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On the species-specificity of face recognition in human adults

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Abstract:

Does the human ability to recognize unfamiliar faces extend beyond human faces to those of other species? In two experiments, face recognition by humans for human, macaque monkey, and sheep faces was investigated with a forced-choice matching task. The experimental variables of orientation (upright or inverted) and familiarisation time were explored. In the first experiment, with 750 ms familiarisation time, we showed an advantage for the upright face with a marked inversion effect for both human and monkey faces. Long-term exposure to unfamiliar face types (i.e. monkeys) may not therefore be a critical determinant of the inversion effect for unfamiliar faces. Human and monkey faces may make use of a common representational prototype which is sensitive to orientation. In a second study, with just 50 ms familiarisation time, an inversion effect was found only for human faces, suggesting that processing of human faces is engaged more efficiently than that for faces of monkeys. Differences between the tasks, and their implications for understanding human face recognition, are discussed.

Introduction

A growing body of research supports the existence of a highly efficient face processing mechanism in human adults. De Haan and Halit's review (2001) showed that although much of this system is present early in life, some of the characteristics of the adult system develop in late childhood (Freire and Lee, 2001). By adulthood, extensive experience with human faces gives rise to expertise in processing human faces. It is known that adult humans are able to recognise hundreds of distinct faces (Bahrick, Bahrick & Wittlinger, 1975). Diamond and Carey (1986) proposed that learning to process faces is 'special', compared to other visual stimuli. Faces are a category of stimuli that, unlike most other objects, are homogenous in terms of the gross position of their elements (two eyes above the nose, nose above the mouth, etc.) and have to be discriminated on the basis of relational information, such as the particular distance between the eyes, or between lips and chin (Leder & Bruce, 2000). The ability to process relational information, called *configural* processing, is posited to be the consequence of experience and thus can only be extended to other categories which are discriminated on the basis of relational information and with which subjects are highly familiar (Diamond and Carey, 1986;

Gauthier and Tarr, 1997). One of the most important indicators of expertise in adults is the inversion effect; the fact that faces are recognised more accurately and faster when presented in their canonical upright orientation than when presented upside-down (Yin, 1969). Diamond and Carey (1986) suggested that the configural information required to accurately identify individual faces is disrupted by inversion, forcing a less accurate featural processing strategy. Hence an inversion effect with facial stimuli is evidence that the face processing system has been engaged.

Drawing on an analogy between the language and face processing systems, Nelson (2001) proposes that the face processing system develops during the first years of life, from a broad non-species-specific system to a human-specific face processor in adulthood. This suggests that the adult face processing system may be species specific and not flexible enough to process faces of other species at an individual level. There are conflicting reports in the literature on the recognition of other species faces. This study suggests that these discrepant results on the species specificity of human face processing may be explained by the nature of the tasks used by researchers.

Pascalis and Bachevalier (1998) using a sensitive visual paired - comparison task (VPC), administered in identical fashion to both humans and monkeys, found that human participants were more skilled at recognizing individual human faces than monkey faces, while the opposite was true for monkeys. In a recent replication of this result, adult participants only showed evidence of discrimination of their own species (Pascalis, de Haan and Nelson, 2002).

Campbell, Pascalis, Coleman, Wallace, and Benson, (1997) however, reported conflicting results in a categorical perception experiment. They showed single images of human, monkey, and cow faces, which were computer-morphed to produce three series of human-monkey, monkey-cow and cow-human images. While the human-cow and monkey-cow series showed categorical perception (enhanced perceptual discrimination for images that straddled the classification boundary), the human-monkey morph series did not show perceptual sharpening at a categorical boundary in the midrange of the series. That is, a single category formed the basis for discrimination of both human and monkey faces. This suggests humans can extend a representational category or prototype to monkey faces - even though they are not familiar with individual monkeys. This

representational category does not, however, encompass faces of other animals such as cows.

