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Physical and perceptual accuracy of upright and inverted face drawings

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ABSTRACT
This study considers the conception that drawing or copying a face that is vertically inverted will improve the accuracy of the drawing by preventing holistic interference. We used a novel parameterized face space both for generating face stimuli and for measuring the physical accuracy of drawings. One group of participants (the *artists*) were asked to draw 16 parameterized faces (eight upright and eight inverted). We computed two physical measures of accuracy by comparing the face-space representation of each drawing to the original face. A second and third group of participants (the *raters*) compared the similarity between each original face and each pair of drawings of that face (one upright and one inverted per artist). For the second group, all faces were presented upright; for the third group, all faces were presented inverted. Our results showed that upright drawings were more accurate than inverted drawings, both in terms of the physical face-space measure and in terms of the perceptual judgments for both orientations. Our data suggest that holistic processing may aid rather than hinder face drawing accuracy.

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KEYWORDS
Face drawing; holistic processing; face space; inversion; perceptual ratings

It is a popular belief that faces are notoriously difficult to draw because our knowledge about faces and their appearance interferes with our ability to copy them accurately. Furthermore, it is a common conception among beginner face illustrators that copying a face that is vertically inverted (upside-down) will improve the accuracy of the drawing because there will be less interference from how we expect the face to look. Art teachers and manuals such as *Drawing for the Absolute and Utter Beginner* (Garcia, 2003) often have students practice drawing inverted faces. Betty Edwards pioneered the exercise of inverted drawing in her book *Drawing on the Right Side of the Brain* (Edwards, 1989). This exercise is based on Sperry (1974) who theorized that the right side of the brain is what we use for facial recognition. According to Edwards, inverting a face allows more accurate face drawing because it allows the drawer to focus on geometric aspects of the drawing with less interference from higher-level visual knowledge. This theory, known as the Innocent Eye hypothesis, suggests that object recognition interferes with the ability to draw something accurately (Ruskin, 1866).

This paper aims to reconcile the popularly held belief that inverting a face will facilitate drawing with decades of face perception literature showing that most aspects of face perception are aided by holistic processing which requires faces to be presented in their canonical, upright orientation (Valentine, 1988; Yin, 1969). Because drawing relies on several cognitive and perceptual stages, it may be that holistic processing aids some of these stages while impairing others.

According to Van Sommers (1984), drawing involves the iteration of several distinct cognitive processes, including perception, memory, motor actions, recognition, and comparison. In other words, drawing involves observing the to-be-drawn object, storing a representation of that object in memory, making the appropriate strokes to replicate that representation, checking for accuracy (and making the necessary corrections), and repeating. For different types of drawing (copying from life, drawing from memory, drawing from imagination), different challenges arise. For example, drawing from life requires the artist the make more representational decisions (transforming a dynamic 3D object into a static 2D drawing); drawing from memory requires instantiating a previously encountered mental image into a concrete depiction. In this paper we focus on *copying*: drawing face stimuli that are presented and remain visible throughout the drawing task.

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By using a copying task, we hope to make the task more accessible to novice drawers, and to help isolate certain drawing behaviours that are outlined by Cohen and Bennett (1997). Specifically, Cohen and Bennett (1997) outlined four stages where drawings errors can occur when copying: (1) the misperception of the object, (2) the misperception of the drawing, (3) the motor actions, and (4) representational decision-making. Faces are particularly difficult to draw because their complex textures and 3D structures require many *representational decisions* on the part of the drawer; for instance, deciding which lines on the nose to include or exclude, or knowing how to denote the curvature of the cheeks using shading (Cohen & Bennett, 1997). Representational decision-making could account for many of the errors we see in drawing faces. Biederman and Kim (2008) demonstrated (with a simple line drawing task) that not only were artists better at representational decision making, the drawings that had better shape representation were judged by raters as better depictions than those without. Ostrofsky, Kozbelt, and Seidel (2012) demonstrate artists' improved ability to select the most representational lines to define shapes in a limited-line tracing task of an elephant. Tracings by artists were rated as more accurate than those by non-artists. Kozbelt, Seidel, ElBassiouny, Mark, and Owen (2010) explore representational decision making in the context of inverted/upright faces with a limited-line tracing task. In this study inversion increased the ability of non-artists to choose representational lines (as determined by artist judges). It is likely the nature of this task that allows for a dramatic increase in performance, but nonetheless highlights the importance of representational decision making in creating accurate depictions. In their review, Chamberlain and Wagemans (2016) review many drawing studies in a broad context, and ultimately confirm the importance of representational decision making in drawing.

