Journal of Vision (2015) 15(13):5, 1–11

Allocentric kin recognition is not affected by facial inversion

Maria F. Dal Martello
Dipartmento di Psicologia Generale,
Università di Padova, Padova, Italy

Lisa M. DeBruine
Institute of Neuroscience and Psychology,
University of Glasgow, Glasgow, Scotland, UK

Laurence T. Maloney
Department of Psychology, Center for Neural Science,
Institute for the Interdisciplinary Study of Decision
Making, New York University, New York, NY, USA

Typical judgments involving faces are disrupted by inversion, with the Thatcher illusion serving as a compelling example. In two experiments, we examined how inversion affects allocentric kin recognition—the ability to judge the degree of genetic relatedness of others. In the first experiment, participants judged whether pairs of photographs of children portrayed siblings or unrelated children. Half of the pairs were siblings, half were unrelated. In three experimental conditions, photographs were viewed in upright orientation, flipped around a horizontal axis, or rotated 180°. Neither rotation nor flipping had any detectable effect on allocentric kin recognition. In the second experiment, participants judged pairs of photographs of adult women. Half of the pairs were sisters, half were unrelated. We again found no significant effect of facial inversion. Unlike almost all other face judgments, judgments of kinship from facial appearance do not rely on perceptual cues disrupted by inversion, suggesting that they rely more on spatially localized cues rather than "holistic" cues. We conclude that kin recognition is not simply a byproduct of other face perception abilities. We discuss the implications for cue combination models of other facial judgments that are affected by inversion.

Introduction

Animals of many different species discriminate between close genetic relatives (kin) and nonrelatives (Chapais & Berman, 2004; Fletcher & Michener, 1987; Hepper, 1991). This ability, *kin recognition*, permits near relatives to cooperate, potentially improving their chances of survival (inclusive fitness theory [Hamilton, 1964a, b]). It also allows individuals to optimize their mate choice (optimal outbreeding theory [Bateson, 1983]).

Previous studies demonstrate that humans use this ability to favor near genetic relatives in prosocial contexts and avoid them in sexual contexts. For example, participants in an economic game cooperated more with players whose faces were more similar to their own face (DeBruine, 2002) and participants were more willing to invest in children whose faces were more similar to their own (DeBruine, 2004; Platek et al., 2003). However, while computer-generated "virtual siblings" are perceived as particularly trustworthy, they are also sexually unattractive (DeBruine, 2005).

Some primates, including humans, reliably detect close genetic relatedness not only between themselves and other individuals but also between other individuals (Parr, Heintz, Lonsdorf, & Wroblewski, 2010), which is an ability we refer to as *allocentric kin recognition*. If kin recognition allows formation of cooperating groups based on kinship, allocentric kin recognition allows recognition of other—potentially competing—groups also based on kinship. Allocentric kin recognition has been demonstrated repeatedly in humans (Brédart & French, 1999; Bressan & Dal Martello, 2002; Nesse, Silverman, & Bortz, 1990). Some current work in computer vision is devoted to developing algorithms for automated allocentric kin recognition (Xia, Shao, & Fu, 2012).

Previous research on allocentric kin recognition of child and adult siblings shows that, in signal detection tasks, human participants reliably discriminate between pairs of humans who were biological siblings and pairs who were not by comparing pairs of photographs of faces (Maloney & Dal Martello, 2006). Occluding masks were also used to measure the amount of kinship information (quantified as a signal detection d'

Citation: Dal Martello, M. F., DeBruine, L. M., & Maloney, L. T. (2015). Allocentric kin recognition is not affected by facial inversion. *Journal of Vision, 15*(13):5, 1–11. doi:10.1167/15.13.5.

doi: 10.1167/15.13.5 Received May 20, 2015; published September 18, 2015 ISSN 1534-7362

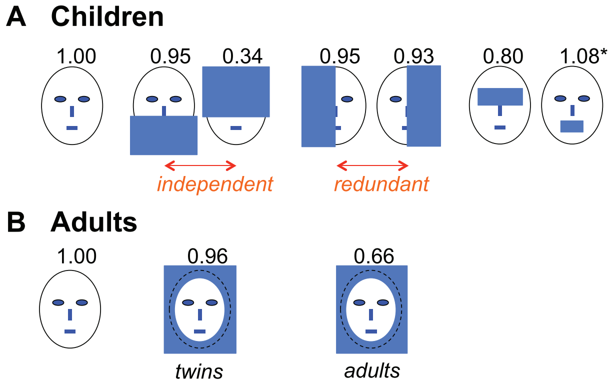

Figure 1. How information about kinship is distributed in the face. A. Results for kinship judgments of children's faces. The d' sensitivity measures for kin recognition performance (relative to full face performance) are shown for each masking condition. The blue regions correspond to the masks occluding parts of the faces. Dal Martello and Maloney (2006) tested whether information about kin recognition in the lower and upper halves of the face were statistically independent and could not reject independence. Dal Martello and Maloney (2010) found that information in left and right halves of the face was effectively redundant. Performance with only a half face was indistinguishable from performance with the full face. B. Results for kinship judgments of adults' faces. Results for full face and for faces masked to hide the exterior contour of the face. The blue regions correspond to the masks occluding parts of the faces and the dotted contour represents the occluded exterior contour under the mask. Results are shown for two experimental conditions (see DeBruine et al., 2009).

measure) in different regions of the face, testing whether information present in different regions of the face (e.g., the upper half of the face or the lower) is statistically independent or redundant (Dal Martello & Maloney, 2006, 2010; DeBruine et al., 2009). In Figure 1, we summarize the results of several experiments, showing how d' varied as parts of the face were masked.