In human adults, face presentation elicits a negative potential, recorded 170 ms after the presentation of the stimulus (the N170), that is larger in amplitude to faces than to other stimuli and is interpreted as electrophysiological evidence for face expertise (Bentin, Alison, Puce, Perez and McCarthy, 1996). De Haan, Pascalis and Johnson (2002) recorded Event Related Potentials (ERPs) in human adults passively watching human faces and monkey faces. They recorded significant differences in amplitude and latency in the N170 elicited by monkey faces and by human faces. De Haan et al. concluded that human and monkey face processing involve different mechanisms. In contrast, Carmel and Bentin (2002) found that when participants performed a categorization task (Human/Primate), the N170 was identical in amplitude but delayed in latency for monkey faces compared to human faces. There was no discriminative N170 response for pictures of other animals (dogs, cats, birds, Bentin and al., 1996). They concluded that the N170 is face specific, but not human-specific, and that unlike the visual processing of other stimulus categories, 'the function of this mechanism is immune to strategic or attentional influences across tasks'. The pattern of results gained with ERPs may reflect a similarity in the representational template for recognizing human and nonhuman primate faces (Campbell et al., 1997).

The different conclusions of the studies reviewed above may, however, reflect the fact that Carmel and Bentin (2002) and Campbell et al. (1997) used an active categorization task, whereas de Haan et al. (2002) and Pascalis et al. (2002) used a passive viewing task (with 5 s familiarisation). The categorization task is an explicit paradigm in which participants have to actively make decisions. In contrast the VPC task requires no explicit categorization. The passive paradigm results indicate human specificity whereas active paradigm results indicate primate specificity. In the passive paradigm the human specific face processing system may be engaged automatically for recognition of human identity, but in the absence of instructions, is not extended to process other primate faces. In the categorization tasks used by Carmel & Campbell, it is possible that the combination of instructions and the stimulus exposure durations (350 & 750 ms respectively), permitted the extension of a human face specific system to other primate

faces. One prediction from this observation is that with reduced stimulus exposure, human face specificity may be demonstrated in an active task.

The two alternative forced-choice (2AFC) task was used in this study because of its structural similarity to the VPC. The VPC task exploits individuals' attraction to novelty in order to assess their recognition memory for previously seen stimuli. The basic procedure is: The participant is first presented with a stimulus for a familiarisation period. Thereafter, s/he is presented with the same stimulus paired simultaneously with a novel one. The dependent variable is the length of time spent fixating each of the two stimuli. The rationale for the paradigm is that any systematic differences in spontaneous looking duration as a function of novelty indicate that the individual has remembered the previously presented material sufficiently well to distinguish it from a more-or-less similar novel item. Participants generally look longer at the new stimulus than at the familiar one.

The 2AFC task, like the VPC task, involves learning a single target, then, after a short interval, the target is again shown together with a similar stimulus (foil). The participant is required to identify the target by a timed response to one or the other item in the recognition pair. This procedure resembles the widely used animal procedure of Delayed Matching to Sample (DMS) which shows visual recognition memory after long delays in both nonhuman and human primate species (Overman and Doty, 1980)¹. In the version of 2AFC used here, both response time and accuracy of response in the decision phase were measured.

Experiment 1

In this first experiment, we aimed to investigate whether face recognition in human adults, as measured with a 2AFC task, is sensitive to species-membership. Human, monkey and sheep face stimuli were presented for a familiarisation period of 750ms. A similar duration was used by Campbell et al (1997) in which primate, rather than human, specificity was demonstrated in a categorisation task. The long familiarisation period was

¹ In the VPC task, participants look spontaneously longer at the new stimulus than at the familiar, once they have recognised the familiar one. Therefore, a longer time spent looking at the new stimulus is an indication that the system detected the familiar stimulus. . In this respect the DMS and the VPC task are similar.

expected to produce similar results with the 2AFC task. The stimuli were presented either upright or inverted. Inversion effects would be interpreted as evidence that the material had been processed as faces, rather than as simple pictorial stimuli distinguishable in terms of local idiosyncratic features.

Participants

Participants were 17 volunteer adults aged from 19 to 42 years (8 females and 9 males) from the Université Louis Pasteur, Strasbourg, France. None had personal experience of individual macaque monkeys nor of sheep.

Stimuli

The stimuli were presented on a 21 inch computer monitor. These were 120 halftone images of faces from three categories: 40 humans (Caucasians), 40 monkeys (rhesus) and 40 sheep. Half of the pictures were presented upright, the other half inverted. All faces were captured with a neutral expression (closed mouth, open eyes, normal muscle tone). In addition, for human faces, individuals had no jewellery, glasses or obvious make up. The size of the image was 10 cm x 6 cm, presented at 40 cm viewing distance. Brightness and contrast levels for all images were computationally manipulated to be uniform (as judged by visual inspection) across pictures in the three categories. For the training session, black and white drawings of various objects were used. Examples are displayed in figure 1.