To simplify the face-drawing process, the present studies use as stimuli *parametric line-drawings* of faces that remove the additional challenge of representational decision-making by providing the drawers with the exact lines and shapes that need to be copied. In addition, we quantify the accuracy of upright and inverted face drawings in three ways: using physical face-space measures, using perceptual ratings based on the drawings presented in an upright orientation, and using perceptual ratings based on the drawings presented in an inverted orientation.

Face perception has been widely regarded as a special case of object perception in the literature, with holistic processing of faces being one of the best indicators of this (Richler, Cheung, & Gauthier, 2011; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). Tanaka and Farah (1993) developed the *part-whole task* and demonstrated that the holistic processing of upright faces makes single part recognition more difficult when presented in the context of the whole face. Richler et al. (2011) demonstrated the importance of holistic processing in face recognition by using the face composite task in facial identity tasks. Identities on the top half of the face were more difficult to recognize when they were aligned with differing identities on the bottom half. In addition to behavioural studies, there is growing functional magnetic resonance imaging (fMRI) evidence that neural representations of faces show hallmarks of holistic processing (Davidenko, Remus, & Grill-Spector, 2012; Kanwisher, Tong, & Nakayama, 1998; Miall, Nam, & Tchalenko, 2014; Yovel & Kanwisher, 2005). Kanwisher et al. (1998) used fMRI to study participants' brain activity when viewing Mooney faces (high contrast two-tone images of faces) upright and inverted. There was a significant drop in fusiform face area (FFA) activity when viewing inverted faces, suggesting a disruption in holistic processing. Yovel and Kanwisher (2005) showed lower neural responses in both the FFA and the fSTS for faces that were inverted, showing neural evidence of a disruption in holistic processing. Similarly, Davidenko et al. (2012) scanned participants while they observed upright or inverted profile face silhouettes. Responses in face-selective regions were significantly lower for inverted face silhouettes. A recent study by Miall et al. (2014) found stronger activation in face-selective cortical regions when participants (novice artists) drew faces compared to non-face control stimuli.

How do we reconcile the common conception that inverting a face can facilitate drawing it accurately with the large body of evidence that suggests holistic processes are integral to face representation? Studies of expert artists may elucidate this question. Zhou, Cheng, Zhang, and Wong (2012) looked at the expertise of art students and how they process faces. They compared the performance on a face composite task of two groups of participants: 50 students from the Guangzhou Academy of Fine Arts with at least two years of face drawing experience and 48 students from Sun Yat-sen University. Even though artists showed a similar level of identification performance as the control group, the authors found reduced holistic processing with artists. The authors attribute this difference to the artists' additional experience in drawing faces, and therefore greater experience in attending to the different parts of a face. The experience of the artists allowed them to become versatile face processors. Versatile face processing is defined here as the ability to utilize both holistic and feature-based processing at will. Zhou theorized that artists fall into this category because they were more likely to focus on individual features and process the faces less holistically than the control group. Expert artists therefore appear to willingly "switch off" holistic processing while drawing life-like images. The idea of versatile switching is supported by brain imaging data. Solso (2006) conducted a fMRI study that looked at an artist while they drew face images. This study showed that the expert artist used the FFA throughout the study, but seemed to rely on it less than novice artists, which suggests that they relied less on holistic processing. Outside the context of faces, artists overall seem to perform better on tasks that require switching between global and local processing (Chamberlain & Wagemans, 2015).

Although inversion may give novice face drawers the advantage of shutting off holistic processing, like the pattern we see in expert face drawers, research suggests that this advantage is not large enough to compensate for the difficulty in drawing a face without holistic processing. Cohen and Earls (2010) collected perceptual accuracy ratings for portraits that were drawn by participants inverted and upright. Participants rated feature accuracy (the individual shape of the features) similarly between upright and inverted faces, but rated spatial accuracy (the relation between the locations of the features) as significantly lower for inverted faces. Similarly, Ostrofsky, Kozbelt, Cohen, Conklin, and Thomson (2016) demonstrated no advantage in drawing accuracy for inverted faces, and participants showed a significant drop in accuracy for long-range spatial relationships (e.g., the vertical distance between the eyes and mouth). These studies highlight the importance of holistic processing for face drawing, especially when it comes to replicating configural information about a face.