These outcomes can be framed in terms of the sort of cue combination model typically found in the face recognition literature, illustrated in Figure 2A. We consider any measurement F made on a facial image as a potential cue: a template match to an eye, a ratio of distances among, for example, facial landmarks. We do not assume that specific facial landmarks correspond to cues nor do we assume that we know the actual cues underlying kin recognition. Several authors distinguish different types of cues (e.g., configural) and we will return to their proposals in the Discussion.

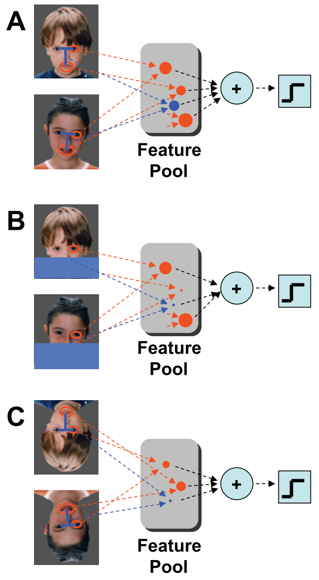

Figure 2. Cue integration model. A. Upright. Corresponding facial cues are compared. One cue (in blue) is an example of a configural cue (the ratio between the distance separating the eyes and the distance from eyes to mouth). See Discussion. B. Partially-masked. The mask disrupts or weakens some cues but not others. C. Inverted. Inversion disrupts or weakens some cues and not others.

While we did not know and could not manipulate each of the cues underlying kin recognition separately, we could, by masking, investigate the contributions of *sets* of cues. In effect, each possible mask disrupts or eliminates kinship information for some subset of facial cues. In Figure 2B we show hypothetically how masking the lower part of the face could effectively eliminate or weaken cues. The size of differently colored dots corresponds to the weights given to each cue. By comparing results with different masks we can determine how the groups of cues affected by each mask type contribute to performance (Dal Martello & Maloney, 2006, 2010; DeBruine et al., 2009) and work out the distribution of kinship information within the face as illustrated in Figure 1.

A different manipulation that likely affects availability of cues is facial inversion. Inversion is known to affect many different facial judgments, suggesting that at least some cues become less informative with inversion. This effect, the Face Inversion Effect (Yin, 1969), has been documented when participants—neurologically intact adults and children after a critical age—show substantial impairment of identity recognition for photographs of faces presented upside-down (Carey & Diamond, 1993; Pellicano & Rhodes, 2003; Picozzi, Cassia, Turati, & Vescovo, 2009).

Many judgments other than identity recognition are also impaired when human face stimuli are inverted. For example, a Thatcherized face (i.e., the eyes and the mouth inverted inside an otherwise upright face) looks frightfully grotesque when presented upright, but loses this quality when inverted (Thompson, 1980). Facial expressions of emotion, such as happiness, disgust, and anger, are less easily recognized when faces are inverted

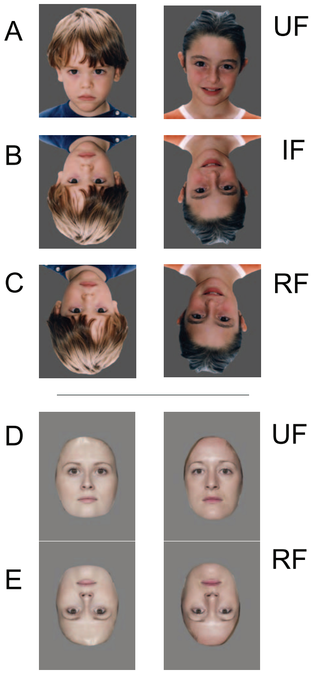

Figure 3. Experimental conditions. A, B, and C: Experiment 1. Upright Face (UF), Inverted Face (IF), and Rotated Face (RF). D and E: Experiment 2. Upright Face (UF) and Rotated Face (RF).

rather than upright (Derntl, Seidel, Kainz, & Carbon, 2009; Valentine & Bruce, 1988). Additionally, the accuracy of gender classification decreases and response latency increases when faces are inverted (Bruce et al., 1993; Bruce & Langton, 1994). Along with impairment of gender recognition, inversion also blunts judgment of facial attractiveness, trustworthiness, intelligence and approachability (Santos & Young, 2008). The effect of inversion on facial age estimation of adults seems to depend on the length of viewing. Participants with unlimited time for the completion of the task did not show an inversion effect (George & Hole, 1995), while participants with limited time showed reduced performance (Bäuml, Schnelzer, & Zimmer, 1997; Santos & Young, 2008).

Given the evidence above, it is plausible that facial inversion weakens or eliminates the cues that underlie a wide range of facial judgments. If kin recognition makes use of a substantial proportion of these cues, we would expect that inversion would lead to lower performance in kin recognition tasks. We test this hypothesis in two experiments conducted in laboratories in two countries with different stimuli and participant populations.

In the first experiment (Padova, Italy), after initial training and instruction (see Methods), participants were shown pairs of photographs of children's faces and asked to judge whether the pair of children were "related" (genetic siblings). Participants were told that half of the pairs were siblings and half were not. There were three conditions in the experiment (Upright Face, Inverted Face, and Rotated Face) as shown in Figure 3A through C and each participant participated in only one condition. The inverted face photos were generated by "flipping" them around the horizontal axis, and the rotated face photos were generated by a 180° rotation in the picture plane.

