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Do Graphic Long-Term Memories Influence the Production of Observational Drawings? The Relationship Between Memory- and Observation-Based Face Drawings

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When drawing a face from observation, nonartists produce systematic errors when reproducing the relative spatial positioning of features (Ostrofsky, Cohen, & Kozbelt, 2014). The present study aims to investigate whether such systematic drawing errors are related to biases inherent in graphic long-term memories that represent the spatial relationships between facial features. Adult nonartist participants produced 2 face drawings: 1 based on memory without the guide of a model and 1 based on their observation of a standard model. Observation-based drawings systematically deviated from the model by depicting: the head too round, the eyes too far up the head, the nose too narrow and the left eye too close to the left side of the face. These systematic drawing errors mirrored long-term memory biases: memory-based drawings of these 4 spatial relationships systematically deviated from the "average adult face" (estimated by measurements of 50 face photographs) in the same direction. Further, observation- and memory-based drawings were positively correlated with respect to their depiction of these and other spatial relationships between facial features (e.g., vertical positioning of the mouth and interocular distance). These findings suggest that biases inherent in graphic long-term memories are one potential source of observational drawing errors, and that individually specific long-term memory representations are a potential explanation for the individual variability in appearance of observational drawings of a standard model.

Keywords: observational drawing, memory drawing, long-term memory, face drawing, drawing biases

Observational drawing is the behavior where individuals attempt to reproduce the appearance of a directly perceived model as accurately as possible. When groups of nonartists are asked to create such drawings based on a standard model, there is a remarkable degree of individual variability in the appearance of the produced drawings. The causes of such individual variability in nonartists' drawings are not well understood, and consequently, have increasingly become a focus of psychological research. Predominately, researchers have focused on investigating how drawing performance is influenced by how the model is perceived and attended to (e.g., Chamberlain, McManus, Riley, Rankin, & Brunswick, 2013; Cohen, 2005; Cohen & Bennett, 1997; Cohen & Earls, 2010; Drake, 2014; Freeman & Loschky, 2011; Kozbelt, Seidel, ElBassiouny, Mark, & Owen, 2010; Mitchell, Ropar, Ackroyd, & Rajendran, 2005; Ostrofsky, Kozbelt, & Seidel, 2012; Tchalenko, 2009). The assumption that unifies these studies is that how information acquired at the time of viewing the model and creating the drawing is processed is what determines the ultimate appearance of the drawing. Further, individual variability in the appearance of drawings is understood to be caused by individual variability in how the model being reproduced is perceived and attended to.

While these studies have reported evidence to suggest that this is the case, this general understanding of what influences drawing performance may be incomplete. In addition to the processing of information present at the time of drawing (the model and emerging drawing), observational drawing performance may also be guided by the processing of information stored in long-term memory (LTM) that has been acquired well before a given observational drawing task begins (Cohn, 2012; Gombrich, 1960; Kozbelt & Seeley, 2007). Everyday experience strongly suggests the existence of stored LTMs of graphic-based information that represents how to draw common objects. This is evident by the ability of normal adults to draw recognizable depictions of common objects from memory without the guide of an external model stimulus. Further evidence of the existence of specialized LTMs that are specific to representing how to draw common objects (as opposed to representations supporting mental imagery of common objects) comes from a study of a neurological patient who was severely impaired in his ability to draw common objects based on his imagination (termed here throughout as *memory-based drawings*) (Trojano & Grossi, 1992). This impairment was accompanied by a normal ability to generate and manipulate mental images and produce quality observational drawings of a directly perceived model. This patient's dissociation in observation- and memory-

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based drawing abilities suggests that these two drawing behaviors are supported by functionally specialized, independent mechanisms.

However, the mechanisms supporting observation- and memory-based drawing performance in neurologically intact adults may interact with one another during the production of an observational drawing. According to this perspective, when attempting to reproduce a model from observation, drawing performance is argued to be influenced by both bottom-up visual information inherent in the model and top-down information inherent in stored LTMs. Thus, this perspective suggests that the individual variability in the appearance of observational drawings is partially caused by individual variability in LTMs that generally represent how to draw the object depicted in the model.

Empirical evidence has been reported that suggests an influence of LTM on the production of observational drawings. For instance, nonartist children and adults produce observational drawings of familiar objects less accurately than unfamiliar objects (Glazek, 2012; Moore, 1987; Phillips, Hobbs, & Pratt, 1978). Since individuals have established LTMs that represent how to draw objects they are familiar with, one may suggest that the drawing accuracy of familiar objects suffers due to the influence of processing information stored in memory that is not inherent in the models being drawn. In contrast, there are no established LTMs representing the graphic properties of unfamiliar objects that could potentially be activated and interfere with the ability to accurately draw the model. Thus, in addition to the perceptual-based information inherent in the model, nonartists' graphic representations of familiar objects stored in LTM appear to influence the production of an observational drawing to some degree.