The body of literature so far suggests that upright faces would be drawn more accurately than inverted faces by novice face drawers when representational decision making is removed from the equation (see Kozbelt et al., 2010). However, several questions are left open that we aim to address in the present study. First, previous studies on drawing and face inversion have either looked at perceptual or physical measures of accuracy, but not both. There is behavioural and neural evidence that physical and perceptual measures of face similarity do not always agree (Busey, 1998; Rotshtein, Henson, Treves, Driver, & Dolan, 2005). Ostrofsky, Cohen, and Kozbelt (2014) found a correlation between physical and subjective measures of face drawing accuracy, but stressed the importance of using both objective and subjective for face drawing analysis. Further, studies that have relied on perceptual ratings always had participants rate drawings in an upright orientation, regardless of the orientation in which the drawings were made. In our study we not only use physical and perceptual measures, but we obtained perceptual ratings under two different conditions: upright comparisons and inverted comparisons. Finally, the causes of errors in previous studies have been difficult to characterize, because the drawings were based on complex life-like face images, which leave many of the representational decisions up to the naive drawer. To better study face drawing in a population of novice drawers, we simplify the face stimuli by using parametric faces that eliminate this difficult step.

Utilizing parameterized faces as stimuli

Previous studies (e.g., Davidenko, 2007; Wilson, Loffler, & Wilkinson, 2002) have successfully used simplified parameterized faces to study perceptual processes. For example, parameterized profile silhouettes (Davidenko, 2007), although lacking internal features and textures, still contain enough facial information to elicit accurate cross-identification with front-view photographs, accurate gender judgments, accurate age estimations, and reliable attractiveness ratings. There are two main benefits of utilizing parametric face stimuli for the present study; first, the simplicity of the stimuli allows us to measure drawing accuracy without the complication of representational decision-making. Unlike arbitrary schematic faces, however, the parametric face space allows us to construct stimuli that look like real faces. Second, the parametric face space itself can provide a reliable metric for measuring the physical accuracy of drawings based on both vector and angular distances between coordinates in the multidimensional space between the drawings and the original stimuli. Hayes and Milne (2011) outlined important quantifiers for measuring 2D accuracy such as feature shape and distance by simplifying the portrait down to a wire-frame. Using parametric face stimuli allows us to perform a similar analysis, but with the added benefit of being able to utilize the parameterized face space to define more objective and nuanced accuracy measures based on a principal components (PC) analysis. PC analysis considers all pairwise distances between key points and accounts for both spatial and angular relationships among the points.

In addition to the use of a face-space measure of accuracy, we present behavioural measures that give us converging evidence on the accuracy of upright vs. inverted face drawings. In two separate studies, participants rated the accuracy of face drawings when presented upright (Experiment 2) and when presented inverted (Experiment 3), regardless of how the faces were originally drawn. This allows us to assess whether the seemingly better results from upright drawings are due to a congruence effect between how a face is drawn and how it is rated, or whether such differences generalize across views.

General methods

In this section we outline the process for generating parametric face stimuli. As outlined in the introduction, the use of parametric face stimuli allows for a simplification of the drawing task for novice participants. To create our stimuli we utilized the face-space paradigm (Valentine, 1991), wherein faces are defined as points in a multidimensional space. Some key features of face space include the mapping of the average face (for that specific face space) in the centre of the space, the ability to morph faces along an axis to create caricatures and anti-faces, and the ability to create stimuli that are equal in perceptual similarity. The face space used in this study is based on the silhouette face space (Davidenko, 2007; Davidenko et al., 2012) but utilizes front-view face images.

Methods

Generation of a front-view face space

We created a front-view face space by coding a large set of over 600 faces compiled from several face databases. For each face, a trained research assistant coded the location of 85 distinctive landmark points on the face, including the outline of the face and several internal features (see Figure 1 for an example).

Determining optimal point placement

The placement of 85 landmark points was determined in a preliminary study examining the recognition of celebrity faces. Celebrity recognition was tested across three levels of parameterized facial detail (accounting for knowledge of celebrity by including a control condition of the actual celebrity photos; see Figure 1A). Participants ($N = 82$) showed the highest level of recognition of celebrity faces with a medium amount of detail (see Figure 1A Level 2). For example, the bridge of the nose and the lines under the eyes facilitated recognition, so those features were included as distinctive points, whereas other features such as the lines defining the cheekbones impaired recognition, so they were eliminated.

