Inverting line drawings of faces
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Two conditions which both disrupt faces processing, inversion and the transformation of the face into an edge-based line drawing, have each been explained at least partially in terms of a disruption of configural information. Five experiments are reported in which the combined effects of the two manipulations were investigated, to find out how the combination of both affects face processing. Moreover, two different tasks were used: sequential matching of person identity and free identification. The general pattern of result revealed that in both tasks effects of both manipulations are rather additive and thus it is concluded that both manipulations are disruptive through different sorts of information processing. It is discussed how at least two different kinds of configural information are involved in face processing. The comparison of the two tasks, identification and sequential matching, indicates that identification is the more critical condition as it cannot be based on inferences that are probably due to short-term representations of critical features – although both tasks reveal similar results.

Key words: Face perception and recognition, line drawings

Faces as visual stimuli convey important information in that they allow us to recognise persons and their emotional states. Faces differ from other objects according to processing requirements as they have to be identified on the subordinate level (Tanaka & Gauthier, 1997). Two lines of evidence concerning “special information” in face recognition are the concepts of surface information and facial configuration.

Surface information

Faces differ from other objects to the amount that surface information (e.g., pigmentation and texture) is involved in the everyday recognition (Bruce & Humphreys, 1994). The importance of textural information is demonstrated by the disruption of face recognition when faces are transformed to edge-based representations. Whereas the extraction of expression still seems possible from line drawings of faces (Etcoff & Magee, 1992; Paramey, Schneider, Josephs & Slusarek, 1994) it is rather difficult to recognise a person’s face using an edge-based representation, i.e. transforming a face into an edge based representation dramatically decreases the accuracy of recognition.

Davies, Ellis & Shepherd (1978) found a decrement from 90% to 47% if faces of famous persons were transformed to detailed line drawings. Davies et al. argue that line drawings might not preserve features that are important for recognition, such as hair colour or skin texture. Recently, Leder (1999) used different views between images of faces, line drawings or photographs and found that line drawings of faces are particularly difficult to match over different views.

Bruce, Hanna, Dench, Healey & Burton (1992) investigated the recognisability of face representations which were constructed using Pearson and Robinson’s filter (1985). The filter combines two components from the fa-
Evidence for the disruption of configural information

In face processing, it has been found that faces presented upside-down, performance at naming each of the halves increased. This was interpreted as decreased accessibility of configural information. The role of configural information available from both real faces and photographs might “glue” the combination of elements into meaningful configural information.

Recent research indicates that line drawings of faces are not only “poor representations” because they lack specific surface-based information such as skin texture and shadows. Measuring the detectability of changes, either by exchanging single features, or replacing feature locations within the face, revealed that configural aspects were less noticeable in line drawings of faces compared with the same manipulations presented in photographs (Leder, 1996b). Moreover it was found that these changes in cue saliency contributed to the difficulty in recognising unfamiliar faces if they were presented as line drawings. To explain the reduction of configural processing from line drawings, Leder (1996b) argued that the texture information available from both real faces and photographs might “glue” the combination of elements into meaningful configural information.

Configural information

There is some evidence that face processing (compared to other objects) is particularly relying on the processing of configural information. The role of configural information in face processing has often been addressed with respect to the “face-inversion” effect (Yin, 1969). The difficulty of recognising upside-down faces might be due to a decreased accessibility of configural information. Young, Hellawell & Hay (1987) combined top and bottom halves of different famous faces, and found that the halves combined in these “composites” were extremely difficult to identify: surprisingly, when the composites were turned upside-down, performance at naming each of the halves increased. This was interpreted as decreased configural interference in the inverted orientation. Other evidence for the disruption of configural information stems from Bartlett & Searcy (1993) who showed that faces that are made “grotesque” through configural distortions are seen as less grotesque when turned upside-down. Leder & Bruce (1998) found that non-grotesque, but distinctive faces were regarded as less distinctive when turned upside down only if the distinctiveness was based on configural properties compared to the same faces manipulated for distinctiveness by enhancing local features.