Figure 1 about here

Procedure

One stimulus was projected in the centre of the computer screen for familiarisation, and two stimuli, horizontally separated by 12cm, were shown 3 seconds later in the recognition test. Orientation was always the same for inspection and recognition. Half the stimuli were presented as inverted images, half as upright, with the orientation of the specific image set balanced across participants. That is, no stimulus was seen in both upright and inverted orientation by any one participant.

Participants were tested individually. They were seated in front of a computer screen, with hands resting on the keyboard. Instructions were read to the participant before test. They were told that one picture would appear on the screen for a brief period (750 ms) which they would later be asked to recognize from a presentation of two images,

and that they should be as quick and accurate as possible at this decision. Following the 750 ms display of the target image a 3 second unfilled interval (grey screen) was seen, then two pictures (the familiar one and a novel one) were simultaneously presented for 750 ms, placed horizontally. Participants were instructed to press the Z key (leftmost on keyboard) if the familiar picture was on the left; the M key (rightmost on keyboard) if it was on the right. The left-right position of the novel stimuli was counterbalanced across trials.

There were six experimental conditions: upright human, inverted human, upright monkey, inverted monkey, upright sheep, and inverted sheep: 10 trials per conditions. The orientation (upright or inverted) and the species (human, monkey, sheep) were randomised across the test. Randomisation was computer controlled and differed for each participant. Thus the experimental series comprised 60 trials. To familiarize participants with experimental materials and procedure, a 32-trial training session preceded the testing session. After completion of the experiment, participants were debriefed about the purpose of the study.

Results

Response time

Mean response time for correct responses were scored for each participant for each condition (figure 2). Moreover, for each participant, for each category (species, orientation), response times that were greater or less than two standard deviations from the mean were rejected. A mean of 1.7 trials were rejected per subject (0-4).

figure 2 here

A Two-way within-subjects ANOVA (species x orientation) on corrected data showed an effect of species ($F(2,32) = 8.85, p < .001$) and a significant effect of orientation ($F(1,16) = 15.12, p < .05$). The interaction between these factors was also significant ($F(2,32) = 5.547, p < .01$). Bonferroni corrected for multiple t-test p showed that response time for sheep faces (mean = 691.21 ms) was significantly different from that for monkey (mean = 642.36 ms) ($p < 0.001$) and for human faces (mean = 647.69 ms) ($p < 0.01$), whereas the speed of response was similar for monkey and for human faces ($p = 0.68$).

A Bonferroni corrected for multiple t-tests showed that upright faces (637.07 ms) were recognised faster than inverted faces (683.71 ms) ($p < 0.01$).

Post-hoc contrast analysis was conducted on the results of the interaction and showed that response time for sheep faces in the upright position differed significantly from response time for human and monkey faces in the upright position ($p < 0,001$). In the inverted orientation, post-hoc contrast tests showed that response time for sheep faces did not differ from the two other categories of stimuli presented in the same orientation ($p = 0,08$). Thus, human faces were recognised faster when presented in the upright position (619.49 ms) than in the inverted position (675.88 ms). This was also true for monkey faces (mean upright = 606.66 ms ; mean inverted = 678.06 ms), but not for sheep faces (mean upright = 685.05 ms ; mean inverted = 697.19 ms).

Accuracy

Figure 3 about here

The accuracy analysis was conducted on non-corrected data (response times that were greater or less than two standard deviations from the mean were not rejected). A two way within-subjects ANOVA (species x orientation) showed an effect of species ($F(2,32) = 11.034, p < 0.001$) with no effect of orientation ($F(1,16) = 0.95, p = 0.34$). The interaction between these factors was not significant ($F(2, 32) = 1.32, p = 0.28$). Bonferroni corrected for multiple t-tests showed that the performance for sheep faces (mean = 75.59 %) differed significantly from both the performance for monkey faces (mean = 87.65 %) ($p < 0.001$) and from the performance for human faces (mean = 85.88 %) ($p < 0.001$). Accuracy for monkey faces and for human faces was identical ($p = 0.53$).