Principal components analysis

The 85 x–y coordinates for the 620 faces were then normalized (by centring each face on the two pupils) and entered into a PC to produce the dimensions for a front-view face space. This produced 166 uncorrelated PCs, with each one accounting for some degree of variation of faces. PCs are listed in order of how much variance they account for among the collection of faces; for example, PC 1 accounts for almost twice as much variance as PC 2, and so on.

Generating eight unique faces for drawing

We then utilized this face space to construct eight face identities by manipulating the coefficients of the first four PCs in opposite directions along each axis. For example, face 1 was defined as having a positive coefficient on PC 1, and face 2 was defined as having a negative coefficient on PC 1; face 3 was defined with a positive coefficient on PC 2 and so on. To render the faces, we wrote a script that connected features and outlines with smooth, bi-cubic splines, creating

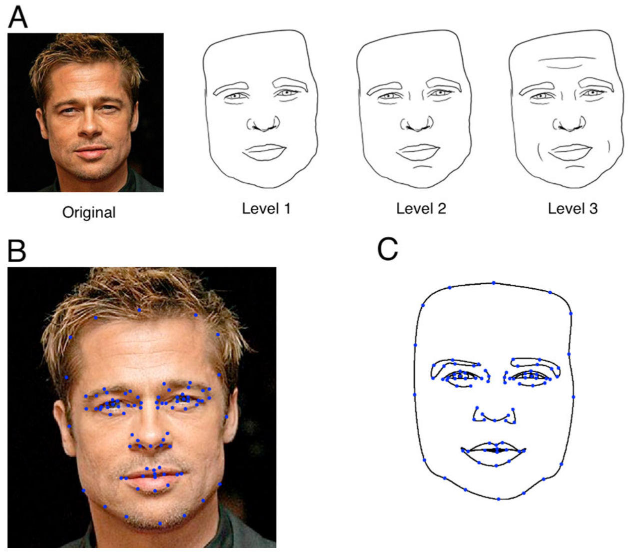

Figure 1. A: Examples of three levels of drawing detail for celebrity Brad Pitt, with the parametric stimulus generated from his 85 points. B: Examples of the 85 key points superimposed on Brad Pitt's face. C: A normalized, parameterized rendering of Brad Pitt's face, with the 85 key points superimposed.

natural looking face stimuli. The resulting stimuli look like simplified line drawings of faces (see Figure 1B–C).

Experiment 1: drawing parametric faces

We instructed participants to produce drawings of parameterized face stimuli on a tablet screen, with eight drawings of upright faces and eight drawings of inverted faces (a total of 16 face drawings per participant).

Participants

Our participants ($N = 13$) were psychology undergraduates at University of California, Santa Cruz, who were compensated with course credit. All participants were right-handed. We asked for a self-report of artistic skill, but did not include this in our analysis because most participants (11/13) self-reported low artistic ability. Data from one participant was excluded for failing to complete all of the drawings; the results we report are based on drawings from the remaining 12 participants. Although each participant produced 16 drawings (total of 192 drawings), we acknowledge that the modest sample size of 12 drawers limits our ability to generalize our results to the broader population.

Procedure

Before the drawing task, we presented three practice trials to familiarize participants with the stylus and touch screen. Participants were then instructed to copy eight upright and eight inverted parameterized front-view faces (for a total of 16 drawings created by each artist) on a Windows Surface Pro, utilizing a stylus on touch screen. Each face identity was drawn twice, once upright and once inverted, with each drawing generated in the same orientation as the stimulus. The parameterized face stimuli were presented on the left side of the screen to participants who were then asked to copy the faces on the right side of the screen using the stylus. All participants were right-handed and had 90 seconds to draw each face. Stimuli were presented in blocks of four by orientation (four upright, four inverted, four upright, four inverted), and the order of blocks was reversed across participants, so every other participant began with a different oriented face block (starting with either four upright or four inverted faces).

Results

Each of the 12 participants produced 16 drawings (eight upright and eight inverted), for a total of 192 drawings to analyse (see Figure 2 for some examples). Because participants copied the same face in both upright and inverted orientations, this design allowed us to compare the accuracy of each participant's upright and inverted drawings on each of the original eight face identities. Key points on the drawings were coded by the same research assistants