With respect to the properties of such graphic LTMs, it is unlikely that familiar objects are identically represented across individuals. Rather, it is more likely that there is individual variability in the prototypical graphic representations of familiar objects. If such LTM representations influence the production of observational drawings, then one explanation of the individual variability in the appearance of such drawings 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 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 LTM. Second, participants were asked to draw a standard model cylinder from observation. Objective measurements of six 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 properties of cylinders are represented in LTM, correlational analyses were conducted assessing the relationship between the spatial measurements of the two types of drawings. All of the measured spatial relationships were associated with reliable positive correlations between the two types of drawings when the memory-based drawings depicted a cylinder in the same orientation as the model cylinder. These results suggest that individually specific LTMs that represent the spatial properties of cylinders were activated and influenced the production of the observational drawings of the cylinder. However, it is presently unclear as to whether the ability of the appearance of memory-based drawings to predict the appearance of observation-based drawings is specific to the drawing of cylinders or generalizes to the drawings of different types of objects. Discussed below, one aim of the current study was to investigate if such a predictive relationship between memory- and observation-based drawings extends to the drawing of faces.

To summarize thus far, there is evidence to suggest that adult observational drawing performance is partially biased by the activation and processing of LTM representations of the object being reproduced. The current study aims to extend this line of research with respect to the drawing of human faces. Many studies have focused on investigating the psychological processes that guide face drawing (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; Ostrofsky et al., 2014), each having demonstrated substantial individual variability in the appearance of nonartists' drawings of a standard model face. Most relevant to this study, Ostrofsky et al. (2014) investigated the nature of errors nonartists produce when drawing a face model, reporting a number of systematic error biases present in most nonartists' drawings of the spatial relationships between facial features. Specifically, most nonartists were observed to draw the head too round, the eyes and mouth too far up the length of the head, the eyes too far apart and the nose too narrow.

Currently, the sources of these directional error biases are not well understood. Here, the current study evaluated the idea that graphic representations of faces stored in LTM might be a related factor in the production of such spatial error biases in nonartists' observational drawings. In order to do so, the current study investigated whether there is a relationship between observational drawing errors and biases inherent in memory-based face drawings that are guided by graphic LTMs.

Two methodological strategies were employed to determine whether such a relationship exists. Nonartist participants were asked to create two face drawings, one guided by their imagination alone (memory-based drawings) and one guided by a standard face model (observation-based drawings). The first strategy aimed to determine if there is a congruency in the directional biases of drawing the relative spatial positioning of features between observation- and memory-based face drawings. In order to determine directional biases in observation-based drawings, the current study replicated the method employed by Ostrofsky et al. (2014) by measuring the degree to which the drawings deviated from the model with respect to multiple spatial relationships (e.g., the roundness of the head, the vertical positioning of the eyes and mouth, the width of the eyes and nose, etc.).

In order to determine if there are directional biases inherent in the graphic representations that guide memory-based drawings, I measured the degree to which the memory-based drawings deviated from an "average face" (estimated through measurements of a collection of photographs depicting different faces) with respect to the same spatial relationships measured in the observation-based drawings. Assuming the photograph collection allows for a representative estimate of the relative spatial positioning of features found in the "average face," any reliable spatial deviations in the memory-based drawings from the "average face" can be considered biases in how the spatial properties of a face are represented in LTM. If systematic error biases present in the observational drawings of a face are partially influenced by long-term memory, one would predict that there should be congruent directional biases between the observation- and memory-based drawings (e.g., in both types of drawings, the eyes should be drawn too far up the head and/or the head should be drawn too round).

The second methodological strategy employed in this study was adopted from Matthews and Adams' (2008) study on cylinder drawings. Specifically, the current study aimed to determine if there was a covarying relationship with respect to the relative spatial positioning of features between the observation- and memory-based drawings. If observational drawings of the spatial relationships between facial features are partially influenced by LTM, one would predict the measured spatial relationships of features to be positively correlated between the two drawing tasks.

Method

Participants

Thirty-eight individuals [32 females and 6 males; *M* (*SD*) age = 22.84 (3.44) years] participated in this study for course credit. Participants were undergraduate psychology students who reported having no formal artistic training in drawing.

Materials

Participants were asked to create a drawing of a face based on a standard model photograph (*observation-based drawings*). The model photograph was taken from the Psychological Image Collection at Stirling (PICS) Utrecht ECVP Database (image "m4001") (see Figure 1). The photograph depicts a frontal view image of an adult Caucasian male face with neutral emotional expression and no facial hair. The photograph was presented to 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. Additionally, participants were asked to create a drawing of a face based on their imagination without any model to guide their drawings (*memory-based drawings*). 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 estimating the average spatial positioning of features in adult Caucasian male faces, 50 photographs depicting such individuals were obtained from four online face photograph databases: (a) PICS Utrecht ECVP database, (b) PICS Aberdeen database, (c) The Informatics and Mathematical Modeling (IMM) Frontal Face Database (Fagertun & Stegmann, 2005), and (d) The Investigative Interviewing Research Laboratory (IIRL) Face Database. Photographs that were selected from these databases always depicted an adult male Caucasian face shown in the fronto-parallel orientation, exhibiting a neutral emotional expression and did not have facial hair.

Figure 1. The model face that guided the observation-based drawings. The photograph was taken from the Psychological Image Collection at Sterling (PICS). Permission to reproduce this photograph was provided by the PICS administrator and the subject of the photograph.