With expected chance level corresponding to a 50% level of success, a two-tailed t-test showed, that the score for sheep faces differed from chance level ($t = 7.78, df = 32, p < 0.0001$).

There was no effect of inversion on accuracy for any face types.

Discussion

Participants were slower and less accurate to recognize sheep faces than primate faces in the upright orientation. The response time advantage for primate faces disappeared when the faces were inverted, suggesting that the advantage was related to face-specific configural processing. Moreover, since human and monkey faces

generated similar responses to each other, whether speed or accuracy was considered, we can infer that similar face-specific processes were engaged whether monkey or human faces were viewed.. Since ovine faces were slower to distinguish, and more error prone, and since they did not generate an inversion effect, we can also infer that sheep faces fail to engage the face-processing system – or that they engage it less efficiently.

The results support Campbell et al's conclusion that a common representational process underlies the recognition of unfamiliar faces of primates, which is not extended to process ovine faces. Accuracy rates for upright monkey recognition of 94% in this experiment, and an inversion effect in the response time for monkey faces, may indicate that a face processing system for humans can adapt to recognize other primate faces, when the inspection period is sufficiently extended (750 ms). However, it is characteristic of human processing of human faces that it is mandatory and can be engaged rapidly and automatically (see for example, Lavie et al, 2003). The second experiment explored the possibility that duration of inspection may be critical to the extent to which human and monkey faces may utilise a single (or similar) processing systems..

Experiment 2

In view of the absence of an inversion effect and the low level of accuracy in ovine recognition found in the previous experiment, this experiment used only Human and Monkey faces with a familiarisation period of 50ms.

Participants :

In this second experiment, 17 new participants aged from 18 to 40 years (9 males and 8 females) from the University of Sheffield UK, voluntarily participated in the experiment. As in the previous experiment they had no experience of individual macaque monkeys.

Stimuli :

A total of 176 human faces and 176 macaques faces, all as half-tone images with neutral expressions, were presented to participants. As in experiment 1, the size of the image was 10 cm x 6 cm. Brightness and contrast levels for all images were manipulated to be uniform across images in the two species categories. A 32-trial training session preceded

the testing session. The pictures used for training were the same as those used in experiment 1.

Procedure

Because of a possible ceiling effect for primate faces in Experiment 1, we decided to make the experiment more difficult by increasing the number of trials presented to 176. There were 4 conditions (human upright, human inverted, monkey upright, monkey inverted), each consisting of 44 trials. Familiarisation time was reduced to 50 ms and the delay between familiarisation and test was reduced to 500 ms. Participants were allowed a 1 minute rest period half-way through the experiment. The settings during the training session (familiarisation time, and delay) were adjusted to those of the testing session. Otherwise the procedure was identical to Experiment 1.

Results

Insert figures 4 and 5 here

Accuracy

Mean accuracy scores for each condition are shown in figure 4. A repeated measures two- way ANOVA (species*orientation) showed a significant effect of species ($F(1, 16) = 30.62, p < 0.001$), a significant effect of orientation ($F(1, 16) = 15.17, p < 0.005$), and a significant interaction between the two factors ($F(1, 16) = 5.03, p < 0.05$).

Post hoc contrasts performed on the interaction showed that accuracy for upright human faces differed significantly from accuracy for inverted human faces and upright and inverted monkey faces ($p < 0.0001$). Independent two-tailed t tests showed that only accuracy for upright human faces (65.37 %) differed significantly from chance (50%) ($t = 6.43, df = 32, p < 0.001$). Accuracy for inverted human faces (52.67 %) ($t = 0.71, df = 32, p = 0.48$), for upright monkey faces (47.86 %) ($t = 0.74, df = 32, p = 0.46$), and for inverted monkey faces (45.59 %) ($t = 1.11, df = 32, p = 0.27$) were all at chance level (not different from 50% of success).

Response time

Mean response time for correct responses was scored for each participant and for each condition. As in the previous experiment, analyses were conducted on corrected data. A mean of four trials was rejected per participant (range 2-7). A two-way ANOVA, (species * orientation) with repeated measures showed no effect of species ($F(1,16)= 0.126$, $p = \text{NS}$) and no effect of orientation ($F(1, 16) = 1.45$, $p = \text{NS}$). The interaction between the two factors was not significant: ($F(1, 16) = 0.639$ $p = \text{NS}$). The response time results are displayed on figure 5.