The design of the second experiment (Aberdeen, Scotland, UK) was similar except that the siblings and nonsiblings depicted were drawn from a database of adult female dizygotic (nonidentical) twins (see Methods) and we included only the conditions Upright Face and Rotated Face (Figure 3D and E). Each participant saw half of the pairs upright and half rotated with pairs counterbalanced across participants.

The data in these two simple signal detection tasks allowed us to separately assess the participants' sensitivity in judging kinship in each condition and also any bias in their responses (See Methods).

Our working model of kin recognition is that participants are sampling information from the two faces present on each trial (Maloney & Dal Martello, 2006). A complete characterization of this information sampling process would be a plot of d' versus time, a speed–accuracy tradeoff curve. A full characterization of this curve is an exciting direction for future research. However, in this paper we are focused on the asymptotic value, the maximum possible performance that the participant is capable of, in order to characterize what information about kinship is available to the participant. This measure corresponds to what has been measured in other studies of inversion effects.

Materials and methods

Experiment 1: Padova

Introduction

In the first experiment, we test the effect of facial inversion on allocentric kin recognition of children's faces using a between-subjects design. The participants' task was to judge whether two children are biological siblings given photographs of the children's faces (Figure 3A, B, and C). The participants were told in advance that half of the pairs viewed were siblings.

Participants

We recruited 118 people in public places within the University of Padova, Italy. Each participant was assigned to one of three conditions—Inverted Face (IF), Rotated Face (RF), or Upright Face (UF)—as described below. There were 20 men and 20 women in the IF condition, 19 men and 19 women in the RF condition, and 19 men and 21 women in the UF condition. Ages ranged from 19 to 37 years with median age 22 years.

Photographic material

We used 72 color photographs, each depicting a child from the neck to the top of the head. Of the 72 children depicted in the pictures, half were girls and half were boys. All of the children came from three adjacent provinces of Northern Italy: Padova, Mantova, and Vicenza. All were White in appearance. We did not alter skin color or eye color since both are potential cues to kinship. In Experiment 1 we did not mask out children's hair since it too is a potential cue to kinship (compare Experiment 2).[1] These are the same pictures used in creating stimuli for Dal Martello and Maloney (2006, 2010). The parents of each child gave appropriate permission for their child's photograph to be used in scientific experiments. We received separate parental permission to use the photographs in Figures 2 and 3A, B, and C as illustrations here. The research described conformed to the Declaration of Helsinki.

Pictures were taken under controlled lighting conditions by the experimenters or their research assistants. The faces were approximately centered in the photograph with the children looking straight ahead. We used Adobe Photoshop® to obliterate all background detail, replacing it by a uniform dark grey field (33% of maximum intensity in each of the R, G, and B channels). The facial expressions were close to neutral.

Conditions

There were three conditions in the experiment. In the UF condition the pictures were presented in the upright position (Figure 3A). In the other two conditions, we altered their orientation relatively to the upright condition. In the IF condition (Figure 3B), we flipped the photographs around the horizontal axis bisecting the picture. In the RF condition (Figure 3C) we rotated the photographs 180°. Consequently, the stimuli in the RF condition were left–right reflections of those in the IF condition.

Picture pairs

Sixty out of 72 of the photographs were used in the main part of the experiment. The remaining 12 were used only in the familiarization and training parts of the experiment, described below. The 60 photographs used in the main part of the experiment included 15 pairs of biological siblings and 15 pairs of children who were not siblings. We refer to the pairs in the first group as *related* and those in the second as *unrelated.*

Within each group of 15, five pairs depicted two girls, five pairs depicted two boys and five pairs depicted a girl and a boy. The 12 photographs used in the familiarization and training stages included three pairs of biological siblings and three pairs of unrelated children.

The children portrayed in the pairs of photographs used in the main part of the experiment ranged in age from 17 months to 15 years. We matched the distributions of age differences for the related and unrelated stimulus pairs used in the main experiment so that age difference provided essentially no information about kinship. The mean and *SD* of the age differences (in months) of the related sample were 40.7 and 21.8, respectively. Those for the unrelated sample were 37.0 and 19.2, respectively.

For privacy reasons we did not verify whether the sibling pairs shared two parents by DNA fingerprinting. Recent research (Simmons, Firman, Rhodes, & Peters, 2004) using DNA fingerprinting shows that the median rate of "extra-pair paternity" is less than 2%. It is likely that a large proportion of our related sibling pairs shared two parents. However, the presence of half-siblings would have little effect on the interpretation of our experiment: such half-siblings would still have 25% of their DNA in common (rather than the 50% shared by siblings other than identical twins), and would still be more closely related than nonsibling pairs. Moreover, their presence in the sample across all conditions should not significantly affect the comparisons across conditions that are central to our analyses.

Procedure

Participants viewed all stimuli on computer monitors and recorded their responses by marking forms. In the main phase of the experiment (below) two face images were presented side by side on each trial. They were separated by a 1.2 cm gap on a 48-cm (19-in.) computer monitor. Each image was 11.1 cm wide by 13 cm high. The background was white. Viewing time was unlimited. The experiment was self-paced and consisted of three phases.