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 memory-based drawings. Here, participants were instructed to create a drawing of the face of a typical adult Caucasian male in the fronto-parallel orientation. More detailed instructions were given that asked participants to (a) only draw a head, neck, and shoulder line, (b) to draw all important facial features including the eyes, nose, and mouth, (c) to draw the face with a neutral facial expression, and (d) 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-min time limit to create the drawing.

After participants completed the memory-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 was 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 sharpener if they needed and that they could use any drawing technique they wanted except for tracing. A 15-min time limit was imposed on this task.

Having all participants complete the memory-based drawings first (as opposed to balancing the order of the two types of drawings across participants) was a strategic feature of this study that has precedent in the memory- and observation-based cylinder drawing study reported by Matthews and Adams (2008). If the order of the drawing tasks were balanced across participants, those who completed the observation-based drawings first may be influenced to some degree by a short-term memory (STM) of the model face when later creating their memory-based drawing. Since the memory-based drawings were intended to probe how faces are represented in LTM, the design adopted here was intended to minimize the influence of STM on the memory-based drawings as much as possible.

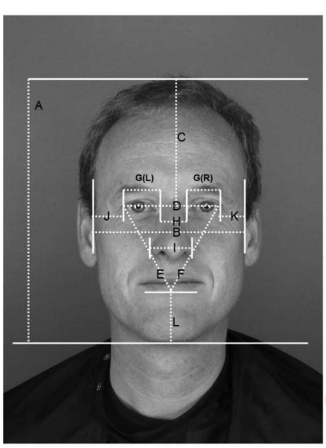
Measurements of Drawn Spatial Relationships and Errors

As illustrated in Figure 2, 12 spatial measurements, A through L (in cm), were made of the observation- and memory-based drawings, the model photograph used for the observational drawing task, and the 50 photographs of adult male Caucasian faces. These measurements were identical to those made by Ostrofsky et al. (2014). Specifically, I measured: (A) the length of the head from the top of the head (including hair) to the bottom of the chin, (B) the width of the head (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 head to the middle of the eye line (if the eye line was not perfectly horizontal in the drawings, 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 corners 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 lower 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 lower lip, (G) the width of the eyes (the width of both eyes were measured and averaged to create one width measurement), (H) the interocular distance between the two inner corners of the eyes, (I) the width of the nose, (J) the horizontal distance between the outer corner of the left eye and the left side of the head (from the observer's perspective), (K) the horizontal distance between the outer corner of the right eye and the right side of the head (from the observer's perspective), and (L) the vertical distance between the center of the bottom of the lower lip and the bottom of the chin.

Based on these measurements, a number of spatial relation ratios were calculated (defined and described in Figure 2, 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 as:

Spatial Drawing Error Ratio = Drawing Ratio Value/Model Ratio Value

Interpretations of the direction of error (error ratio values greater than vs. less than 1) are specific to each ratio and are defined in Table 1.



Spatial Relation Ratios

Ratio	Description	Model 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 2. Illustration of how the drawings, model and photograph collection were measured, definitions of the 13 spatial relation ratios that were computed and the values each spatial relation ratio of the model face. Permission to reproduce this photograph was provided by the PICS administrator and the subject of the photograph.

Results

Multiple questions will be addressed in the analyses reported below. First, the observation-based drawings will be analyzed to determine whether errors in reproducing the spatial relationships between features are random or systematically biased in a particular direction. Second, analyses will be conducted to probe LTM biases by comparing the average spatial relation ratio values between the memory-based drawings and the collection of face photographs described above. The first two sets of analyses will allow us to determine if observation- and memory-based drawings, on average, contain congruent directional biases in how these spatial relationships are depicted. Finally, it will be determined if there are predictive relationships between the memory- and observation-based drawings of these spatial relationships by determining if there are positive correlations with respect to the spatial relation ratio values between these two types of drawings.

Observational Drawing Biases

Table 2 contains the means and standard deviations of the values of the spatial relation ratios and the error ratios for each of the 13 spatial relationships depicted in the observational drawing task. The aim here was to determine whether the distribution of errors in drawing each of the spatial relationships was randomly distributed around zero error or whether they were systematically biased in a single direction. In order to determine this, 13 single-sample *t* tests were conducted comparing the distributions of the error ratio values to a test value of 1 (representative of no error), the results of which are contained in Table 2. Five systematic error biases were observed using a Bonferroni-corrected $\alpha = .004$. Participants reliably drew the head 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 farther up the length of the head than they were positioned in 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

Table 1
Interpretations of 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.

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 a more average symmetrical placement that was minimally shifted to the left side of the face (mean value of (J – K)/B = −0.003).

Memory-Based Drawing Biases

Having found a number of directionally biased spatial errors in the observation-based drawings, one question that arises is whether these stereotyped errors are reflective of biases inherent in the LTMs that guide the production of memory-based face drawings. In order to determine this, the memory-based drawings and the collection of 50 photographs of males were measured according to the 13 spatial relation ratios defined in Figure 2. If one assumes that the mean values of the spatial relation ratios measured in the photograph collection closely approximates the central tendency of these relationships in the adult Caucasian male face population, then one can probe spatial memory biases by comparing the mean spatial relation ratio values between the memory-based drawings and the photograph collection. This was done by conducting 13 single sample *t* tests where the distributions of the spatial relation ratio values of the memory-based drawings were compared to a test value defined as the mean values of the spatial relation ratios of the photograph collection.