Discussion

In this experiment using short (50ms) familiarisation displays and large numbers of images, performance was at chance level for monkey faces (both orientations) and inverted human faces. Only upright human faces were recognised at above chance levels. High levels of accuracy with both monkey and human faces in the first experiment suggested that as long as the viewer has sufficient time to inspect the image, immediate (human) face recognition can extend to monkey faces. Enhanced accuracy for upright human faces, which did not generalise to monkey faces, as demonstrated in this experiment with an active task, replicates the results obtained by Pascalis and Bachevalier (1998) and by Pascalis et al., (2002) with the VPC task. Under time restriction, and for some passive viewing tasks, unfamiliar human face-processing works better for (human) conspecifics suggesting a species-specific processing system. The results of Experiment 1 however suggest that it can be flexible, and that given enough time, may be extended to process other primate faces.

General Discussion

The aim of the experiments reported here was to investigate the extent to which, and the conditions under which human face processing of human faces might be engaged when humans view faces of other species. It was suggested that conflicting reports in the literature might be explained by differences in the tasks used. In general, passive tasks were shown to produce results indicating a human specific system while active tasks indicated a primate specific system. Passive tasks, if properly controlled, can indicate the

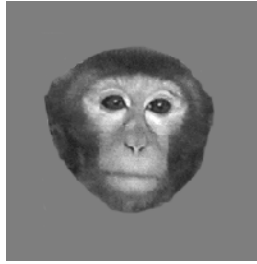
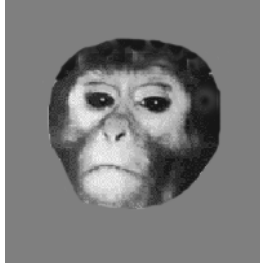
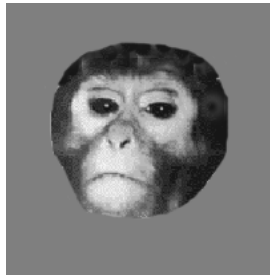
extent to which face-processing is automatically engaged, whatever the task or conditions of the study. Compared with the first experiment, the second one showed that under impoverished viewing conditions (reduced duration of presentation) upright human faces can be processed effectively, whereas monkey faces and inverted faces (which showed similarities to human faces in Experiment 1) cannot. A similar rationale was used by McKone et al (2001) to show upright human faces have a unique ability to be detected in noise. With active tasks, when instructed to discriminate between species, and when participants have sufficient time to recruit strategic systems to the task, they may be able to adapt their human specific system to process primates. However, as was shown in a previous study (Campbell et al, 1997), this deployment of the face-recognition system may not extend beyond primate faces. One factor that allows the extendibility of face processing to primates may be structural similarity of human and other primate faces, compared with the faces of other animal species. This remains to be demonstrated empirically (i.e. by computational measures of similarity between displays).

Experience (expertise) in recognizing faces of conspecifics is believed to play a great role on the specialisation of the human face processing system, especially in the development of its sensitivity to configural structure – and hence to orientation. Humans are experts at recognising faces, but more specifically, they are experts at recognising human faces and they generally have experience with human and not monkey faces. But what exactly is the role of expertise on the specialisation of the system ? Can expertise acquired at adulthood lead to such a specialisation, or does the system depend on experience acquired during development?

As mentioned earlier, Nelson (2001) proposed that, like language, the face processing system develops, during the first years of life from a system which can identify and distinguish faces of all sorts to one tuned to human faces (and possibly to faces of restricted ethnicity) specifically. Recently, Pascalis, et al. (2002) tested the discrimination of human and monkey faces by 6-month-olds, 9-month-olds, and adults using the visual paired comparison procedure. The youngest group showed discrimination between individuals of both species, while older infants and adults only showed evidence of discrimination of their own species. The hypothesis of a narrowing of the perceptual window during development is also supported by two event-related potential studies

(Nelson, 1993, de Haan, et al., 2002) in which it was demonstrated that 6-month-old infants, but not adults, processed facial identity in human and monkey faces comparably. The conclusion of those studies was that a face processing system, tuned to the characteristics of conspecifics, emerges during the first year of life. Considering those data, the specificity of the system would then be strongly dependent on experience acquired during childhood. To test this hypothesis, it would be of great interest to test primate face recognition in primatologists (whose expertise is acquired in adulthood). If the above assertion is true, this kind of expertise may not be strong enough to allow subjects to perform better than non experts in a two alternative-forced-choiced task with limited familiarisation time. Expertise acquired during childhood, only, would be efficient.