Thus, there is evidence to suggest that the deficits in recognising faces that are presented as line drawings, and those presented upside-down, may both involve a disruption of facial “configural” information.

On the other hand, there are several interpretations about what exactly “configural information” might be. There is a wide variety of possible candidates for the “configural features” that are used for recognition, e.g. distances between each pairs of local information sources, or even higher order relations comprising more than two of these features: faces could be encoded in terms of more abstracted, or collapsed codes, such as “slim” or “long”, or “oval” (see Rhodes, 1988, for a detailed discussion).

It is still under debate what configural information in faces means. Tanaka & Farah (1993) seem to favour an interpretation of configural as holistic, i.e. not decomposed into parts such as distinctive facial features. Evidence for this understanding of configural information stems from studies in which they showed that information about facial parts is better retrieved from the whole face compared to isolated presentation. In a recent approach (Leder & Bruce, 2000) it was also shown that face perception is sensitive to relational information which consists of locally-distinctive-distances between local features and which is probably encoded without reliance on holistic representations. The conclusion that more than one sort of configural information and representation is involved in face processing got recent support by the finding that the configural processing of the Young et al. (1987) composites and the disruption of configural information when faces are turned upside down, do probably not rely on the same processing mechanism as both show different developmental courses (Carey & Diamond, 1994).

Given the differing definitions of the term configural, it is also possible that turning the face upside-down affects a kind of “configural information” that is different from that which is affected by the line transformation. For example, the unusual orientation could cause encoding problems for the location of some features, e.g. because the left eye is found on the “wrong” side when turned upside down, and therefore, could be mismatched in memory. This hypothesis is supported by the left-right asymmetry of human faces (Kowner, 1996). In contrast, line drawings may affect the formation of higher-order configural information as the line representations alone do not allow...
any classification that is based on surface information, such as “a blond middle aged person”. This line of arguing is supported by the findings of Leder (1996a) that estimations of a person’s age cannot be reliably made from line drawings.

To uncover the relationship between the two conditions which both are disruptive for face recognition (line transformation and inversion) effects of both conditions were tested alone and in combination. The interpretations of the present study follow the logic that when both conditions disrupt the same kind of information processing then the combined effects are expected not to be additive but less than additive. If on the other hand both manipulations affect different sorts of information processing then turning line drawings upside down should have clearly additive or over additive effects. The hypotheses tested in our experiments were concerned with the outcome when both manipulations were applied at the same time: When both manipulations affect the same underlying processes then non-additive interactions would be predicted, thus inverting line drawings should not produce an effect larger than transforming a face into a line drawing alone. On the other hand, if both manipulations affect different processes then it is expected that they produce main effects but do not interact. This reasoning is in accordance with Bruce, Hanna, Healey, Mason, Coombes, Fright & Linney (1993), who discussed the combined effects of inversion and “transforming a photograph into a photonegative” (negation) in sex classification and Bruce & Langton (1994), who investigated the independent as well as the combined effects of negation and inversion in face recognition and found independent effects for the combined manipulations.

Before we present the experiments and results some further assumptions have to be made. In some studies the disruption of configural aspects has been found to be stronger when face internal features (by concealing hair and chin, see Fig. 1) were used (Leder & Bruce, 1998; Bruce, Burton & Dench, 1994). When faces are matched one after each other participants might tend to use the dominant and large features of overall head shape and hair style – and therefore avoid the processing of the internal features which might be important for the disruption of some configural information. Thus we ran all conditions using face internal features only – but include two experiments in which full faces were used in the matching task.

Face recognition can be measured in different terms and investigated in different tasks. In everyday live we often see people and have to match them with representations which are encoded in our memory. In experiments this situation was often modelled using matching paradigms. However, two variants have to be distinguished: when unfamiliar faces are used, the participant encodes a face and decides whether a second presented face is that same person or a different one. With unfamiliar faces this decision may base more on familiarity than on explicit person identity (Bruce & Young, 1986). On the other hand, if familiar faces are used then the matching might base on explicit person identity – but still differs from everyday situations in that the second face in a matching task is recognised after it has just been presented, thus the memory content consist of a very recently seen picture of that person. In the present study familiar as well as unfamiliar faces were used in the different experiments.