Table 3 displays the results of these analyses in addition to the means and standard deviations of the spatial relation ratio values of the memory-based drawings and the photograph collection. For the most part, the memory-based drawings reliably deviated from the average adult Caucasian male face in the same direction as the participants erred in the observation-drawing task. For 11 out of the 13 spatial relation ratios assessed in this study, the mean direction in which the memory-based drawings deviated from the photograph collection was the same as the mean direction of error in the observation-based drawings. Further, out of the five spatial relation ratios that were associated with a systematic direction of error in the observation-based drawings, four of them in the memory-based drawings were associated with a directionally congruent systematic deviation from the photograph collection (using a Bonferroni-corrected $\alpha = .004$). Specifically, in comparison to the photograph collection, the participants' memory-based drawings were biased to draw: (a) the head too round (B/A ratio), $t(37) = 7.76$, $p < .001$, Cohen's $d = 1.26$, (b) the eyes too far up the length of the head (C/A ratio), $t(37) = -8.61$, $p < .001$, Cohen's $d = 1.40$, (c) the left eye too close to the side of the head (J/B ratio), $t(37) = -7.47$, $p < .001$, Cohen's $d = 1.21$, and (d) the

Table 2
Spatial Relation Ratio Values and Error Ratio Values of the Observation-Based Drawings

Ratio	*M* (*SD*)	Error ratio *M* (*SD*)	*t*	*p* (2-tailed)	Cohen's *d*
B/A	0.67 (0.07)	1.13 (0.11)	7.20	<.001	1.17
C/A	0.45 (0.04)	0.92 (0.08)	−6.67	<.001	1.08
E/D	0.96 (0.10)	0.98 (0.11)	−1.23	.226	0.20
F/D	0.96 (0.10)	0.96 (0.10)	−2.63	.012	0.43
E/F	1.01 (0.06)	1.02 (0.07)	2.24	.031	0.36
G/B	0.23 (0.03)	1.04 (0.13)	1.65	.107	0.27
H/B	0.22 (0.06)	1.06 (0.32)	1.25	.220	0.20
J/B	0.16 (0.05)	0.83 (0.24)	−4.31	<.001	0.70
K/B	0.16 (0.04)	1.08 (0.28)	1.79	.082	0.29
I/B	0.22 (0.04)	0.85 (0.14)	−6.90	<.001	1.12
L/A	0.18 (0.03)	0.98 (0.18)	−0.57	.570	0.09
(GL – GR)/G	0.03 (0.10)	0.62 (2.09)	−1.11	.274	0.18
(J – K)/B	−0.00 (0.06)	−0.08 (1.55)	−4.32	<.001	0.70

Note. *t* statistics were generated from single-sample *t*-tests with 37 degrees of freedom comparing the distribution of error ratio values to a test value of 1 (indicative of zero error).

Table 3
Spatial Relation Ratio Values of the Memory-Based Drawings and the Photograph Collection

Ratio	Drawing *M* (*SD*)	Photos *M* (*SD*)	*t*	*p* (2-tailed)	Cohen's *d*
B/A	0.74 (0.12)	0.59 (0.03)	7.76	<.001	1.26
C/A	0.40 (0.06)	0.49 (0.02)	−8.61	<.001	1.40
E/D	0.92 (0.12)	0.97 (0.13)	−2.54	.016	0.41
F/D	0.91 (0.13)	0.97 (0.13)	−2.48	.018	0.40
E/F	1.00 (0.06)	1.00 (0.03)	0.44	.665	0.07
G/B	0.27 (0.06)	0.22 (0.01)	4.87	<.001	0.79
H/B	0.22 (0.10)	0.22 (0.02)	−0.12	.905	0.02
J/B	0.11 (0.04)	0.16 (0.02)	−7.47	<.001	1.21
K/B	0.12 (0.04)	0.16 (0.02)	−5.93	<.001	0.96
I/B	0.20 (0.06)	0.27 (0.02)	−6.84	<.001	1.11
L/A	0.16 (0.05)	0.17 (0.02)	−0.06	.956	0.01
(GL – GR)/G	0.02 (0.08)	0.02 (0.05)	−0.58	.563	0.09
(J – K)/B	−0.01 (0.04)	0.01 (0.02)	−0.8	.427	0.13

Note. *t* statistics were generated from single-sample *t*-tests with 37 degrees of freedom comparing the distribution of spatial relation ratio values of the memory-based drawings to a test value defined as the mean spatial relation ratio value of the photograph collection. With the exception of the H/B and K/B spatial relation ratios, the mean direction in which the memory-based drawings deviated from the photograph collection were the same as the mean direction in which the observation-based drawings deviated from the model face.

nose too narrow (I/B ratio), $t(37) = -6.84$, $p < .001$, Cohen's $d = 1.11$. Thus, these results indicate that there are some spatial biases inherent in LTM that are directionally congruent with the strongest error biases present in observational drawings, suggesting that these LTM biases might be related to the production of observational drawing errors.