An alternative hypothesis would be that extensive training with non-human primates could indeed lead adults to develop an automatic primate face processing system as efficient as their human specific system. Work by Gauthier has shown that human adults can learn to use their face processing system to process 'greebles' after a relatively short period of acquiring expertise for this type of stimuli (Gauthier and Tarr, 1997). Comparable mechanisms to those used for faces were engaged to process those stimuli. Diamond and Carey (1986) showed the same phenomenon with dog experts. We have shown that the specificity of the system could be demonstrated with a two-alternative-forced-choiced task, and that the data are consistent with results obtained with passive tasks. Thus, applying these techniques to experts in primatology could give more answers about the role of expertise on the specialisation of the face recognition system.



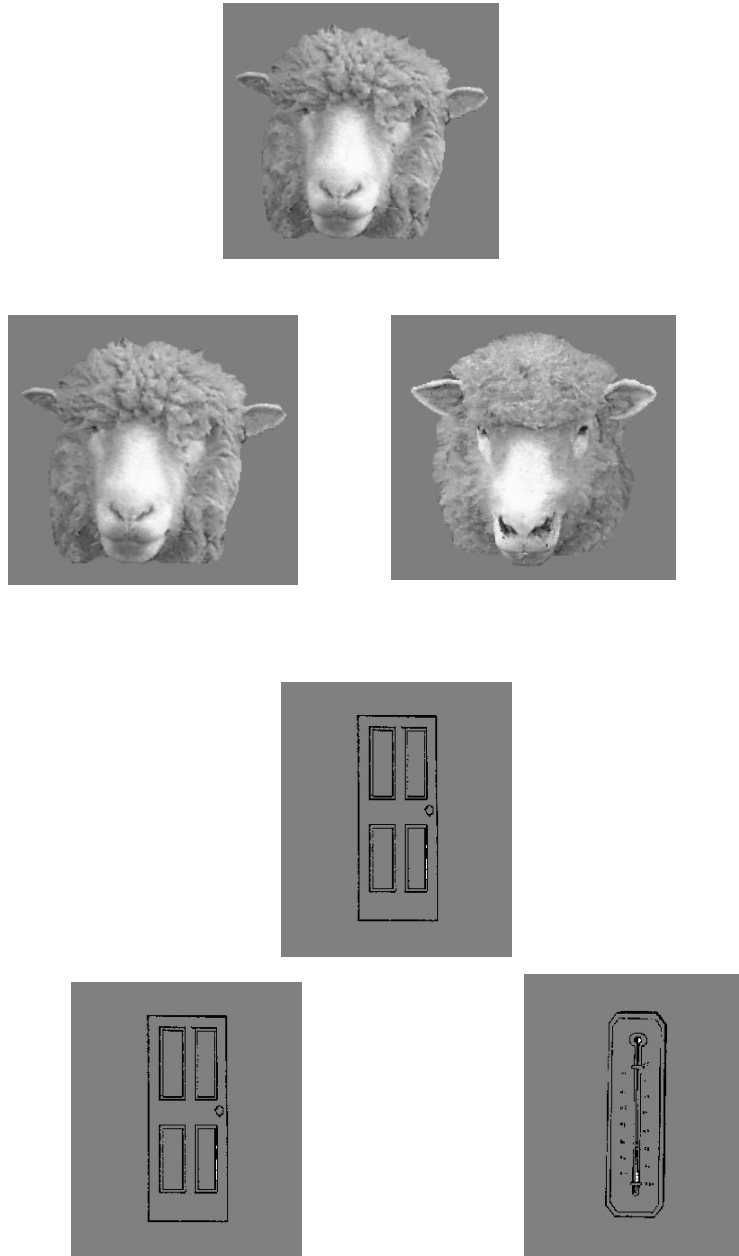


Figure 1: examples of the stimuli used in experiment 1.

