatial frequencies. These three groups of drawings were measured using subjective ratings of perceived accuracy. Drawings of the high and low spatial frequency model stimuli were perceived to be more accurate than drawings of middle-spatial frequency models. This finding suggests that high and low spatial frequencies contain the most useful information to process in order to create an accurate drawing, whereas middle spatial frequencies do not contain as much useful information in guiding drawing performance.

However, the use of holistic ratings of perceived accuracy raises the question of whether all elements of face drawing are negatively impacted by isolation of middle spatial frequencies and facilitated by isolation and low-and high spatial frequencies. Previous findings suggest that this might not be the case if, as the misperception hypothesis suggests, the way information is perceptually encoded affects drawing performance. For instance, the vertical position of the eyes on the length of the face are most accurately perceived when face stimuli are isolated for middle spatial frequencies compared to when isolated for low- and high spatial frequencies. In contrast, the horizontal inter-ocular distance is perceived most accurately when face stimuli are isolated for high spatial frequencies compared to when isolated for middle spatial frequencies. Further, perception of the inter-ocular distance is more accurate when face stimuli's middle spatial frequencies are isolated compared to when the low spatial frequencies are isolated (Goffaux, 2008). Such effect patterns were found with respect to the perception of both upright and upside-down faces.

Thus, different spatial frequencies provide information that is differentially related to the perception of different spatial relationships in a face. It is interesting to note that neither vertical eye position or horizontal distance between the eyes have been found to be perceived least accurately when the middle spatial frequencies are isolated (Goffaux, 2008), despite Freeman and Loschky's (2011) finding that middle spatial frequency-isolated models were drawn least accurately. Regardless, objective measurements can allow one to further probe the effects of differential spatial frequency isolation on drawing performance by determining whether the previously reported perceptual patterns of effects are congruent with patterns of drawing error of vertical and horizontal spatial relationships across different spatial frequencies. Such findings are predicted by the misperception hypothesis, and thus, such a study would provide an additional means of testing this popular hypothesis. As Study 3 revealed, the findings from such a study may find that the relationship between spatial frequency isolation and face drawing accuracy is not as simple as the findings of Freeman and Loschky (2011) suggest.

More generally, future research aiming to test specific theories assessing how certain experimental manipulations affect drawing accuracy should use objective measurements of drawing error in conjunction with subjective ratings of perceived accuracy. Such a strategy will allow clearer assessments of how different elements of drawing accuracy are affected by such manipulations, and allow clearer evaluations of theories which, when thought through, predict differential patterns of effects on different elements of drawing accuracy.

5. General Discussion

To summarize the findings of the three studies reported in this dissertation: First, some reliable directional error biases were found with respect to the reproduction of spatial relationships between facial features. Several of these errors were robust over the drawings of the four different model face stimuli employed across the three studies, such as drawing the face too round in shape, the eyes too far up the length of the face, and the nose too narrow relative to the width of the face. Other present directional biases appeared to be reliable for a given model face but were not robust across different model faces, such as drawing the mouth too far up the length of the face. Further, such directional biases of error are robust over different orientations of the model face, suggesting that such directional errors exist with respect to the canonical orientation of the face rather than the orientation of gravity (e.g., the eyes are drawn farther up the length of the canonically orientated face regardless of whether the face is upright or upside-down; in other words, the eyes are not simply drawn too far up the length of the paper).

Further evidence suggests that one major source of errors in reproducing spatial relationships in observational drawing of faces involves the activation and processing of long-term memories that represent the relative spatial positioning of facial features. The most reliable and robust directional spatial drawing errors made in observational drawing of faces were congruent with directional spatial drawing biases inherent in long-term memory, as assessed by non-artists' memory-based drawings of faces. Moreover, spatial positioning of facial features produced in memory-based drawings predicted how these features were reproduced in the observational drawing of a face model. All told, these results suggest that when drawing a model face from observation, drawing performance is influenced by both bottom-up visual information inherent in the model stimulus and top-down information inherent in long-term memory.