Additionally, there were two spatial relationships depicted in the memory-based drawings that reliably deviated from the photograph collection that were not associated with a reliable direction of error in the observation-based drawings. Namely, participants were biased to draw: (a) the eyes too wide (G/B ratio), $t(37) = 4.87$, $p < .001$, Cohen's $d = 0.79$, and (b) the right eye too close to the right side of the head, $t(37) = -5.93$, $p < .001$, Cohen's $d = 0.96$. All other comparisons of the memory-based drawings to the photograph collection were not associated with reliable directions of bias ($p > .004$).

Co-Varying Relationship Between Observation- and Memory-Based Drawings of the Spatial Relationship Between Facial Features

To this point, the drawing errors and biases analyzed have been treated on the level of the sample and not on the level of individuals. Thus, it is not known whether a specific individual's direction and degree of bias in the memory-based drawings is similar to that of the errors they made in the observation-based drawings. Consider the finding that participants draw the head too round in the observation- and memory-based drawing tasks. 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 memory-based drawings), does this mean that the degree of roundness that the head 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 relationships 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 interocular distance) and L/A (reflecting the vertical position of the mouth) in the observation-based drawings. Even though these two ratios were not associated with a single reliable direction of error on average, 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. Alternatively, 42% of participants drew the eyes, on average, 22% (+/− 19%) closer together than they were in the model photograph. 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 head than it was in the model and 45% of participants drew the mouth, on average, 18% (+/− 13%) farther down the head than it was in the model. Thus, even though there were no reliable directional error biases in the sample's observational drawings for these and other spatial relation ratios to be similar or dissimilar to the directions of bias in the memory-based drawings, this does not mean that there are no substantial idiosyncratic directions of error and bias that can be found to be similar across memory- and observation-based drawings within specific individuals.

So, in order to generate more evidence that bears on the claim that memory biases are related to observation-based drawing errors, it is important to assess the covarying relationship of the spatial positioning of features between these types of drawings. If the way spatial relationships between facial features are represented in memory influence how these relationships are reproduced when drawing a model face from observation, it would need to be shown that the individual variability of the spatial relation ratio values produced in the memory-based drawings are positively correlated with the values of the spatial relation ratios reproduced in the observation-based drawings. To evaluate if this is the case, 13 Pearson *r* correlation coefficients were calculated assessing the direction and magnitude of the relationship between the memory- and observation-based drawings for each spatial relation ratio.

Upon inspection of Table 4, one can see that 11 out of the 13 spatial relation ratios are associated with positive correlations between the memory- and observation-based drawings, ranging in magnitude from 0.22 to 0.65. To determine an average correlation, all positive *r* values were converted to *z*' values, whose average was computed and then retransformed back to a *r* value (Silver & Dunlap, 1987). From this method, the average correlation for the spatial relation ratios between the two drawing tasks was 0.39 ($p < .05$).

All four of the spatial relation ratios that were associated with a common reliable direction of error/bias in the observation- and memory-based drawings were associated with reliable positive correlations between the two types of drawings: (a) the degree of roundness of the head (B/A ratio), $r(36) = .44$, $p < .01$, (b) the vertical position of the eyes on the length of the head (C/A ratio),

Table 4
Pearson r Correlation Coefficients Indicating the Relationship Between the Spatial Relation Ratio Values of the Observation- and Memory-Based Drawings

Ratio	*r*	*p* (2-tailed)
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
H/B	0.32	.057
J/B	0.22	.197
K/B	0.23	.177
I/B	0.54	<.001
L/A	0.65	<.001
(GL – GR)/G	0.36	.031
(J – K)/B	0.40	.016

Note. $df = 36$.

$r(36) = .33, p < .05$, (c) the width of the nose relative to the width of the face (I/B ratio), $r(36) = .65, p < .001$, and (d) the distance between the left eye and the left side of the head (J/B ratio), $r(36) = .32, p = .06$.

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 memory drawings, the degree of symmetry relating to the distances between the left and right eyes' distance from the sides of the face ([J – K]/B ratio) was positively correlated between the two drawing tasks, $r(36) = .40, p < .05$.

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 from each other relative to the average width of the eyes was positively correlated between the memory- and observation-based drawing tasks ([GL – GR]/G ratio), $r(36) = .36, p < .05$. There was a marginally nonsignificant trend for the interocular distance to be correlated between these two types of drawings (H/B ratio), $r(36) = .32, p = .06$. All remaining spatial relation ratios were not associated with reliable correlation coefficients, five of whose correlation coefficients were positive (E/F, K/B, and G/B ratios) and two of which were negative (E/D and F/D ratios).

Combined Influence of Model- and Memory-Based Information on Observational Drawings

The finding that multiple drawn spatial relationships between facial features were positively correlated between the observation- and memory-based drawings suggests that there is an influence of how these spatial relationships are represented in LTM on observational face drawing performance. However, these correlations were far from perfect in strength, suggesting the influence of additional information on observational drawing performance. Since the observation-based drawings were guided by a standard model, it seems likely that the visual information inherent in the model also influenced the appearance of the observational drawings. If there is a combined influence of memory- and model-based information on observational drawings of faces, one would expect that the relative spatial positioning of features in the observational drawings should fall between how the features were positioned in the model and the memory-based drawings (which are assumed to reflect how the spatial relationships are represented in LTM). I tested this post hoc hypothesis by focusing on the eight spatial relation ratios that were associated with a reliable positive correlation between the memory-based and observation-based drawings (at a liberal $\alpha = .10$ level). As one can see in Table 5, the mean values of all eight 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 model stimulus that was being reproduced in the observation-based drawing task.