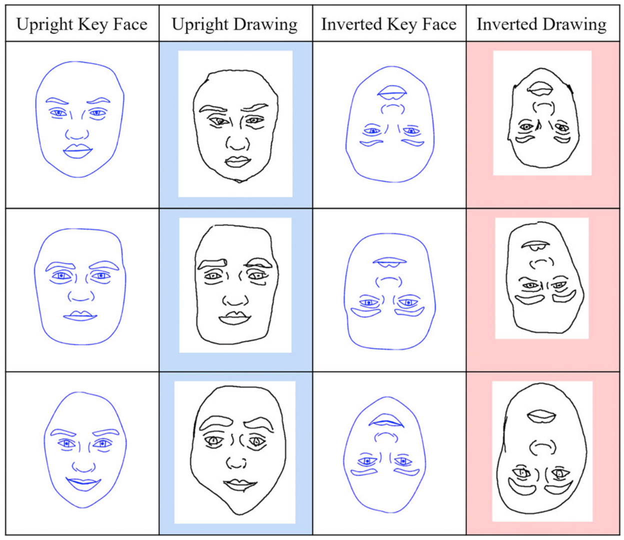

Figure 2. Examples of key faces and corresponding drawings for upright (blue background) and inverted (pink background) stimuli.

who coded the original faces into the face space, which allowed us to represent the drawings in the same face space as the original stimuli. The proportional nature of a PCs analysis weighs the first components most heavily, so to eliminate details related to minor strokes, we reduced the face space to the first 32 dimensions. For the analyses below, we compared upright to inverted errors for each of the eight faces across the 12 participants.

We defined two different error measures based on the face-space position of each drawn face and the corresponding key face: a *vector distance* error measure based on the Euclidean distance between the 32-element face vectors, and an *angular distance* error measure based on the angular difference between face vectors, computed as the arctangent of the dot product between the two unit-normalized face vectors. This angular measure controls for differences in "distinctiveness" (i.e., distance from the average in face space) between drawings.

Vector distance measure

A 3-way repeated-measures ANOVA with factors drawer, face identity, and orientation, yields significant results of all three factors and no interactions in predicting accuracy. That is, the accuracy of drawings depended on the drawer ($F(11,172) = 10.6$, $p < 10^{-10}$), on the face identity ($F(7,172) = 2.03$, $p = .05$) and most importantly on the orientation of the face ($F(1,172) = 4.83$, $p = .03$; see Figure 3 top panel). The mean error for upright faces, in face-space units, was 12.7 (SD = 4.1) and the mean error for inverted faces was 13.7 (SD = 3.8; Cohen's d = 0.25). Figure 3 (top panel) shows the how all three factors influence accuracy scores.

Angular distance measure

We conducted a similar 3-way repeated-measures ANOVA based on the angular distance error measure. Like the vector distance error measure, the angular distance error measure depended on the drawer ($F(11,172) = 4.3$, $p < .0001$), on the face identity ($F(7,172) = 4.1$, $p < .0001$) and most importantly on the orientation of the face ($F(1,172) = 8.61$, $p = .004$; see Figure 3 bottom panel). The mean error for upright faces, in units of degrees, was 76.4° (SD = 10.6°) and the mean error for inverted faces was 80.3° (SD = 10.5°; Cohen's d = 0.37). Although the two error measures are correlated, as can be seen in the first column of Figure 3, they are not identical, as can be seen in the second column of Figure 3. Nevertheless, the two measures yield the same qualitative result regarding the role of orientation: our population of novice drawers produced more physically accurate drawings when copying upright versus inverted faces, even when representational decision-making was taken out of the equation by the use of simplified parametric faces.

Discussion

Our objective measurements of accuracy based on the face space we created shows more accurate

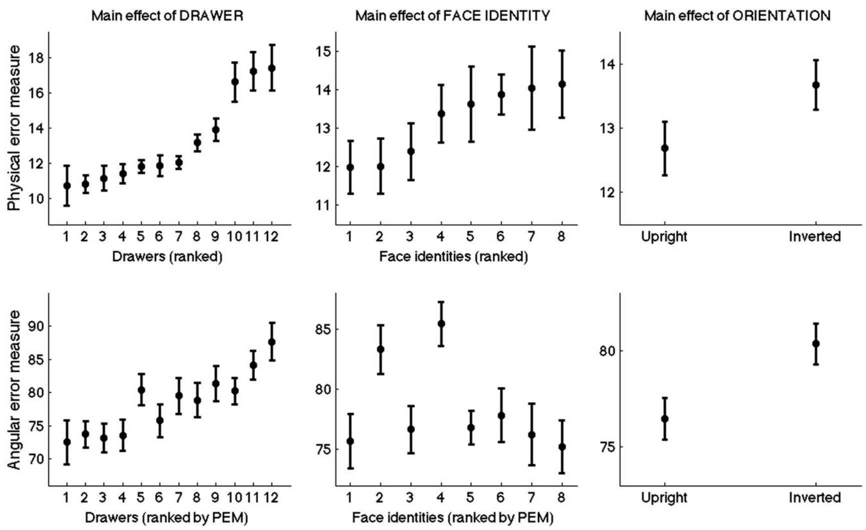

Figure 3. Results for Experiment 1. Top row shows the effects of drawer (left panel), face identity (middle panel), and orientation (third panel) on the physical error measure. For each panel, the data is shown ranked from smallest to largest error. Bottom row shows the same analysis for the angular error measure, with data ranked in the same order as in the top panel. Error bars indicate one standard error of the mean.