Finally, computational processes resulting in perceptual transformations additionally appear to influence drawing behaviors, bearing on the notion that the misperception of a stimulus is a significant source of drawing errors (Cohen & Bennett, 1997). The present set of findings provided mixed evidence in support of the misperception hypothesis. On the one hand, drawings of the vertical eye position on the length of the face were associated with greater errors when drawing 180 degree and 90 degree rotated faces relative to drawing upright faces, an effect pattern that has been previously observed when individuals provide perceptual judgments of faces (Crookes & Hayward, 2012; Goffaux, 2008; Goffaux & Rossion, 2007; Goffaux et al., 2009; Sekunova & Barton, 2008). Further, when comparing upright and upside-down drawings of faces, the detrimental effect of rotation was weaker on drawing errors of the inter-ocular distance than of the vertical positioning of the eyes – another effect pattern that has been observed with respect to perceptual judgments of upright and upside-down faces. On the other hand, drawings of the inter-ocular distance were reliably more accurate when drawing a 90 degree rotated face versus an upright face, a pattern opposite to that observed for perceptual judgments of upright and 90 degree rotated faces (Goffaux, 2008). Thus, the misperception hypothesis accurately predicted rotation effects with respect to the drawing of the vertical position of the eyes, but not with respect to the drawing of the horizontal inter-ocular distance. Thus, it is presently unclear whether perceptual transformations caused by face rotation are a major source of the errors found when drawing upright and rotated faces. Such perceptual transformations may be specific to the particular element of drawing accuracy considered (e.g., vertical position of the eyes, but not horizontal distance between eyes). Alternatively, such patterns of drawing error may be accounted for by other, non-perceptual factors.

Regardless, the set of studies described here demonstrate how objective measurements of drawing accuracy are a beneficial tool in the empirical study of drawing performance. Such objective measures allow precise quantifications of the errors individuals make in their drawings, and thus allow one to assess how memory- and perceptual-based factors are specifically associated with different elements of drawing accuracy. Research on the psychological basis of drawing ability would greatly benefit by moving away from considering drawing accuracy exclusively as a unitary variable that can be measured by a single dimension of accuracy (i.e., by holistic ratings reflecting the perceived accuracy of drawings) and moving towards complementing the use of subjective ratings with operationally defining drawing accuracy according to specific elements that quantify the precise errors present in a drawing. This will allow for clearer assessments of the relationships between drawing accuracy and other psychological variables, as well as how specific manipulations affect drawing accuracy, thus providing a better understanding of the psychology of drawing behavior.

5.1 Moving Forward – Future Directions of Research.

In this section, I wish to broaden the scope of discussion and highlight potential directions research on the psychology of drawing can take moving forward. Here, I will specifically focus on how future research can adopt different theoretical approaches that can potentially serve to generate novel insights on the psychological processes relating the drawing performance and skill acquisition. As with the studies presented in this dissertation, the history of empirical research concerning drawing behavior has generally investigated the relationships different psychological processes have with drawing performance in isolation of one another. For instance, studies generally seek to see how a given perceptual process or a given memory process is related to or affects drawing behaviors. However, research in this domain might benefit if we start to consider how different psychological processes interact with one another to influence the production of observational drawings. Some previous theoretical discussions have adopted this approach (e.g., Kozbelt & Seeley, 2008), but unfortunately this hasn't yet influenced the nature of empirical investigations of drawing performance to date.