This pattern was assessed on the individual level by conducting binomial tests. If the ordinal rank pattern of the spatial relation ratio values of the memory-based drawings, observation-based drawings, and the standard model face reproduced in the observational drawing task was random, one would expect 33% of par-

Table 5
Mean Values of Memory- and Observation-Based Drawings and Model Values of the Spatial Relation Ratio Values That Were Reliably Correlated Across the Two Types of Drawings

Ratio	Memory-based drawing mean value	Observation-based drawing mean value	Model value	% of participants with target pattern
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
(GL – GR)/G	0.02	0.03	0.05	24
(J – K)/B	−0.01	−0.00	0.04	32

Note. Target pattern indicates that the mean spatial relation ratio value of the observation-based drawing fell in between the mean ratio value of the memory-based drawings and the model ratio value. Binomial tests indicate that a significantly larger percentage of participants' drawings fell within this pattern than the 33% of participants expected to have this pattern by random chance alone for the B/A ($p < .001$), C/A ($p < .001$), G/B ($p < .001$), J/B ($p < .01$) and I/B ratios ($p < .001$).

ticipants, by chance, to have a spatial relation value from the observation-based drawing that falls in between the spatial relation ratio values of the memory-based drawings and the model (a pattern that represents 2 out of the 6 possible rank ordinal patterns that could have been observed). It was observed that the percentage of participants whose spatial relation ratio values fell within this pattern was reliably greater than what one would expect by random chance for the B/A ratio (representing the roundness of the head), 63%, $p < .001$, the C/A ratio (representing the vertical position of the eyes), 61%, $p < .001$, the G/B ratio (representing the average width of the eyes), 58%, $p < .001$, the J/B ratio (representing the horizontal distance between the left eye and left side of the head), 55%, $p < .01$, and the I/B ratio (representing the width of the nose), 68%, $p < .001$.

Discussion

To my knowledge, this is the only study to date to demonstrate that adult nonartists' memory-based drawings of the spatial relationships found in a face are systematically biased in specific directions away from the average adult face. Specifically, it was observed that such drawings contain reliable biases to draw the head too round, the nose too narrow, and the eyes too far up the head, too wide, and too close to the sides of the head. Although the specific causes of these reliable biases are unknown, it is interesting to note that some of these biases have been previously observed in the memory-based face drawings produced by young children. Similar to the memory biases observed here, 3–11-year-old children from all around the world have been observed to draw the head too round and the eyes too far up the length of the face (McManus et al., 2012; Ostrofsky, in press). This suggests that at least some of the biases inherent in graphic LTMs representing the spatial positioning of facial features originate in early childhood and persist into adulthood (albeit, in a less exaggerated state). Thus, our understanding of the underlying causes of such memory-drawing biases in adults may be advanced by future research that investigates why these biases are present in the drawings of young children.

Regardless of the cause of the memory-based drawing biases, the results of the current study suggest one possible cause of the systematic error biases adult nonartists produce when creating an observational drawing of a face. Specifically, evidence is provided here that supports the idea that how some spatial relationships of facial features are represented in LTM influences how these relationships are reproduced in observational drawings. To summarize, there was a congruency in the direction of the spatial relation ratio errors/biases between memory- and observation-based drawings for the four spatial relationships that were associated with the strongest directional error biases in the observational drawings (drawing the head too round, drawing the eyes too far up the head, drawing the nose too narrow, and drawing the left eye too close to the side of the head). Further, on the individual-level of analysis, the ratio values that quantified these four spatial relationships in the memory-based drawings reliably predicted those values reproduced in the observation-based drawings. 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 memory-based drawings (the vertical position of the mouth on the head, the horizontal centering of the eyes, the interocular distance and the difference in widths between the left and right eyes). Finally, the current study provided evidence that suggests that the observational drawing of the spatial relationships between facial features is guided by a combined processing of top-down information stored in LTM and bottom-up information visually apparent in the model. Since the relative spatial positioning of multiple features in the observational drawings fell in between how the features were positioned in memory-based drawings and the model, it appears that observational drawings of these spatial relationships deviated from the model in the direction of how these features are represented in LTM. However, since the observational drawings of these spatial relationships were not identical to those produced in the memory-based drawings, the observational drawings of these relationships deviated from how they are represented in long-term memory toward how they appeared in the model.

With respect to the latter point, it is currently unclear as to the precise way in which top-down and bottom-up information interact during the production of observation-based drawings. It could be that the mechanism that directly guides observation-based drawings is simultaneously influenced by distinct input from LTM and visual perception processes. In this perspective, observational drawing marks are influenced by a combined processing of top-down and bottom-up information that are processed in parallel with one another. In contrast, the interaction between top-down and bottom-up information may interact sequentially, as suggested by the "making and then matching" theory proposed by Gombrich (1960). According to this perspective, individuals start the process of observational drawing by drawing from a LTM representation (the "making"), and then evaluate the degree to which the drawing deviates from the model being reproduced. When such deviations are identified, then the individual modifies the drawing to better fit the appearance of the model (the "matching"). Therefore, the interaction of bottom-up and top-down processing is conceptualized as a sequential feedback loop where initial drawing marks guided by top-down memory processes are later corrected through guidance of bottom-up perceptual processes.