The paper is structured as follows. Three sorts of Experiments are reported, matching tasks (“do the two sequentially presented faces in each trial depict the same or different faces?”) using unfamiliar faces, matching tasks using familiar faces and finally an identification task using familiar faces. In both matching versions two different experiments are combined in which either whole faces or face internal features are used in which hair and chin were cut out, as shown in Figure 1. The general discussion includes a section in which the outcomes are interpreted in regard to information in face processing while in a closing section methodological consequences are discussed.

Figure 1: Example of stimuli: Left column photographs, right column line drawings. The frame in the left upper picture shows the selected parts in the “face internal” versions of Experiment 2 and 4.
The two manipulations tested in the present study (line transformation and inversion) both affect recognisability of faces. In the free identification experiment (Experiment 5) recognition rates were measured. In matching experiments the outcomes not only allow the measurement of error rates and reaction times but also the error rates include false-alarm as well as hit rates. To make the results of all experiments comparable we decided to present the results of the matching experiments (Experiment 1 to 4) in terms of a non-parametric combination of false alarm and hit rates (\(A'\)) (Snodgrass & Corwin, 1988). \(A'\) is a nonparametric measurement which combines hit-rates and false-alarm rates into one single index. When Hit-Rate (H) \(\geq\) False-Alarm rate (FA), then \(A' = (H^2 + FA^2 + 3H – FA – 4FAH) / [4FA (1 – FA)]\) and when Hit-Rate (H) < False-Alarm rate (FA), then \(A' = (H – H^2 + FA – FA^2) / [4FA (1 – H)]\). The resulting values vary from 0.5 which indicates guessing to 1.0 which indicates perfect recognition. \(A'\) allows to easily compare outcomes of matching-studies and recognition rates (Leder, 1999). Thus, all experiments are analysed in terms of recognition performance. However, the raw data of the matching experiments are presented in the Appendix.

Reaction times were not analysed in these experiments for the following reasons: first the participants were not required to respond as fast as possible, which makes reaction times difficult to analyse. In some conditions error rates reached up to 30% in some conditions which also makes reaction times difficult to interpret. Moreover, we present one experiment (Exp. 5) in which no response time could have been measured.

Matching unfamiliar faces: Experiment 1 and 2

In the matching-experiments (Experiment 1 to 4) of the present study the participants were requested to decide fast and accurately whether two sequentially presented pictures of faces depicted the same or different persons. Both pictures always comprised different orientations (frontal versus 3⁄4-quarter-views) of the face to prevent the use of pictorial codes. The experiments contained as many “same” trials as “different” trials. In each trial a photograph of a face was either followed by a photograph or a line drawing, and the second stimulus was either presented upright or inverted.

The two kinds of manipulations, ORIENTATION (upright-inverted) and MODE (photograph – line-drawing) varied as within-subjects-factors in the matching Experiments. In Experiment 1 matching performance was measured using complete unfamiliar faces while in Experiment 2 face internal features were used.

Experiment 1

Method

Participants

16 students, 10 males and 6 females, participated to fulfill course requirements. Mean age was 25 years.

Stimuli

Stimulus pictures were taken from 20 male faces (which were unfamiliar to the participants)\(^2\). Each face was photographed from two perspectives, one frontal photograph and a ¼-view. They rotated their head to their right (Fig. 1) when portrayed for this condition, resulting in photographs in which the nose pointed to the left side of the picture. The persons were 25–35 years of age. For each of the 40 photographs a line-drawing was produced by the following procedure: the photographic stimuli were digitised and transformed to 8-bit images containing 256 shades of grey. The photographs were then processed using an automatic edge extraction filter. The resulting representations were increased in luminance and served as the basis of drawings that were produced directly on the screen using an electronic pen. Thus the draughtsman produced a continuous line version based on automatically located edge fragments. This procedure guarantees (a) that the location of the lines is valid in the drawings, and (b) that the draughtsman was able to set lines that represented the following facial “features”: eyes, eyebrows, nose, mouth outline, the most visible lines such as wrinkles around the mouth, and the overall facial outlines. Figure 1 gives an example of the four versions available for each person’s face.