Familiarization: The purpose of this part of the experiment was to familiarize the participants with the range of faces that they would see in the main part of the experiment. The participant was first directed to perform a recognition memory task involving all of the experimental stimuli, all presented in the upright orientation. The 66 photographs of faces were shown in groups of six per display in random order. The participants were asked to study the display and were told that, immediately after studying each group, they would be shown a probe photograph and would be asked to report whether this photograph had been among the group of six just studied. The probe

photographs were the photographs described above which were not used in the main part of the experiment.
Training: The participants practiced the response for their condition (UF, IF, or RF) on six pairs of photographs that did not overlap with the photographs used in the main part of the experiment. These pairs were drawn from the photographs not used in the main part of the experiment, organized so that there were three pairs that were biological siblings and three that were not. The purpose of this part of the experiment was to let the participants become comfortable with the procedure and responses required. In this phase, the participants were told that half of the pairs portrayed genetic siblings and were asked to classify each pair as related or not related, just as in the main experiment. Feedback was not given, again as in the main experiment.
Main: The participants were again told that half of the pairs of the set of photographs in the main phase were genetic siblings and half were not. Their task, as in the training phase, was to classify each pair as "related" or "not related." We presented the 30 pairs of photographs to the participant in random order. We used two separate randomizations and participants were assigned to one or the other at random. Participants completed the experiment in about 10 minutes.

Experiment 2: Aberdeen

Introduction

In the second experiment, we again test the effect of facial inversion on allocentric kin recognition, this time in adult faces using a within-subjects design. The participants' task was to judge whether two adult women were biological siblings given photographs of their faces (Figure 3D and E). The participants were told in advance that half of the pairs viewed were siblings.

Participants

Twenty-five women and 22 men were recruited as participants. Their ages ranged from 19 to 48 years (median age: 21.3 years). The participants were randomly assigned to one of two groups: group A (15 women and nine men) and group B (10 women and 13 men). All of the participants viewed pairs of faces in both conditions: Rotated Face (RF) and Upright Face (UF), described below, although no participant viewed the same pair of faces in more than one condition. Participants were allowed to take breaks at any time during the experiment and completed the experiment in about 4 min ($M = 221.7$s, $SD = 123.9$s, $range = 61$–586s). The research described conformed to the Declaration of Helsinki.

Photographic material

The stimuli used were from previous research on adult allocentric kin recognition (DeBruine et al., 2009). These stimuli were color face photographs of 16 pairs of adult female dizygotic (nonidentical) twins and 16 pairs of same-age unrelated women. Each twin pair was age-matched to an unrelated pair. The twins had been recruited from the TwinsUK adult twin registry. The photographs had been taken by the experimenter under controlled lighting conditions and with the same digital camera on a uniform background. All the photographed people were White in appearance. We did not alter skin color or eye color since both are potential cues to kinship. The faces were resized so that the pupils were aligned and at the same position and the images were masked so that hair, clothing and background were not visible. The ages of the photographed people ranged from 26–46 years ($mean = 37.9$ years, $SD = 4.7$).

Conditions

There were two conditions in the experiment: UF (Upright Face) and RF (Rotated Face). In the UF condition, the pictures were presented in the upright position (Figure 3D). In the RF condition we rotated the photographs 180° (Figure 3E).

Picture pairs

Sixty-four photographs were used in the experiment and they included the 16 pairs of female twins and the 16 pairs of unrelated women described above. We refer to the pairs in the first group as *related* and in the second as *unrelated.*

Procedure

The experiment was conducted in a computer classroom at the University of Aberdeen. Participants individually viewed all stimuli on a computer monitor and responded by clicking buttons labeled "siblings" or "not siblings." Two face images were presented side by side on each trial, separated by a small gap. Each image was 300 pixels wide by 400 pixels high. The background was black. Viewing time was unlimited. Participants completed the experiment in about 4 min. The participants were told that half of the pairs were genetic siblings and half were not. We presented the 32 pairs of photographs in each of two randomly allocated conditions. For each condition, half of the related pairs were presented in the UF condition and half were in the IF condition, while half of the unrelated pairs were presented in the UF condition and half in the IF condition. The orientation was counterbalanced in the two conditions, so that the stimuli presented upright in

	d'	*SD* (d')	β	*SD* (β)
Upright Face	1.058	0.076	0.967	0.039
Inverted Face	1.197	0.077	1.054	0.051
Rotated Face	1.048	0.079	1.033	0.043

Table 1: Results for Experiment 1, by condition. The d' estimates and likelihood criteria β for the signal detection analysis. Standard deviations were estimated by a bootstrap procedure (Efron & Tibshirani, 1993) based on 10,000 replications.

the first condition were presented inverted in the second condition and vice versa.

Results

Experiment 1: Padova

We measured signal detection estimates of sensitivity d' and likelihood criterion β in each condition (Green & Swets, 1966/1974). Signal detection theory allows us to discriminate between participants who simply prefer to say "yes" (or "no") and participants who are actually more sensitive in discriminating siblings from non-siblings. A value of β greater than 1 implies the participant is biased to classify stimulus pairs as unrelated, a value smaller than 1 implies the participant is biased to classify stimulus pairs as related, and a value of 1 implies the participant is unbiased.

All estimated values are reported in Table 1. We first discuss the d' values. In carrying out the hypothesis tests below, it would be appropriate to correct for multiple tests by a Bonferroni correction. However, for all of the tests in this experiment, a Bonferroni correction would not change any conclusions (as the reader can verify). Consequently, we simply present the exact *p* values or upper bounds on the *p* values for each test.