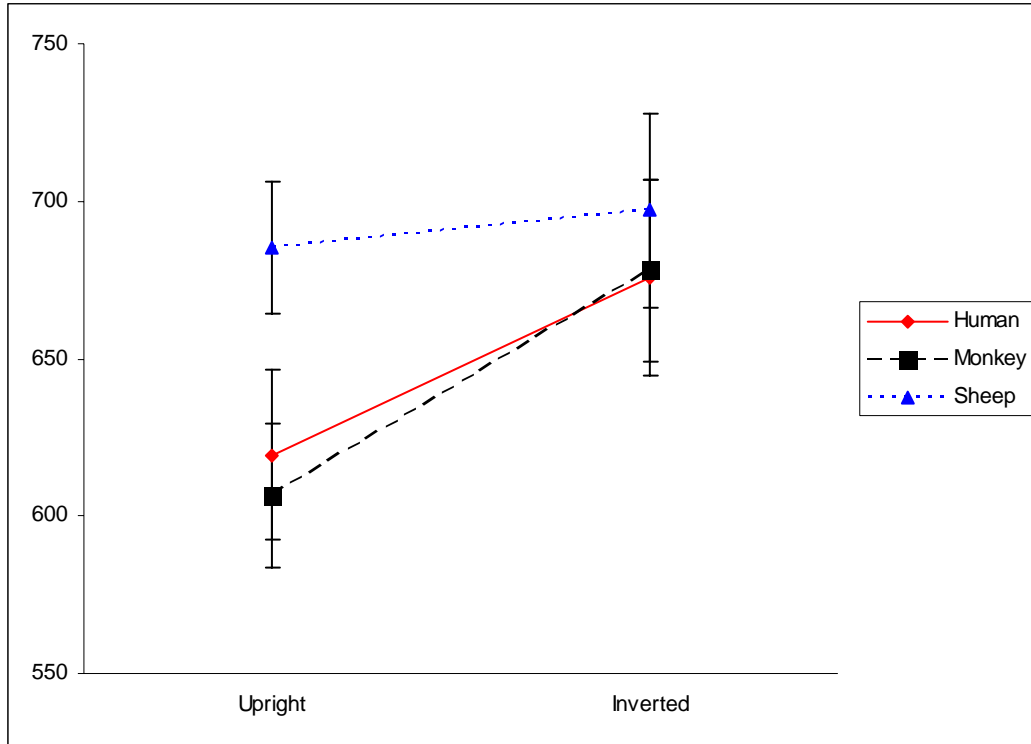


Figure 2: mean response time (ms) for each species, upright and inverted with a 750 ms familiarisation period.

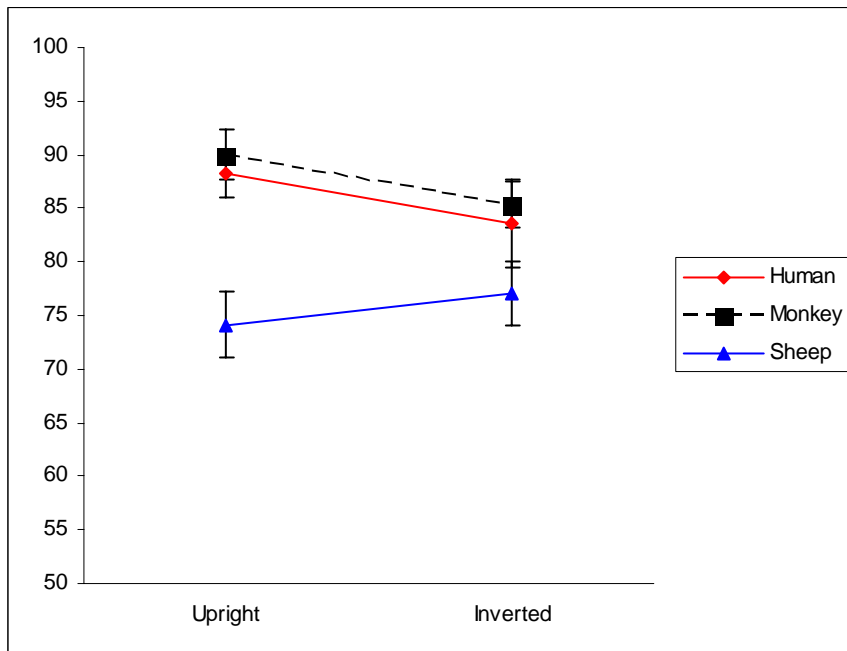


Figure 3: Accuracy for human, monkey and sheep faces with a 750 ms familiarisation period.