Procedure and Design

Participants performed one experimental block of 80 trials, 40 “same” and 40 “different”-trials. The first picture in each trial was always a photograph (presented for 2 seconds, followed by a 500 ms blank). The photograph was followed by either a line drawing or a photograph, either upright or inverted of either the same person or a different person’s face. In the “same”-trials each stimulus face was used as the first stimulus in one of each of two views, either frontal, or three-quarter. For the “different”-trials each photographic version was followed by a randomly selected different persons’ face. Four different sets of trials were created to counterbalance all “same”-conditions. Each set was exposed to four different subjects. During the test the trials were presented in a random order.

\(^2\) The stimuli were identical to the ones used by Leder (1996b).
The stimuli were presented on a full grey scale Macintosh computer screen. Two keys were assigned to record the response ("same" [Y] or "different" [M]). The presentation and registration were controlled by a program especially developed to allow fast presentation of full colour photographs in a matching task (Leder & Theiler, 1997). Participant’s viewing distance from the screen was approximately 70 cm; the pictures had an overall screen size of about 10 cm heights, resulting in a visual angle of approximately 8°. The line-drawings differed in overall luminance (mean cd/m² ~ 90 for photographs and 175 cd/m² for the line representations).

Participants were tested individually. They were instructed to decide “same” or “different” if the person’s identity was the same or different across the two pictures of one trial. They were informed about the different picture formats, the orientations and the different perspectives. The experimental session took about twenty minutes.

Results

The mean error rates of Experiment 1–4 are presented in the Appendix. The error rates of all conditions were combined into the nonparametric A’ for each participant. The mean A’ of all four conditions are shown in the upper part of Table 1.

The results (A’) of each subject were submitted to an ANOVA with MODE and ORIENTATION as repeated-within factors. The analysis revealed a main effect of MODE, F(1, 15) = 32.206, p < .001, and a main effect of ORIENTATION, f(1, 15) = 8.441, p < .01, but no interaction (F = .248).

Discussion

The outcome of the ANOVA is not in accordance with the hypothesis that both manipulations disrupt processing through the same mechanism. Thus it is concluded that transforming a face into a line drawing and turning it upside down probably affect different aspects of configuration.

However, when whole faces are matched then participants might use a strategy which relies on the gross facial features such as facial outline or hairstyle. Most studies which demonstrated a disruption of configural processing such as detecting changes in the location of eyes nose or mouth used manipulations of face internal features (Haig, 1986; Leder, 1996b). To exclude that the availability of the gross geometrical features has covered the effects of configural processing, Experiment 2 used face internal features only.

If the presence of the hairstyle and facial outlines dominated the processing of the stimuli in Experiment 1, then the effect of the combined manipulations could be different when these “gross” features are excluded. This case was investigated in Experiment 2. Showing the face internals features may produce a greater reliance on configural information and reveal whether both manipulations affect the same information processing.

Experiment 2

Experiment 2 was identical to Experiment 1 except that face internal features were used instead of complete faces. These internal features are important in face recognition, because they are invariant to short-term changes such as changes in hairstyle.

Method

Participants

16 students, 9 female and 7 male adults, participated in Experiment 2 to fulfil semester requirements. Mean age was 26 years.

Stimuli and Procedure

To create “face internal” versions of the stimuli used in Experiment 1, parts of the face were cut out containing the eye, nose and mouth-region. In Figure 1, a small frame shows the part of the face that was used in Experiment 2. The overall procedure was identical to the one described in the methods section of Experiment 1.