Sensitivity d′

A d' value of 0 corresponds to chance performance (50% correct), a value of 1 corresponds to 84% percent correct, and a d' value of 3.5 or greater corresponds to effectively perfect performance. In Figure 4A, the d' value (1.058) in the upright face (UF) condition was significantly different from 0 ($z = 13.843$, $p < 0.0001$, one-tailed). The one-tailed test is justified, as it is plausible to assume $d' \geq 0.$. The participants, when judging the face in the upright orientation, could classify the pairs as siblings or not siblings at a level markedly above chance. The d' values are very close to those found for upright full-face conditions in earlier related work using these stimuli (Dal Martello & Maloney, 2006, 2010; Maloney & Dal Martello, 2006).

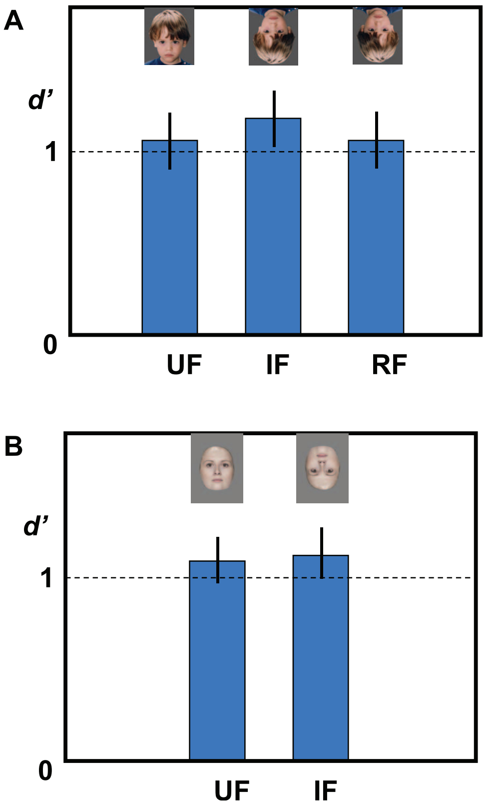

Figure 4. Results: A: Experiment 1. The results of Table 1 plotted. The lines are 95% confidence intervals. B: Experiment 2. The results of Table 2 plotted. The lines are 95% confidence intervals.

The d' value (1.197) in the inverted face (IF) condition was significantly different from 0 ($z = 15.519$, $p < 0.0001$, one-tailed): when the faces were flipped about their horizontal axis, participants could detect kin markedly above the chance level. The d' value (1.048) in the rotated face (RF) condition was also significantly different from 0 ($z = 13.343$, $p < 0.0001$, one-tailed): participants could also discriminate kin from non-kin at a level markedly above chance when the face was rotated 180° relative to the upright orientation.

The d' value for the IF condition was slightly higher than in the other conditions, but did not differ significantly from either the RF ($z = 1.360$, $p = 0.174$, two-tailed) or UF condition ($z = 1.287$, $p = 0.198$, two tailed), nor did the RF and UF conditions differ significantly from each other ($z = 0.091$, $p = 0.927$, two-tailed).

We conclude that participants detected kinship between children in all three conditions: they were not significantly hindered by the inversion or by the 180° rotation of the faces. If anything, their performance

	d'	SD (d')	β	SD (β)
Upright Face	1.059	0.069	0.932	0.036
Rotated Face	1.140	0.077	1.080	0.045

Table 2. Results for Experiment 2, by condition. The d' estimate and the likelihood criterion β for the signal detection analysis are shown. Standard deviations were estimated by a bootstrap procedure (Efron & Tibshirani, 1993) based on 10,000 replications.

tended to be slightly (but not significantly) better in one of the inverted orientations.

Criterion

The β values (likelihood criteria) reported in Table 1 measure the bias of the response towards classifying the children as kin ($\beta < 1$) or not kin ($\beta > 1$). The actual prior odds that the pairs are related are 1:1 (half of the pairs portray siblings), and, as noted above, the participants were given this information. The β value in the UF was not significantly different from both the value in the IF ($z = 1.359$, $p = 0.174$, two-tailed) and in the RF condition ($z = 1.144$, $p = 0.252$, two-tailed), and the β value for IF did not differ significantly from the β value in RF ($z = 0.313$, $p = 0.754$, two-tailed)). We tested the β values against 1 (unbiased performance). The β value in the UF ($z = 0.841$, $p = 0.400$, two-tailed), IF ($z = 1.067$, $p = 0.286$, two-tailed), and RF condition ($z = 0.780$, $p = 0.435$, two-tailed) are not significantly different from 1: participants did not show any significant bias in classifying children as related or unrelated in any of the three conditions.

Our main conclusion, that inversion or rotation does not lead to decreased d', is based on a failure to reject a null hypothesis. Therefore, we must consider the power of the test. Are the results simply a Type II error in statistical parlance? While possible, this interpretation seems unlikely. The confidence intervals based on the reported standard deviations in Table 1 serve as proxies for the power of the tests. Moreover, what differences there are, while nonsignificant, favor the inverted conditions.

Experiment 2: Aberdeen

Signal detection estimates of sensitivity d' and likelihood criterion β are reported in Table 2. In this experiment, there is only one inverted condition (rotated: RF). The d' values in both the UF and RF conditions were significantly different from 0 (UF: $d' = 1.059$, $z = 15.787$, $p < 0.0001$, one-tailed); (RF: $d' = 1.140$, $z = 16.430$, $p < 0.0001$, one-tailed). As in Experiment 1, participants could correctly classify kin from non-kin at a level markedly above chance, even when faces were inverted.