5.1.1 The Integrative Influence of Perception and Memory on Drawing.

In the studies reported in this dissertation, I investigated the relationships that perception and memory have with drawing accuracy separately from one another. However, novel insights may be had by investigating the integrative role of perception and memory on drawing performance. It is well-established in the psychological literature that perception and memory do not operate in isolation from one another. Multiple lines of evidence suggest that activated memory representations have a strong influence on the activated content of perceptual representations. For instance, a number of studies relating to the perception of ambiguous figures, visual stimuli that can activate at least two distinct identity-based perceptual representations, have demonstrated that priming the activation of memory content can bias the perceptual representation activated when viewing such figures (e,g. Balcetis & Dale, 2007; Bugelski & Alampay, 1961; Goolkasian & Woodberry, 2010). For instance, Bugelski and Alampay (1961) presented participants with an ambiguous figure that could either be perceived as a rat or man. Before this figure was presented, participants were shown images that were semantically associated with one of the two possible interpretations of the ambiguous figure (e.g., semantic associates of man were images of humans; semantic associates of rat were images of animals). When shown the images semantically associated with man, 77% of participants identified the ambiguous figure as depicting a man. In contrast, when shown the images semantically associated with rat, 87% of participants identified the ambiguous figure as depicting a rat. Similarly, in one experiment reported by Balcetis and Dale (2007), participants were presented with an ambiguous figure that could be identified as a woman's face or a saxophone player. Before presenting participants with this figure, participants read one of two passages that discussed issues that were semantically related to either women or saxophone players. Participants who read a passage about pornography more often perceived the ambiguous figure as a depiction of a woman's face compared to participants who read a music-related passage, who tended to perceive the ambiguous figure as depicting a saxophone player. Thus, these two studies show that information activated in memory, whether by visual or verbal cues, is capable of biasing the perception of visual stimuli.

Not only can memory influence the perceptual identification of objects, but it can also influence more basic-level perceptual attributes of an object. For instance, Ropar and Mitchell (2002) reported evidence that knowledge can influence shape perception. Here, participants were presented with an image of an ellipse in isolation of any surrounding contextual cues. Before being presented with the image, one group of participants were told that they were viewing a circle shown at a slant whereas the other group of participants were told that they were viewing an ellipse. After instruction, both groups were presented with the target ellipse stimuli and were provided with a separate comparison object that they adjusted in shape until it matched the specific shape of the target ellipse they were viewing. Despite the fact both groups of participants viewed identical ellipse target stimuli, participants who were told that they were viewing a slanted circle adjusted the comparison shape to be more circular than participants who were told that they were viewing an ellipse. Thus, the evidence suggests that being told they were viewing a slanted circle activated a memory representation of a circle which biased their perception of the apparent shape of the target stimuli.

With these findings in mind, it could be the case that the influences of perception and memory on drawing performance are related to one another. Transformational processes that affect perceptual and drawing errors alike (e.g., shape constancy: Mitchell et al., 2005; Ostrofsky et al., submitted) could be driven or influenced by how the objects depicted by the target stimuli are represented in memory. Top-down, memory-based influences that alter perception could then consequently affect drawing performance. Future drawing-related research interested in evaluating this claim may benefit from the use of ambiguous figures as stimuli. One could potentially replicate features of the experiments described above (Bugelski & Alampay, 1961; Balcetis & Dale, 2007). However, instead of assessing how visual or verbal priming cues affect perceptual identification, which is well established, one could assess how such priming cues affect drawings of such ambiguous figures. Previous research has employed such a strategy, seeking to determine how figure interpretations affect procedural aspects of drawing performance such as the sequence in which lines are drawn (Van Sommers, 1984; Vinter, 1999). However, future research may want to determine if priming cues affect the content of drawings. For instance, after participants create a prime-preceded drawing of an ambiguous figure, independent judges could be provided with the participants' drawings and asked to make a judgment as to what object the drawing is attempting to depict. If such primes affect the content of the drawings, then primes that have been found to bias the perceptual identification of the figure towards one object-interpretation would also be predicted to bias the production of drawings to appear like that same object-interpretation more than the alternative object-interpretation. If such a finding were to be observed, then that would indicate that activated memory representations influence perceptual identification, which in turn influences drawing performance.