Results

The lower part of Table 1 shows the results of Experiment 2 in terms of A’. As in Experiment 1 the mean A’ values of each of the 16 subjects (in all 4 conditions) were submitted to an ANOVA with MODES (photograph-line drawings) and ORIENTATION (upright-inverted) as within-repeated-factors. The analysis revealed a main effect of MODE, F(1, 15) = 35.784, p < .001, and an effect of ORI-
Discussion

This outcome again is not in accordance with the hypothesis that both manipulations disrupt processing through the same mechanism as both manipulations do not interact. Turning faces upside down did not produce a strong disruption. This is not in accordance with the general claim that inversion disrupts recognition. However, in previous studies it was claimed that inversion effects strongly rely on a memory component that is not as much involved in the matching paradigm (see Valentine, 1988, for a discussion). In accordance with this view Valentine (1988) reports evidence of own studies and a study by Bruyer & Velge (1981) in which there was no disproportionate effect of inversion when a short time matching paradigm was used. However, in Experiment 2 there was trend for an inversion effect, but the Experiment reveals that the matching task may not be ideal to investigate the inversion effect. A discussion of this point is deferred to the general discussion.

In Experiment 3 familiar faces were used. Ellis, Shepherd & Davies (1979) and Young, Hay, McWeeny, Flude & Ellis (1985) have reported that the face internal region is more important in face processing of familiar faces. Therefore, in Experiment 3 we investigate how the use of familiar faces instead of unfamiliar faces affects the processing of both manipulations. Moreover, the processing of familiar faces might differ from the processing of unfamiliar faces in that other information might be used to recognise familiar faces. Thus, if configural information plays a stronger role in the processing of familiar faces then the use of familiar faces should reveal whether both manipulations affect this kind of processing.

Experiment 3

Method

Participants

16 students, 8 female and 8 male adults, took part in Experiment 3 to fulfill semester requirements. All participants reported to have normal, or corrected-to-normal vision. Mean age was 27 years.

Stimuli

For Experiment 3, the faces of ten famous male people were selected. For each person two photographs were used showing two different “views”. The views were unavoidably not as standardised as in Experiments 1 or 2, but they differed in an amount that required the use of structural codes (Bruce & Young, 1986). The ten celebrities were: J. Nicholson, M. Gorbachov, J. Travolta, B. Clinton, H. Grant, F. Mitterand, Prince Charles, T. Blair, C. Richards and C. Eastwood. Line drawings of each face were constructed using the procedure described in the “Method” section of Experiment 1.

Procedure

The experimental procedure here differed from Experiment 1 in the following respects: in order to achieve the same number of trials per condition and subject, all faces were shown twice as often as in Experiment 1. The familiarity with the faces is one of the features of Experiment 3, therefore the repetition of the faces was felt not to be critical. A list of all target names was shown to the subjects before the beginning of the experimental block and they were asked if they were familiar with the person’s face. Only subjects who knew all the persons in the list were included in the present study.

Results

The A’ mean values (sampled over subjects) of all four conditions are shown in the upper part of Table 2. When photographs were presented upright, subjects in average made less than one error. Turning the faces upside-down increased the difficulties with both modes.

The results (A’) of each subject were submitted to an ANOVA with MODE and ORIENTATION as repeated-within factors. The analysis revealed a main effect of MODE, F(1, 15) = 35.590, p < .001, and a main effect of ORIENTATION, F(1, 15) = 54.253, p < .001, and a significant interaction F(1, 15) = 15.516, p = .001. Post comparisons revealed that inversion affected line drawings more than photographs. Interestingly, neither inverting a face (t = 1.718, p < .106) nor transforming a face to a line drawing (t = 1.622, p < .126) produced significant differ-
ences to the upright photographs, thus the decrease of performance when line drawings were turned upside down is the only significant effect.

Discussion

As in the previous experiments, this outcome is not in accordance with the hypothesis that both manipulations disrupt processing through the same mechanism.