The d' value for the RF condition was slightly higher than in the UF condition, but did not differ significantly from that of the UF condition ($z = 0.560$, $p = 0.576$, two-tailed). We conclude that participants were sensitive to kinship between adult women in both conditions and inversion of the women's faces did not significantly affect kin recognition. Indeed, the d' in the RF condition is higher than that in the upright condition but not significantly so. The d' values are plotted as a bar plot in Figure 4B with 95% confidence intervals.

Again, the β values reported in Table 2 measure the bias of the response towards classifying the children as kin or not kin. The β value in the UF condition was less than 1 and the difference is nearly significant ($z = 1.925$, $p = 0.054$, two-tailed). The β value in the RF condition was greater than 1 and the difference was also nearly significant ($z = 1.786$, $p = 0.074$, two-tailed). However, the β values in the two conditions differed from one another ($z = 2.596$, $p = 0.0094$, two-tailed). While rotation had little effect on accuracy (d'), participants classified adult upright faces as related more often than adult inverted faces. As in Experiment 1, the confidence intervals based on the reported standard deviations in Table 1 serve as proxies for the power of the tests. The observed difference between the d' values in the upright and inverted conditions is not only nonsignificant, but also favors the inverted condition.

Discussion

Many facial judgments have been studied, and, among them, allocentric kin recognition appears to be special. Almost all facial judgments, such as age, gender, and emotion, are markedly impaired by inversion. In contrast, we find, in two different experiments, that allocentric kin recognition is not impaired by inversion. In one experiment, participants judged children's faces, in the other, adults' faces. One experiment used a between-subjects design, the other, a within-subject design. The participants in the two experiments were drawn from nonoverlapping experimental pools, in Italy and in Scotland. Other factors that might affect kinship judgments, including age difference or gender difference, were controlled.

Several authors (Carey & Diamond, 1977; Diamond & Carey, 1986; Maurer, Le Grand, & Mondloch, 2002; Rhodes, Brake, & Atkinson, 1993; Rossion, 2008; Sergent, 1984) suggest that the face inversion effect is evidence that the processes used in the recognition of the upright face are (a) qualitatively different from

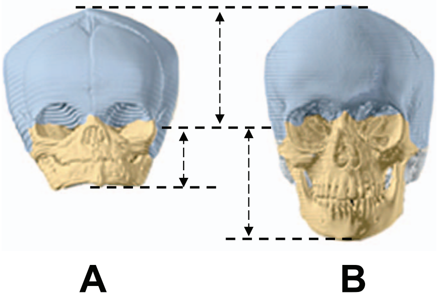

Figure 5. Development of the human skull. Neonate (A) and adult (B) human skulls. The neonate skull is scaled to match that of the adult in order to emphasize the relative growth of the cranial vault (blue) and lower face (beige). © Cassio Lynm 2000. Figure 1 from Dal Martello, M. F., & Maloney, L. T. (2006). Where are kin recognition signals in the human face? *Journal of Vision*, *6*(12):2, 1356–1366, doi:10.1167/6.12.2.

those used for the inverted face, and that (b) this difference is an effect of different magnitudes of experience with upright and inverted faces. We discuss these conjectures in terms of the cue combination framework of Figure 2.

Terminology in the facial judgment literature differs from one group of researchers to another. Some refer to configural processing, others configural information or, occasionally, configural features. For simplicity, we refer to those cues that depend on ratios of distances in the face as *configural cues* (“relational” is also used) and contrast them to *nonconfigural cues*. While configural cues carry configural information and are presumably the result of configural processing, we emphasize the information they carry and how they enter into facial judgments over their origin. This usage is congenial to the cue combination framework we employ and consistent with previous work.

Configural cues

The most widely accepted explanation of the face inversion effect is that inversion interferes with the perception of relational information present in second-order cues (Rhodes et al., 1993) that we refer to as configural cues. This information is determined by the relative distances between single facial cues such as the eyes, nose and mouth. In Figure 3A, for example, the ratio of lengths of the two blue lines (eye separation divided by eye height above mouth) is a possible configural cue.

The interpretation of our experimental results within this framework leads to the conclusion that kin recognition in both upright and inverted faces depends almost exclusively on information carried by cues that are not configural.

An alternative hypothesis is that inversion disrupts “holistic” coding—the “Gestalt” of the face (Farah, Tanaka, & Drain, 1995; Rhodes et al., 1993; Rossion, 2008). The holistic information of the face is, according to Rossion (2008) “the simultaneous integration of the multiple features of a face into a single perceptual representation” (p. 275). Tanaka and Farah (1993) defined holistic representation as a “[representation] without an internal part structure” (p. 241) and argue that face perception is holistic. If we accept this hypothesis then we would further conclude that kin recognition gives no detectable weight to configural cues resulting from holistic processing.

But why are configural/holistic cues little used in making kin recognition judgments? One possible reason, at least for judgments involving children’s faces, is that the changes in shape and relative cue locations that occur during development (see Dal Martello & Maloney [2006] for an extended discussion and references) selectively disrupt configural information. While the shape of the upper half of the skull is roughly constant after 1 year of age, the lower part of the face elongates dramatically between ages 1 and 12 (Figure 5). We suggest that facial plasticity in development reduces the reliability of configural cues that involve the lower half of the face, particularly when comparing children across the age range of Experiment 1.

We also see no evidence for use of configural information in adult face pairs that are exactly matched for gender and age (female nonidentical twins) in Experiment 2, in which developmental changes no longer disrupt configural information and it is plausible that configural cues carry information about kinship. Still, if kin recognition is learned on sets of faces with large age differences including both children and adults (i.e., within an extended family), it may be that configural cues, objectively carrying little kinship information, have correctly been given little weight and that this bias against configural cues carries over into judgments of adults.