performance in face drawing for upright faces compared to inverted faces, suggesting holistic processing aids rather than hinders drawing accuracy. Although the results based on our physical error measures are encouraging, they may not reflect what is going on perceptually. As discussed by Ostrofsky et al. (2014), subjective and objective measures of accuracy are related, but not strongly (see also Busey, 1998; Rotshtein et al., 2005). While spatial measures influence subjective ratings of a face, they cannot account for all perceptual judgments. Therefore in Experiments 2 and 3, new groups of participants rated the accuracy of the face drawings by selecting which drawing from each pair (one drawn upright and one drawn inverted) resembled the original face more in a forced-choice paradigm.

Experiment 2: subjective ratings of drawings presented upright

In this section we discuss the method for determining subjective accuracy. Accuracy measurements were collected from a new group of naive participants who did not participate in the original drawing study.

Participants

Participants ($N = 70$) were psychology undergraduates at University of California, Santa Cruz, who were compensated with course credit. Participants were naive to the hypothesis of the experiment and did not participate in Experiment 1. Three participants were eliminated from the study for failing to follow instructions. The analyses below are based on the remaining 67 participants.

Procedure

We defined the perceptual accuracy measure by comparing ratings from participants ($N = 67$) on pairs of drawings for each face (192 total drawings, 96 trials). For each artist we presented each of the original faces along with both drawings (upright and inverted) shown on either side of the original face (displayed in blue). In each trial, all three faces were displayed in an upright orientation, and the side on which the upright-drawn face was presented was randomly determined. Participants were instructed to select which of the two drawn faces was more similar to the key face in the centre. The data point for each trial was logged as whether the participant selected the face that was originally drawn upright or inverted. Although previous studies investing ratings of individual drawings used Likert scales, we decided to use a forced choice paradigm in this experiment (as well as in Experiment 3) for two reasons: first, people's use of Likert scales can vary substantially. Since the orientation in which faces were rated varied across participants (upright in Experiment 2 and inverted in Experiment 3), participants might have used different criteria to select Likert ratings in the two experiments. Therefore, a forced choice task in which participants choose which drawing is more similar to the original face is likely to provide a more consistent measure across experiments. Second, the forced choice task on pairs of drawings could be completed much more quickly than a Likert scale on individual drawings, allowing for participants to complete all ratings in the allotted experiment time.

Results

For each participant, we determined the proportion of trials in which the upright face was chosen over the inverted face. We found that average proportion of upright selections across observers was 0.563 (SD = 0.063); upright-drawn faces were selected significantly more often than chance ($t(66) = 8.21$, $p < 10^{-10}$; Cohen's d = 1.01; see Figure 4 left).

Discussion

These results corroborate our physical measures from Experiment 1: faces drawn upright are judged as more accurate representations of the key face compared to faces drawn inverted. However, we considered a possible caveat, which is that people may rate the upright-drawn faces as more accurate because the drawings were rated in an upright orientation. Perhaps faces drawn upright look more accurate when shown upright, but faces drawn inverted will look more accurate when shown inverted. To test against this caveat, we replicated this study in a new group of participants, but obtained ratings on all the drawings shown inverted.

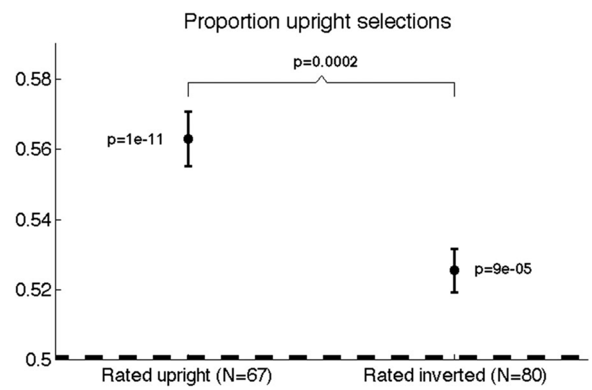

Figure 4. Proportion of selections of upright-drawn faces in Experiment 2 (left) and Experiment 3 (right). Faces drawn upright were consistently chosen as more accurate than faces drawn inverted, regardless of the presentation (upright or inverted) during the rating process. The proportion of upright selections was significantly higher in Experiment 2 than Experiment 3. Error bars indicate one standard error of the mean across raters.