Again the same experiment was run using face internal features only, to exclude that effects had been covered by the gross facial features in Experiment 3.

Experiment 4

Experiment 4 was identical to Experiment 3 except that face internal features were used instead of complete faces.

Method

Participants

16 students, 11 female and 5 male adults, took part in Experiment 4 to fulfil semester requirements. Mean age was 21.6 years.

Stimuli

For Experiment 4 each famous face from the set used in Experiment 3 was cut out in an oval which included the internal parts of the faces covering the regions between the ears and from chin to the beginning of the hair. This shape had to be used because of the greater variability between the different pictures (compared to Experiment 1 and 2).

Procedure

The experimental procedure here was the same as in Experiment 3.

Table 2: A’ data of Experiment 3 (complete) and 4 (internals) for both ORIENTATIONS (upright versus inverted) and both MODES (photo versus line)

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Complete</th>
<th>Internals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Photos</td>
<td>Line drawings</td>
</tr>
<tr>
<td>upright</td>
<td>.973</td>
<td>.919</td>
</tr>
<tr>
<td>inverted</td>
<td>.946</td>
<td>.865</td>
</tr>
</tbody>
</table>

Results

The A’ of all four conditions are shown in Table 2. Matching face internal features only was more difficult than matching the complete faces. As in the Experiments 1 to 3 the results in the line-inverted condition do not show a pattern that would be expected if both manipulations disrupted the same processes since inverted line drawings are more difficult to match than upright ones.

An ANOVA using the mean results (A’) of each subject with MODE and ORIENTATION as repeated-within factors revealed a main affect of MODE, F(1, 15) = 26.364, p < .001, and a main effect of ORIENTATION, F(1, 15) = 12.124, p < .01, but the two factors did not interact (F = 2.052).

Discussion

As in the previous experiments it is concluded that transforming a face into a line drawing and turning it upside down probably affect different aspects of configuration. Thus in none of the matching experiments there was evidence to suggest that both manipulations affect the same kind of processes. However, inversion and line transformation effects have been found to be strong, when recognition or identification instead of sequential matching was used (Yin, 1969; Davies et al., 1978). Thus in Experiment 5 an identification task was used. In this task the perceiver has to identify a person’s face from his or her memory representation of that person.

Identifying inverted line drawings: Experiment 5

In Experiment 5, stimuli of Experiment 4 (internal features of the famous faces) were used in an identification task to reveal whether the inverted-line drawings produce a non-additive pattern of interaction when identification instead of matching person identity is required.

Table 3: Mean identification rates in Experiment 5 for the faces presented either as upright photographs, upright line drawings, inverted photographs or inverted line drawings. In brackets the relative recognition to photographs correctly identified

<table>
<thead>
<tr>
<th>Orientation</th>
<th>upright</th>
<th>inverted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>photo</td>
<td>line</td>
</tr>
<tr>
<td></td>
<td>.899 (.100)</td>
<td>.263 (.283)</td>
</tr>
<tr>
<td></td>
<td>.463 (.485)</td>
<td>.138 (.145)</td>
</tr>
</tbody>
</table>

Swiss J Psychol 59 (3), 2000, © Verlag Hans Huber, Bern
Method

Participants
Thirty-two students, 16 female and 16 male adults, took part in Experiment 5.

Stimuli
For Experiment 5, one picture of each of the ten famous persons from Experiment 4 was used. Each stimulus was printed as a laser copy and the line drawings and the photographs were combined to two booklets.

Design and Procedure
In Experiment 5 each participant saw the famous faces either as line drawings, or photographs, either upright or inverted. Thus each subject saw ten face internals of famous faces in only one mode and all in one orientation. Therefore, both factors (MODE and ORIENTATION) varied between subjects.