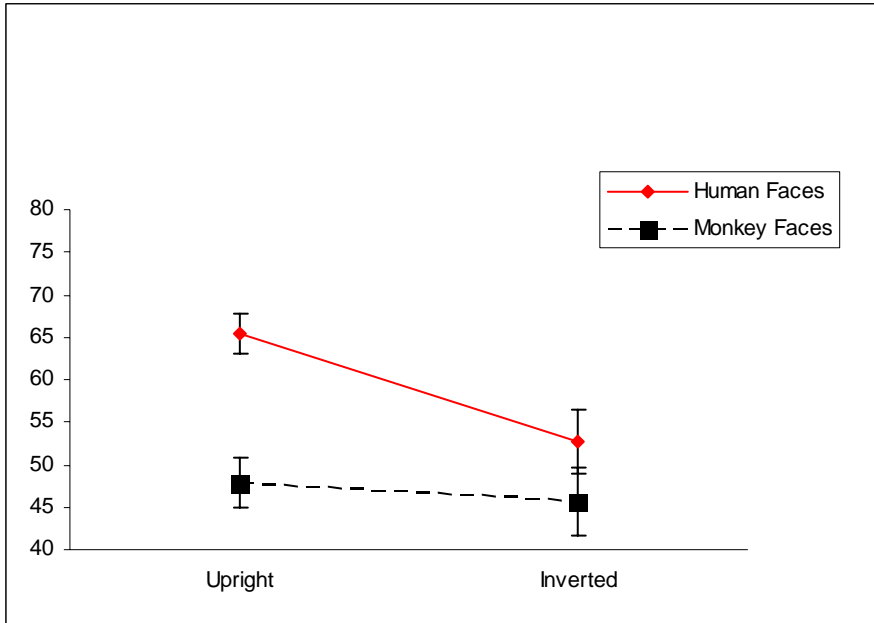


Figure 4: Accuracy (%) for human and monkey faces with a 50 ms familiarisation period.

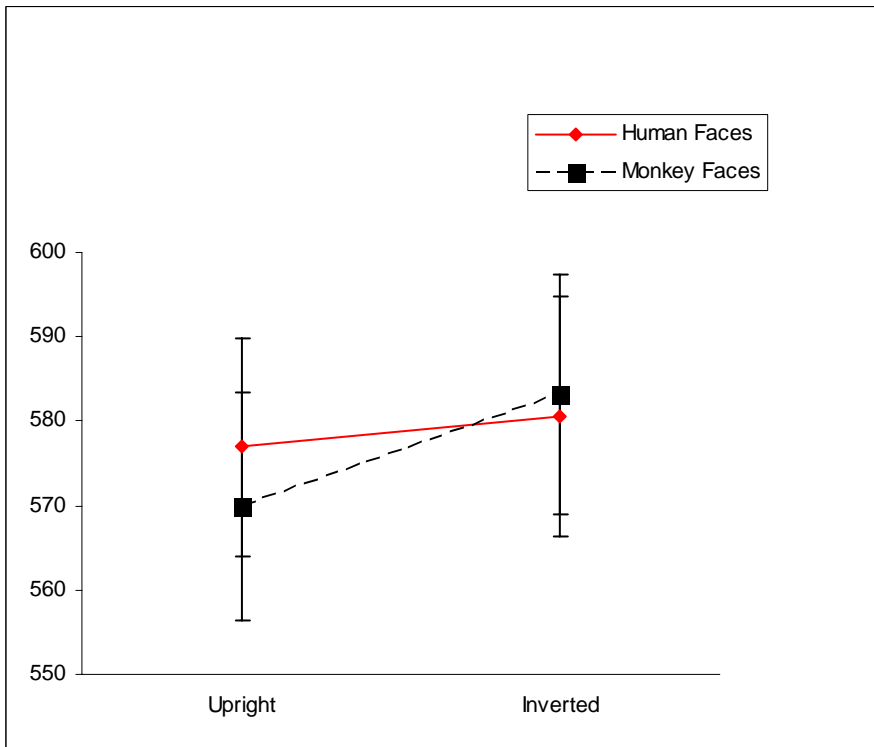


Figure 5: mean response time (ms) for each species, upright and inverted with a 50 ms familiarisation period.

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