Experiment 3: subjective ratings of drawings presented inverted

In this section we discuss the method for determining a new measure of subjective accuracy of the drawings rated with inverted presentation.

Participants

Our participants ($N = 80$) were psychology undergraduates at University of California, Santa Cruz, who were compensated with course credit. Participants were naive to the hypothesis of the experiment and did not participate in Experiment 1.

Procedure

The procedure was identical to Experiment 2, except that all faces were presented inverted, regardless of the orientation in which they were originally drawn. That is, in each trial, all three faces were displayed inverted, and the side on which the upright-drawn face was presented was randomly determined.

Results

As in Experiment 2, we examined the proportion of trials in which subjects chose the upright-drawn face over the inverted-drawn face. Similar to the results of Experiment 2, we found that upright-drawn faces were selected significantly more often than chance (0.526; SD = 0.055; $t(79) = 4.1$, $p < .0001$; Cohen's d = 0.46; see Figure 4 right). Comparing results across Experiments 2 and 3, the probability of selecting upright-drawn faces was significantly higher in Experiment 2 (when drawings were shown upright) than in Experiment 3 (when drawings were shown inverted; two-sample t-test: $t(145) = 3.84$, $p < .001$; Cohen's d = 0.61). This may either indicate the presence of a small congruence effect, or it may reflect that it is more difficult to appraise the quality of face drawings when observing them in the inverted orientation. This difficulty might manifest as more chance responses on the rating task, and in turn a smaller statistical effect of orientation.

Discussion

The results of Experiment 3 are consistent with the results of Experiment 1 and 2: faces that were copied upright were judged as more accurate representations of the original faces than faces that were drawn inverted. This was true even though participants saw all faces in the inverted orientation. Therefore, the higher accuracy of upright face drawings does not just manifest when the drawings are presented upright (congruent with the way the upright faces were drawn) but also manifests when drawings are presented inverted.

General discussion

In the present experiments, we measured a hallmark property of holistic processing by measuring whether naive participants' drawings of faces are more accurate when faces are presented upright or inverted. Although inverting a face may disrupt holistic processing and allow the drawer to avoid influences of higher level visual knowledge, our results suggests that the costs of face inversion outweigh their benefits.

Mechanistically, it may be that the intervals between looking and copying may lead to memory errors that manifest different for upright versus inverted drawings. Short-term memory for faces is known to influence drawing ability (Devue & Grimshaw, 2017). Because inversion severely hinders short-term memory for faces, we should expect that memory can account for some of the accuracy differences between upright and inverted face drawings (Davidenko, 2007; Freire, Lee, & Symons, 2000; Valentine, 1988, 1991; Yin, 1969). In addition, Cohen (2005) found that face drawing accuracy is positively correlated with gaze frequency (how often a drawer looks back at the model face), which suggests that the less information a drawer has to hold in visual working memory at a time, the more accurate the depiction. We therefore would predict that a drawing paradigm that reduces the spatial distance between the model and the drawing would allow for more frequent gaze, reducing memory load, and in turn increasing performance.

The face processing literature reveals a wide gap between our remarkable abilities to perceive and recognize faces with our modest to poor abilities to accurately draw them. Research that attempts to identify the causes of and reduce this gap may lead to improvements in eyewitness face reconstructions. Indeed, with the proper training, eyewitnesses may be able to produce useful likeness of a face even without the use of face reconstruction software.

Previous studies have shown that face drawings tend to be more accurate when they are produced on upright versus inverted faces (Cohen & Earls, 2010; Ostrofsky et al., 2016). Two possible reasons for higher accuracy of upright drawings that are (a) it is easier to make representational decisions with upright faces, and (b) the ratings of accuracy themselves are done with upright faces, possibly favouring the drawings that were done upright (congruent with the orientation at which they were rated). Our experiments control for representational decision-making by providing simplified face stimuli that consist only of curves that can be easily copied by novice artists. Furthermore, our data show that the advantage of upright drawing manifests in three independent measures: (1) physical measures of accuracy based on face-space coordinates, (2) perceptual ratings done on the upright faces, and (3) perceptual ratings done on the inverted faces.