Future investigations of this issue may benefit from video-recording techniques where individuals' step-by-step process of producing observational drawings is observed. Here, one can evaluate the degree to which observational drawings are modified throughout the course of production. If individuals produce such drawings with little-to-no correction/modification of prior marks, this may lend support to the idea of parallel processing of top-down and bottom-up information guiding observational drawings. However, if individuals produce such drawings with regular use of correction/modification, this would support the idea that top-down and bottom-up information sequentially interact during the course of production, especially if the initial marks are extremely similar to those produced in memory-based drawings and the corrections are made in the direction of the appearance of the model being reproduced.

Limitations

One of the strongest limitations of this study relates to the correlational nature of the analyses conducted to assess potential influences of LTM on observational drawing performance. Although it is the case that if LTMs influence observational drawing performance, one would expect to observe the positive correlations between observation- and memory-based drawings that were demonstrated here, that does not necessarily mean observing such correlations prove that LTMs directly influence observational drawing performance. However, one can rule out the possibility that observational drawing biases influence memory-drawing biases as participants in this study always produced their memory-based drawings before their observation-based drawings. However, our method does not allow us to rule out the possibility that the biases found in the two types of drawings are correlated due to unaccounted variables that might influence both types of drawings while the processes guiding the two types of drawings themselves are not causally related.

Another limitation of this study relates to differentiating the nature of the memory representation that is related to observational drawing performance. Here, the similarities in how the spatial relationships of features were depicted in the observation- and memory-based drawings were conceptualized as potentially indicating a relationship between LTM and observational drawing performance. However, because the observation-based drawings were produced immediately after the memory-based drawings, it is possible that a more short-term, priming-based memory established during the memory-based drawing task could account for the similarities between the two types of drawings. However, there is a reason to suspect that the observational drawing errors demonstrated in this study are not produced due to priming effects of the memory-based drawing. Many of the systematic error biases in the observational drawings observed in this study (drawing the head too round, the eyes too far up the head, the nose too narrow, and the left eye being too close to the left side of the head) have previously been observed when observational drawings are not produced before a memory-based drawing has been completed (Ostrofsky et al., 2014). Thus, it does not appear that these observational drawing biases are caused by priming of the memory-based drawings. Nevertheless, one could potentially test between LTM and short-term priming hypotheses by replicating this study where the time delay between the productions of the two types of drawings are manipulated. If the covarying relationship between these two types of drawings is related to influences of LTM, then manipulations of time delay should not affect the degree of similarity to which these spatial relationships are depicted in the two types of drawing tasks. In contrast, if the covarying relationship between these two types of drawings is related to influences of short-term priming processes, then longer delays between the productions of the two drawings should decrease or eliminate the similarity between them compared to shorter or immediate delays.

Future Directions of Research

The results of this study raise three interesting sets of questions that could be addressed with future research. The first question raised by this study concerns the nature of the graphic LTMs that guide memory-based drawings and potentially influence observation-based drawings. It is presently unclear as to what types of information are represented in the graphic LTMs that guided the memory-based drawings in this study. For instance, graphic LTMs relevant to this study may represent the visual appearance of faces that individuals have previously been exposed to. Speculatively, this seems unlikely with respect to actual human faces, as the memory-based drawing biases observed here do not correspond to the visual appearance of typical adult faces. However, the visual appearance of face drawings created by others that contain similar biases could be represented in the LTMs that guide memory-based face drawings (e.g., the commonly seen yellow smiley face whose eyes are set far up the face and the head is depicted as a circle as one extreme example). Alternatively, graphic LTMs guiding such drawings could be in part procedural in nature, where information pertaining to the sequential order in which features are drawn is represented. Here, the memory-drawing biases could be caused by habitual mark-making sequences that influence how the features are spatially positioned relative to one another. Yet another possibility could be that the graphic LTMs guiding memory-based drawings contain symbolic information, where stylistic ways of depicting common objects become habitualized over time and stored in LTM (see the discussion of the memory- and observation-based drawings of isolated facial features below). A final possibility may be that declarative information is stored in graphic LTMs, which may be especially relevant with respect to the drawing of the spatial relationships between features. Such declarative information may represent verbalized rules pertaining to the spatial positioning of the features. Drawing manuals provide such declarative knowledge when instructing individuals how to draw a face, such as the canonical rules that the shape of the head is ovular and the eyes are positioned approximately half-way down the head (e.g., Hamm, 1963). It could be the case that nonartists' LTMs misrepresent such knowledge (e.g., the nose is in the middle of the face, the head is circular, the eyes are approximately one third down the length of the head), and that such LTMs influence the production of a memory-based face drawing.

Unfortunately, the method of the current study is not capable of determining the types of information represented in the LTMs guiding performance in these two drawing tasks. It is also currently unclear as to whether graphic LTMs represent a single type of information that guides all aspects of memory-based drawings, or whether there are different types of information represented in such LTMs that guide the memory-based drawing of different objects and/or different elements within a single type of object. Finally, it is unknown as to whether there is individual variability or not in the type of information represented in graphic LTMs that primarily guide one's memory-based drawings (e.g., some individuals may be primarily guided by verbalized declarative information and others primarily guided by symbolic information, and yet others that are primarily guided by some combination of different types of information stored in graphic LTM). Future research aimed at developing methods useful for determining the answers to these questions would be very useful for the development of art-instruction interventions that are targeted at increasing the accuracy of memory- and observation-based drawings.