Experience

For any class of stimuli with which the participant has extensive experience (such as upright faces), participants can potentially extract the statistical distribution of spacing between facial landmarks and this configural information could supplement nonconfigural information in facial judgments. Under this account, both configural and nonconfigural information can be used in identity recognition of upright faces, whereas judgments of inverted faces have to rely mainly on nonconfigural information (Bartlett & Searcy, 1993; Carey & Diamond, 1993;

Leder & Bruce, 2000; Valentine & Bruce, 1988). If this account is correct, then kin recognition should be little affected by experience, suggesting that kin recognition abilities might reach adult performance levels earlier than other facial judgments—a testable conjecture.

Our results, in summary, demonstrate that judgments of kinship from facial appearance are special. They do not rely on cues that are disrupted by inversion demonstrating, first of all, that kin recognition is not simply a byproduct of other face perception abilities that *are* degraded by inversion. Face recognition, for example, involves a comparison of a currently visible face against faces previously seen, held in memory. Could kin recognition use the same perceptual and cognitive mechanisms as face identity recognition? Our results suggest otherwise. Face identity recognition is markedly impaired by inversion while kin recognition is not.

Second, based on previous work in the literature, we conclude that kin recognition relies on a well-defined and theoretically important set of cues that are not configural in the sense commonly used in the literature. A combination of masking and inversion manipulations and comparison of performance in different facial judgments should serve to characterize the special nature of the cues underlying kin recognition and determine why they are little affected by inversion.

In the past 25 years or so, researchers have intensively investigated how human perceptual systems integrate information from multiple individual cues (Landy, Maloney, Johnston, & Young, 1995; Trommershäuser, Körding, & Landy, 2011). As mentioned in the Introduction, the face can be viewed as a collection of cues that form the basis for any facial judgment. Different rules integrate these atomic "facts" to synthesize judgments about the face. Masking, and now inversion, provide powerful tools for manipulating the availability of cues and characterizing them.

Success in modeling multiple facial judgments in a common framework of facial cues and rules of integration would represent a major breakthrough in our understanding not just of facial perception, but also of human information integration in general.

Keywords: kin recognition, face perception, signal detection theory, face inversion effect

Acknowledgments

MFDM was supported by funds from MIUR (Italian Ministero dell'Università e della Ricerca Scientifica e Tecnologica). LMD was supported by grant ES/I031022/1 from the UK Economic and Social Research Council and grant 647910 (KINSHIP) from the European Research Council. LTM was supported by grant EY019889 from the National Institutes of Health, National Eye Institute. The results of Experiment 1 were previously reported at the Annual Meeting of the Vision Sciences Society (Maloney & Dal Martello, 2011).

We thank Dottoressa Giulia Cremon and Dr. Andrea Pittarello for assistance in collection of data.

Commercial relationships: none.

Corresponding authors: Laurence T. Maloney; Maria F. Dal Martello.
Email: Laurence.Maloney@nyu.edu; maria.dalmartello@unipd.it.
Addresses: Department of Psychology, New York University, New York, NY, USA; Dipartmento di Psicologia Generale, Università di Padova, Padova, Italy.

Footnote

[1] Although hair is visible we still use the term "face" in describing stimuli, for convenience.

References

Bartlett, J. C., & Searcy, J. (1993). Inversion and configuration of faces. *Cognitive Psychology, 25,* 281–316.

Bateson, P. (1983). Optimal outbreeding. In P. Bateson (Ed.), *Mate choice*. (pp. 257–278). Cambridge, UK: Cambridge University Press.

Bäuml, K.-H., Schnelzer, M., & Zimmer, A. (1997). The influence of inversion on the judgment of facial and non-facial attributes. *Acta Psychologica, 96,* 27–42.

Brédart, S., & French, R. M. (1999). Do babies resemble their fathers more than their mothers? A failure to replicate Christenfeld and Hill (1995). *Evolution and Human Behavior, 20,* 129–135.

Bressan, P., & Dal Martello, M. F. (2002). Talis pater, talis filius: Perceived resemblance and the belief in genetic relatedness. *Psychological Science, 13*(3), 213–218.

Bruce, V., Burton, A. M., Hanna, E., Healey, P., Mason, O., Coombes, A., . . . Linney, A. (1993). Sex discrimination: How do we tell the difference between male and female faces? *Perception, 22,* 131–152.

Bruce, V., & Langton, S. (1994). The use of pigmentation and shading information in recognizing the sex and identities of faces. *Perception, 23,* 803–822.

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. *Science, 195,* 312–314.

Carey, S., & Diamond, R. (1993). Are faces perceived as configurations more by adults than by children? *Visual Cognition, 1*(2/3), 253–274.

Chapais, B., & Berman, C. (Eds.). (2004). *Kinship and behavior in primates*. Oxford, UK: Oxford University Press.

Dal Martello, M. F., & Maloney, L. T. (2006). Where are kin recognition signals in the human face? *Journal of Vision, 6*(12):2, 1356–1366, doi:10.1167/6.12.2. [PubMed] [Article]

Dal Martello, M. F., & Maloney, L. T. (2010). Lateralization of kin recognition signals in the human face. *Journal of Vision, 10*(8):9, 1–10, doi:10.1167/10.8.9. [PubMed] [Article]

DeBruine, L. M. (2002). Facial resemblance enhances trust. *Proceedings of the Royal Society B: Biological Sciences, 269,* 1307–1312.