Limitations

Although we found significant differences between inverted and upright drawing accuracy across several measures, given the modest sample size of 12 drawers in Experiment 1 it is difficult to know how our results might generalize to the broader population. The participants were primarily non-artist first-year college students, so it is not clear whether our results would generalize to other populations, such as older adults, children, trained artists, etc. We believe these are interesting questions worth addressing in future research. It would be particularly interesting to compare trained artists and novices on their performance across face orientation. Although we would expect better performance overall from trained artists, we would still predict lower accuracy for inverted faces, as trained artists seem to utilize a skill switching paradigm that takes advantage of both holistic and featural information (Cohen & Earls, 2010; Zhou et al., 2012).

There are a few general issues to address with our methodology. One caveat is the use of a tablet and stylus to record face drawings. Although we familiarized participants with drawing on the tablet by asking them to copy three basic shapes before proceeding to copy faces, many subjects experienced difficulty using the tablet and stylus. Although drawing directly onto a tablet facilitates the coding procedure, there could be a benefit to having participants draw faces on paper and then scanning them for analysis post study. While this is a methodological issue, we do not believe the difficulty with the stylus affected our results; if there was a drop in accuracy, it would manifest on both upright and inverted faces and cannot account for the differences we found.

Another potential issue is that we limited face drawing trials to 90 seconds. Some participants did not use the full 90 seconds, while other participants felt rushed. We kept every trial an equal length to control for time spent on drawing (theoretically encouraging those who would rush to slow down, and vice versa). A possible alternative to this would be to allow a larger span of time per trial but to also keep track of how much time participants spent per drawing, to account for individual differences in a post-study analysis.

Although our parametric face model is ideal for creating stimuli for this experiment, there are some limitations on how much information participants are provided. Our parametric face models are missing texture, colour, and depth cues that are known to impact face processing. Although the elimination of these cues aided in the drawing task for the novice artists, it limits how much we can generalize our results to drawing from life.

To determine the physical accuracy of the drawings, we normalized each drawing by matching the positions of the two pupils via translation, rotation, and scaling. The purpose of this normalization was to place all face drawings in the same coordinate system and ignore differences in size and orientation among participants' drawings. However, this way of normalizing the faces may have had particular effects on our error measure. For example, if a participant's errors were related to the distance between the eyes, these would not be reflected in our error measure because this distance is always normalized to be constant. Instead, the error would manifest as distortions in the contour of the face resulting from the normalization process. In future studies, we propose the use of a normalization procedure that is not tied to specific features, but rather finds the optimal transformation that reduces the error between the key face and drawn face.

Future directions

Many studies suggest that one benefit of inversion may be to improve the detection of individual features (Tanaka & Farah, 1993). While holistic processing greatly improves the overall subjective and objective accuracy of a face drawing, a feature analysis could determine how much of that improvement manifests in the configural versus featural aspects of the face. Cohen and Earls (2010) conducted this proposed analysis with subjective ratings, but found no effect. An important next step in face drawing research is to consider objective accuracy measures that can characterize short-range (featural) versus long-range (configural) spatial relationships, as inversion may impact one type of information over the other (Ostrofsky et al., 2016). If an analysis of the physical accuracy of individual features reveals better accuracy for inverted versus upright features, this would inform us that inversion can in fact provide some benefits for drawing; namely better accuracy for reproducing fine-level details of individual features.

A long-term goal of this project is to develop paradigms to train novice artists to improve their ability to draw faces, not only in a copying paradigm but also when drawing from memory. Our parameterized face space can be exploited for this purpose by using it to provide real-time feedback to participants about the accuracy of their drawings, as well as provide suggestions for how to improve each drawing. If such training paradigms are successful, they may indicate that drawing can be a useful technique for face reconstruction in eyewitness situations.

Conclusion

By comparing the accuracy of upright and inverted face drawings across two physical and two perceptual measures, we observe that any improvements in drawing caused by the disruption of holistic processing in inverted faces is outweighed by the impairments associated with drawing inverted faces. Physical error measures based on face-space representations reveal larger errors for inverted drawings, and subjective ratings based on both upright and inverted presentations of the face drawings reveal a reliable bias towards selecting faces that were drawn upright as being more accurate representations of each target face. We conclude that, overall, holistic processing aids rather than hinders face drawing in novice artists.

Disclosure statement

No potential conflict of interest was reported by the authors.

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