The second question raised by this study pertains to the influence of LTM on observational drawings over the course of drawing ability development. Since the drawing performance of nonartists was studied here, one may question the role of LTM in the drawing performance of expert artists highly skilled in observational drawing. In the literature, there are two different theoretical perspectives regarding how the acquisition of drawing skill impacts the role of LTM on observational drawing performance. Some theorists have argued that the processing of information stored in LTM is a major cause of drawing errors and something to be overcome in the development of drawing skill (e.g., Edwards, 2012; Glazek, 2012; Ruskin, 1857/1971). According to this perspective, expert artists draw better than untrained nonartists because they have developed the ability to suppress the activation of graphic LTMs during observational drawing production, and thus, are primarily guided by the processing of the bottom-up perceptual 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 LTM (e.g., Cohn, 2012; Gombrich, 1960; Kozbelt & Seeley, 2007). According to this perspective, trained artists produce more accurate observational drawings than nonartists because they have acquired through training LTMs that are more sophisticated and accurate representations of the graphic properties of common objects. This latter perspective would be consistent with the use of "how-to" drawing manuals that are widely used and referenced in drawing instruction (e.g., Hamm, 1963). 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.

The methods employed in this study could be adopted to test between these two theoretical accounts in a relatively straightforward way. One could potentially replicate this study sampling both artist and nonartist participants and comparing the degree to which memory- and observation-based drawings are correlated between these groups. If LTMs exclusively interfere with observational drawing ability, then skilled artists should show significantly weaker correlations between the spatial-relation measurements between these two types of drawings compared to nonartists. However, if memory-based information similarly affects both artists and nonartists, and artists just have more accurate and/or sophisticated LTMs of the spatial relationships between facial features than nonartists, then the degree to which imagination-based and observation-based drawings are correlated should not reliably differ between these two groups.

The final question raised by the results of this study concerns the influence of LTMs on other aspects of observational face drawing performance other than the reproduction of the spatial relationships between features. One aspect of observational face drawing accuracy that has been neglected in this study is related to the drawing of the isolated facial features. Are the LTM representations of isolated facial features that guide memory-based drawings related to 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 objective, quantitative methods of measuring the drawing accuracy of isolated features is not as straightforward a process as measuring spatial relationships between the features.

However, informal qualitative observations of participants' memory- and observation-based drawings produced in this study's sample suggest a relationship between LTMs and observational drawings of the isolated facial features, for at least some participants. Figure 3 presents isolated segments of selected participants' memory- and observation-based drawings of the eyes, mouth and nose. Upon inspection of these images, one observes stylistic similarities in how these features are depicted in both drawings that are dissimilar from how they appear in the model. Such observations suggest that styles of drawing individual features stored in LTM are related to how individual features are reproduced in an observational drawing. This idea is consistent with Edwards' (2012) "symbol-system" theory of nonartist drawing performance, which proposes that when faced with the task of drawing common objects from observation, symbolic representations that "stand for" the features trying to be reproduced are activated and guide drawing much more strongly than the actual appearance of the feature found in the model.

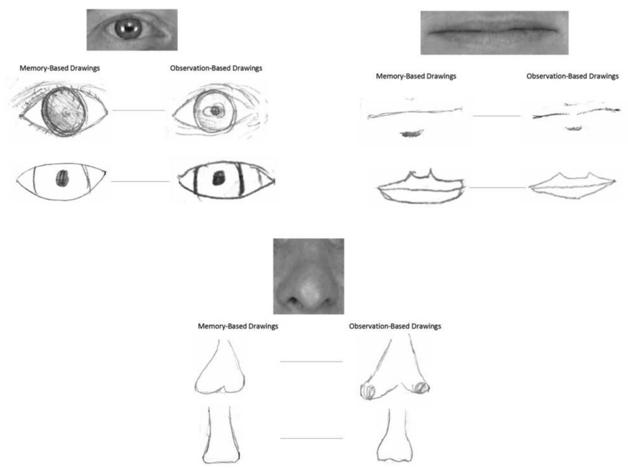


Figure 3. Examples of how the eyes, mouth and nose were drawn in the observation- and memory-based drawings of six selected participants. Drawings were permitted to be reproduced by the participants' signing of the informed consent form before participation in the study began.

Conclusion

As stated in the Introduction, the predominant approach in observational drawing research to date is to understand how drawing performance is influenced by how individuals perceive and attend to the model and emerging drawing during the drawing production period. However, evidence provided here suggests that a fuller understanding of drawing performance will be had if we focus on what information has been acquired and stored in memory long before a particular drawing is initiated in addition to the perceptual and attentional processes engaged during the time a particular drawing is being produced. Such an integrated theoretical understanding of drawing performance could inform more effective art education practices. Drawing training that focuses on both modifying how individuals perceive and attend to a model being reproduced in addition to modifying individuals' LTMs to be more sophisticated graphic representations of common objects could be a more effective pedagogical approach than if one focused on either one of these types interventions in isolation of the other.

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