DeBruine, L. M. (2004). Resemblance to self increases the appeal of child faces to both men and women. *Evolution and Human Behavior, 25,* 142–154.

DeBruine, L. M. (2005). Trustworthy but not lust-worthy: Context-specific effects of facial resemblance. *Proceedings of the Royal Society of London B: Biological Sciences, 272,* 919–922.

DeBruine, L. M., Smith, F. G., Jones, B. C., Roberts, S. C., Petrie, M., & Spector, T. D. (2009). Kin recognition signals in adult faces. *Vision Research, 49*(1), 38–43.

Derntl, B., Seidel, E. M., Kainz, E., & Carbon, C. C. (2009). Recognition of emotional expression is affected by inversion and presentation time. *Perception, 38,* 1849–1862.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General, 115*(2), 107–117.

Efron, B., & Tibshirani, R. J. (1993). *An introduction to the bootstrap*. New York: Chapman & Hall.

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance, 21,* 628–634.

Fletcher, D. J., & Michener, C. D. (1987). *Kin recognition in animals*. Chichester, UK: John Wiley & Sons.

George, P. A., & Hole, G. J. (1995). Factors influencing the accuracy of age estimates of unfamiliar faces. *Perception, 24,* 1059–1073.

Green, D. M., & Swets, J. A. (1974). *Signal detection theory and psychophysics*. Huntington, NY: Krieger. First published by Wiley & Sons, New York (1966). Reprinted with corrections.

Hamilton, W. D. (1964a). The genetical evolution of social behaviour. I. *Journal of Theoretical Biology, 7*(1), 1–16.

Hamilton, W. D. (1964b). The genetical evolution of social behaviour. II. *Journal of Theoretical Biology, 7*(1), 17–52.

Hepper, P. G. (Ed.). (1991). *Kin recognition*. Cambridge, UK: Cambridge University Press.

Landy, M. S., Maloney, L. T., Johnston, E. B., & Young, M. (1995). Measurement and modelling of depth cue combination: In defense of weak fusion. *Vision Research, 35,* 389–412.

Leder, H., & Bruce, V. (2000). When inverted faces are recognized: The role of configural information in face recognition. *The Quarterly Journal of Experimental Psychology Section A, 53,* 513–536.

Maloney, L. T., & Dal Martello, M. F. (2006). Kin recognition and the perceived facial similarity of children. *Journal of Vision, 6*(10):4, 1047–1056, doi:10.1167/6.10.4. [PubMed] [Article]

Maloney, L. T., & Dal Martello, M. F. (2011). Kin recognition based on viewing photographs of children's faces is not affected by facial inversion. *Journal of Vision, 11*(11): 664, doi:10.1167/11.11.664. [Abstract]

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*(6), 255–260.

Nesse, R. M., Silverman, A., & Bortz, A. (1990). Sex differences in ability to recognize family resemblance. *Ethology and Sociobiology, 11*(1), 11–21.

Parr, L. A., Heintz, M., Lonsdorf, E., & Wroblewski, E. (2010). Visual kin recognition in nonhuman primates: (*Pan troglodytes* and *Macaca mulatta*): Inbreeding avoidance or male distinctiveness? *Journal of Comparative Psychology, 124,* 343–350.

Pellicano, E., & Rhodes, G. (2003). Holistic processing of faces in preschool children and adults. *Psychological Science, 14*(6), 618–622.

Picozzi, M., Cassia, V. M., Turati, C., & Vescovo, E. (2009). The effect of inversion on 3- to 5-year-olds' recognition of face and nonface visual objects. *Journal of Experimental Child Psychology, 102,* 487–502.

Platek, S. M., Critton, S. R., Burch, R. L., Frederick, D. A., Myers, T. E., & Gallup, G. G., Jr. (2003). How much paternal resemblance is enough? Sex differences in hypothetical investment decisions but not in the detection of resemblance. *Evolution and Human Behavior, 24,* 81–87.

Rhodes, G., Brake, S., & Atkinson, A. P. (1993). What's lost in inverted faces? *Cognition, 47,* 25–57.

Rossion, B. (2008). Picture-plane inversion leads to qualitative changes of face perception. *Acta Psychologica, 128,* 274–289.

Santos, I. M., & Young, A. W. (2008). Effects of inversion and negation on social inferences from faces. *Perception, 37,* 1061–1078.

Sergent, J. (1984). An investigation into component and configural processes underlying face perception. *British Journal of Psychology, 75,* 221–242.

Simmons, L. W., Firman, R.C., Rhodes, G., & Peters, M. (2004). Human sperm competition: Testis size, sperm production and rates of extrapair copulations. *Animal Behaviour, 68,* 297–302.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46A*, 225–245.

Thompson, P. (1980). Margaret Thatcher: A new illusion. *Perception, 9,* 483–484.

Trommershäuser, J., Körding, K., and Landy, M. S. (2011). *Sensory cue integration*. New York: Oxford.

Valentine, T., & Bruce, V. (1988). Mental rotation of faces. *Memory and Cognition, 16,* 556–566.

Xia, S., Shao, M., & Fu, Y. (2012). Toward kinship verification using visual attributes. In X. Name (Ed.), *IEEE International Conference on Pattern Recognition (ICPR)* (pp. 549–552). Tsukuba, Japan: IEEE Publishing.

Yin, R. K. (1969). Looking at upside-down faces. *Perception, 81*(1), 141–148.