An alternative approach to testing this idea would be to partially replicate the study conducted by Ropar and Mitchell (1997), where participants are presented with an ellipse and told it is either a "slanted circle" or an "ellipse". Since it is known that such knowledge affects the perceived shape of the target ellipse, one can further attempt to determine if such knowledge affects the drawings of the target ellipse in similar ways. If individuals who are told that they are to draw the "slanted circle" draw the ellipse as more circular than individuals who are told to draw the "ellipse", this would also be pretty convincing evidence of the integrative influences of memory and perception on drawing performance, as knowledge alters the perception of the shape and, consequently, affects how the shape is drawn.

Regardless of the methodological approach, the effects of perception and memory on drawing performance are probably not as isolated as they have been empirically treated in the research literature. Future work should aim to investigate how perception and memory mutually interact with one another to influence the production of observational drawings.

5.1.2 Relationship Between Memory and Attention on Drawing Performance.

Another way we can approach the psychological study of drawing in a more integrative fashion would be to study how attentional factors interact with memory-related processes associated with drawing performance. Attention is a psychological factor that, like perception and memory, has been investigated with respect to drawing performance in a relatively isolated fashion. For instance, previous research has investigated the differences between trained artists and non-artists with respect to what visual information is attended to and/or what model-based visual information is included and excluded from a reproduction (Biederman & Kim, 2008; Kozbelt et al., 2010; Ostrofsky et al., 2012). These studies have suggested that the perceived accuracy of a reproduction is related to what individuals visually attend to with respect to the features of the model being reproduced.

For instance, Biederman and Kim (2008) and Ostrofsky et al. (2012) reported evidence that trained artists include more T-, L- or fork-junctions in their reproductions of a model than non-artists do. Such vertices are features of objects that provide crucial information when recognizing objects (Biederman, 1987) and are features of objects that strongly suggest the depth and form of an object. The importance of such features are evident in drawing, as Ostrofsky and colleagues (2012) reported that the artists, whose depictions included more vertices, created reproductions that were perceived to be more accurate than those made by non-artists. Further, Biederman & Kim (2008) more directly demonstrated that drawings that include T-junctions are perceived to be more accurate than drawings excluding T-junctions. Thus, these findings suggest that one potential source of skilled drawers' ability to produce highly accurate reproductions of models is that they visually attend to and include in their drawings the most essential features of an object that support object recognition, whereas non-artists are more likely to ignore and exclude such crucial visual information from their drawings (see also Kozbelt et al., 2010).

Research has not only demonstrated differences between skilled and unskilled drawers with respect to what they pay attention to, but rather, how they pay attention to the model they are copying (Miall & Tchalenko, 2001; Tchalenko, 2009). For instance, Miall and Tchalenko (2001) recorded eye-movements made by one highly skilled, famous artist (Humphrey Ocean) and three non-artists while creating an observational drawing of a face. One interesting observation was that, during any single glance at a model, the artist and non-artists differed in how visual attention was deployed across the model stimulus. They observed:

> Ocean’s fixations were always single, whereas the [non-artists’] were generally multiple. Ocean locked his gaze onto one position, apparently taking in a single detail, while the [non-artists] fixated on two or more positions, sometimes quite separate. The briefer and less consistent fixation durations of the novices were more typical of everyday eye movements and more typical of Ocean’s fixation pattern when not drawing. (p.38)

If the observations of the authors were correct and generalizable to other artists and non-artists, then this suggests that one aspect of acquiring drawing skill is the development of a domain-specific strategy of how to deploy visual attention across a model during drawing. The strategy of viewing a visual stimulus by targeting eye fixations to a single, small region of an object seems to be an unnatural behavior during everyday perception, but one that might facilitate drawing performance. Thus, a part of drawing training might involve training the visual system to deploy attention in such a novel, unnatural way. Without such training, non-artists will likely approach attending to a model in the same way they approach attending to any visual stimulus during any situation.

As interesting as these sets of findings are, they do not indicate how attention interacts with other psychological factors that are related to drawing accuracy, as the relationship between attention and drawing was studied in isolation from other potentially relevant factors. Attention is not a psychological factor that operates in isolation from other psychological factors such as memory. For instance, it has been shown that activated memory representations are capable of biasing how objects and scenes are visually attended to (Duncan & Humphreys, 1989; Neider & Zelinsky, 2006; Reeder & Peelen, 2013). In studies investigating visual search performance, it has been found that activating a representation in memory of the target object biases search performance, both with respect to deployment of saccadic eye movements across a scene and speed of target detection. Visual information in a scene that matches information inherent in the activated memory representation captures attention more strongly than scene-based information not represented in the activated memory.

For instance, Duncan and Humphreys (1989) presented participants with displays that could contain letter-stimuli that were upright “L”s and 0, 90 (clockwise and counter-clockwise) and 180 degree rotated “T”s. Before the displays were presented, participants were asked to, when presented with the display, report as quickly as possible whether the “L” stimulus was present or not. In one condition, “L” targets were presented alongside distracters that were 90 degree counter-clockwise and180 degree rotated “T”s. These specific rotations of “T”s resulted in the appearance of “L” shaped-features being apparent in the distracters (the “high similarity” between target and distracter condition). In the other condition, the “L” targets were presented alongside with “T” distracters that were rotated either 0 or 90 degrees clockwise. Such rotations do not result in the presence of “L” shaped features being apparent in the “T” distracters (the “low similarity” condition). The authors reported two important findings. First, reaction times to detect the “L” targets were faster in the low similarity condition relative to the high similarity condition. Second, reaction times to detect the “L” target were not affected by the number of distracters in the low-similarity trials, but were in the high-similarity trials (slower reaction times for displays with more distracters).

These findings suggest that when participants were informed to report the presence versus absence of an “L”, a memory representing the appearance of this object was activated in memory. When the search display was presented, this activated memory seemed to function to bias attention towards regions of the display that most closely matched the information represented in the activated memory and bias attention away from regions of the display that did not closely match this memory representation. In the high-similarity trials, detection times were slower and affected by the number of distracters because every object in the display contained a feature matching the information represented in the activated memory. Thus, attention was biased to be directed towards every object in the display. Alternatively, in the low-similarity trials, none of the distracters contained an “L” shape feature, and thus, attention was not biased towards any of the distracters, resulting in faster target detection times and no effect of the number of distracters present. Thus, when there is a pre-defined goal for visual analysis of a scene, information about that goal is activated in memory and biases attentional allocation to the regions of a scene that most closely resemble the information represented in memory.

This effect of memory on attention may be relevant to understanding drawing performance differences between skilled and unskilled drawers. For instance, the finding that artists attend to including more vertices in their reproductions than non-artists may be caused by memory-related effects (Kozbelt & Seeley, 2008). Through training, artists may acquire the knowledge that vertices are an important graphical feature that contributes to the accurate rendering of the form and depth of an object’s appearance. Consistent with this, well-known “how-to” drawing manuals stress the importance of representing T-junctions either explicitly (e.g., Hamm, 1963, p.48) or implicitly (by stressing the importance of overlapping forms, which result in the production of T-junctions: Beakley, 1982, p. 9; Dodson, 1985, p. 130) in drawings in order to provide a sense of depth. If artists develop such knowledge, then when given the task to draw a model from observation, activations of long-term memories representing junction-based information could occur and thus bias visual attention to seek out, and ultimately draw, these features. In contrast, since non-artists have not acquired explicit training emphasizing the importance of including such features, no memory representation is available to be activated during a drawing task that would serve to bias attention to selectively process these features, resulting in such features being less frequently represented in a drawing.

Such a mechanism may not only be related to the drawing of specific features such as junctions, but might also be related to the drawing of spatial relationships between features, such as those found in a face or the human figure. Many drawing manuals explicitly teach what spatial relationships to pay attention to when reproducing the relative spatial positioning of an object's various features. For instance, with respect to frontal views of faces, Hamm (1963, p. 4-5) teaches that the length of an ear is approximately the vertical distance between the top of the eyes and the bottom of the nose, or that the distance between the eyes is approximately the width of one of the eyes. With respect to non-foreshortened views of the human figure, Hamm (1963, p. 39) teaches that the length of the head is a good unit of measure to determine the proportions of the rest of the body. For instance, he notes that the height of the adult body is approximately 7.5 heads long, and the width of the shoulders is approximately the width of two horizontally oriented heads. Once acquired, activation of these knowledge representations during an observational drawing task can serve to bias visual attention to selectively process these relationships, and thus, while accounting for a model's slight deviations from these general rules of thumb, result in more accurate reproductions of the relative spatial positioning of an object's features.

The idea that drawing accuracy is affected by how visual attention is deployed across a model stimulus, and that activated memory representations can bias what is paid attention to in a model, is amenable to empirical testing. For instance, one could conduct a study with untrained non-artists where one group of individuals are provided with explicit instructions that T-junctions and other vertices are extremely important features to include in a drawing, while another group of individuals are not provided with such instruction. Afterwards, individuals can be asked to observationally draw a model stimulus that contains many available vertices to potentially reproduce. In order to determine whether instruction affected individuals' attention to including these features, one could compare the number of depicted vertices between the two groups, with the expectation that the group provided with explicit instruction would depict vertices more than the group not provided such instruction. If this were the case, then one could also have independent judges rate the accuracy of the drawings to evaluate whether the knowledge-mediated attentional differences between the two groups affect the perceived accuracy of the drawings.

The same intervention-based methodological strategy could be applied to studies investigating the drawing of spatial relationships between an object's features, such as those of a face that were investigated in this dissertation. For instance, consider the finding that non-artists regularly draw the vertical eye-line too far up the length of the face. This may be due to the fact that they have not acquired the knowledge that the vertical eye-line is approximately halfway down the length of the face, or less specifically, that the vertical position of the eye-line on the length of the face is an important spatial relationship to accurately depict in order to support the production of a quality rendering of a face. The lack of such knowledge may result in non-artists not selectively attending to assessing this particular spatial relationship, and thus drawing it inaccurately. One could test whether knowledge-mediated attention to this spatial relationship affects drawing performance by instructing one group of individuals that the vertical position of the eyes on the length of the face is an important spatial relationship, while another group is not provided with such instruction. In order to see if such instruction affects attention to this relationship, one could compare the degree of error between the two groups in representing this spatial relationship. If it is found that the instructed group more accurately depicts the vertical position of the eye-line, it would suggest that the acquired knowledge served to bias attention towards encoding this spatial property, and that such attention served to increase drawing accuracy.

Thus, one potentially fruitful direction of future research concerning drawing performance might want to look at how memory representations bias visual attention to support the ability to reproduce a model stimulus accurately in an observational drawing task. More generally, the study of how multiple psychological processes interact with one another to affect drawing performance, as opposed to studying how each process affects drawing performance in isolation, will likely lead to a more nuanced and complete understanding of this complex behavior.

5.1.3 Product- versus Process-Oriented Approaches to Drawing Research.

The studies reported in this dissertation and the majority of studies concerning the psychology of drawing published to date can be characterized as a *product-oriented research approach*. Such studies aim to understand how the quality, accuracy, or content of the finished drawing are related to other psychological variables and/or how they are affected by specific experimental manipulations. However, a minority of drawing research studies can be characterized as a *process-oriented research approach*. Here, the major concern of the studies is not necessarily the final drawn product, but rather, the sequence of actions it took to generate the final drawing. Multiple general-level questions can be addressed with such an approach. One could also ask how mark-making sequences affect the accuracy of the final drawn product. A common feature in print and online "how-to" drawing manuals is instructions about how to draw common objects in step-by-step fashion. For instance, Beakley (1982) instructs how to accurately draw linear perspective in scenes and Hamm (1963) instructs how to draw faces, eyes, human figures, hands and legs via step-by-step procedures. Does the sequential process of mark-making in drawing affect the accuracy of the final drawn product? Can the difference in drawing accuracy between skilled and unskilled drawers be partly accounted for by differences in the step-by-step procedures they take to depict objects from observation? Answers to these questions could potentially be found by video-based analyses of artists' and non-artists' drawings.

Beyond attempting to understand how sequences of marks affect the accuracy of the final drawn reproductions, one could ask how other psychological factors, such as memory, perception and/or attention, affect the sequence of marks made in producing a drawing. Van Sommers (1984) adopted this approach in a study where participants were presented with an ambiguous figure that could be interpreted as two mice kissing or two swords crossing. Participants drew this ambiguous figure after being provided with one of the two interpretations. Interestingly, the sequence of drawing strokes was affected by which interpretation the participants were provided. When provided the crossing swords interpretation, participants tended to make two long diagonal strokes that intersected in the middle (e.g., like how one would write the letter "X"). In contrast, participants who were provided the two mice interpretation tended to draw to side-ways V's next to each other (e.g., like a "greater than" and "less than" symbol side-by-side: “>” “<”). This finding suggests that the provided interpretation activated a representation in memory of the interpreted object, and that there are different drawing-related motor sequence programs stored in long-term memory specific to different categories of objects that guide the sequential process of drawing.

Assessing the role of long-term memory representations in sequential drawing behaviors could be further studied using an alternative strategy beyond the use of ambiguous figures. For instance, one could compare imagination- and observation-based drawings to one another, as did Matthews and Adams (2008) and Study 2 of this dissertation. Using faces, for instance, one could ask participants to create imagination- and observation-based drawings while being videotaped and assess the degree of similarity in the sequences of drawn features. If drawing-related long-term memories represent a motor sequence program containing information about the sequence of drawn marks, the sequence of drawn features made in the imagination-based drawings should be able to predict the sequence of drawn features in the observation-based drawings. Challenge would include being able to develop a coding scheme that adequately represents the drawing sequence, and to find a way to quantitatively assess the degree of similarity of sequences between the two types of drawings. Regardless, adopting such a process-oriented approach may allow future research to discover whether motor sequence programs, in addition to spatial relationships and features, are represented in long-term memories that bias the production of observational drawings of faces and other common objects.

5.2 Conclusion.

The studies reported in this dissertation and the discussion of the broader psychological issues relevant to this line of inquiry highlight the importance of future research taking a more integrative approach to studying drawing performance. For one, integrating different forms of measurement of drawing accuracy can lead to a clearer understanding of drawing performance and ability, as the traditional method of using subjective accuracy ratings and the objective measurement of drawing error method reported here and elsewhere (Carson & Allard, 2013; Mitchell et al., 2005; Ostrofsky et al., submitted; Tchalenko, 2009) each provide distinct contributions of understanding the quality of a observational drawing. The former indicates how outside observers perceive the overall accuracy of a drawing, while the latter indicates precisely how drawings deviate from the model being reproduced. Additionally, integrating different theoretical approaches that have traditionally been treated in isolation can lead to a more comprehensive understanding about how psychological processes are related to and affect the quality of a drawing. Investigating how perception, memory, attention, and other psychological factors interact with one another to influence the final drawing and sequence of actions it took to produce the final drawing can lead to novel insights and more unified theories about drawing behaviors.

Psychological research into normal adult drawing behaviors is still in quite an early stage, and hopefully, the trend over the last 15 years of increased research into this extremely interesting, yet poorly understood behavior, will continue to progress into the future. Such research promises to yield significant insights not only about the activity of drawing itself, but about broader psychological issues relating to perception, attention, memory, motor planning and execution, expertise, and creativity.

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