At the beginning of Experiment 5 subjects received a list of the names of the ten celebrities and were asked to indicate whether they were familiar with the persons on the list. Afterwards the ten stimuli were presented for about five seconds each to each subject in one of the four conditions. The task for the subjects was to identify the stimuli. It was stressed that the interest really was “identification”, so participants were instructed not to guess, if the face did not give them an impression of someone they had recognised. The correctly identified items were recorded by the experimenter. Afterwards all faces were shown in the photograph-upright condition (except for those subjects who started with this condition) to reveal whether these versions could be recognised by the subjects. This revealed the chance to exclude stimuli that would not be recognised by the subjects in this condition.

Results
Table 3 shows the mean proportion of correctly identified stimuli in Experiment 5, sampled over eight subjects in each cell. In the table the proportions are calculated relative to the faces recognised in the photo-upright condition to minimise the differences in the groups in regard to the familiarity with the persons depicted in the stimuli. The control group who only saw upright photographs revealed a mean hit-rate of 89.9%. Mean identification rates of each subject were submitted to a 2-way ANOVA with MODE (photograph, line-drawing) and ORIENTATION (upright, inverted) as between subjects factors. The analysis revealed main effects of MODE, F(1, 31) = 43.402, p < .001, ORIENTATION, F(1, 31) = 128.798, p < .001, and both factors produced a significant interaction, F(1, 31) = 10.162, p < .005. Simple post-comparisons revealed that inverted photographs as well as upright line drawings both produced significantly lower error rates (photo-upright/lines-upright, t = 2.539, p < .039) than the inverted-line drawings (lines-upright/lines-inverted, t = 5.077, p < .001).

Discussion
The aim of Experiment 5 was to investigate the pattern of results when inverted line drawings had to be recognised from long term memory representations. When the photographs were presented upside down, less than a quarter of the items were recognised. Transforming the face into line drawing reduced the recognition rates for about the half. This indicates that both manipulations probably did not disrupt the same processes. When inverted line drawings were presented the recognition was even more disrupted – indicating that both manipulations together made a memory retrieval nearly impossible.

The comparison between the two manipulations alone suggests that the line drawings at least preserve a higher proportion of configural information than do the upside-down faces but that the difficulties with both manipulation result from different sources of information processing.

General discussion
The aim of the present study was to investigate two manipulations which are known to disrupt face processing and which both affect aspects of configural processing of faces. The hypotheses tested in our experiments were concerned with the outcome when both manipulations were applied at the same time: when both manipulations affect the same underlying processes then non-additive interactions would be predicted, thus inverting line drawings should not produce an effect larger than transforming a face into a line drawing alone. If both manipulations affect different processes then both manipulations were expected to produce main effects – and if interactions occur these should be due to an increase in difficulty to process inverted line drawings, in other words “over-additive”.

The results of all experiments correspond to this latter prediction: in three out of five experiments both manipulations produced main effects without interaction (except that in Experiment 2 there was a trend for a main effect of inversion only). In both cases where interactions occurred (Experiment 3 and 5) the pattern clearly shows that inverting line drawings made the processing significant more difficult.

We predicted that if both manipulations affect the same kind of underlying processes than turning line drawings
upside-down should not make their processing more difficult. This was not the case. Thus we conclude that both manipulations affect different sorts of information and information processing. In the next section the information processing from faces in both situations as line drawings and turned upside down are discussed in the light of our findings.

Information in faces

In all experiments of the present study the transformation of a face into line drawings disrupted its processing. This is in accordance with previous findings (Davies et al., 1978; Bruce et al., 1992). The lack of surface information – in terms of 3-D information as well as shading both may cause this effect (Bruce et al., 1992). When line drawings are turned upside-down the orientation makes their processing even more difficult. Turning faces upside-down is disruptive and several studies showed that aspects of configural information are disrupted: these findings include a reduction in sensitivity to relational features such as eyes-nose distances (Leder & Bruce, 2000), a reduced formation of a “new configural impression” in face composites (Young et al., 1987) and a disruption of holistic processing in terms of context superiority of upright presented faces (Tanaka & Farah, 1993). The inversion effect of line drawings may have two sources. (a) Transforming a face into a line drawing reduces a different kind of configural information than does inversion, or (b) the line transformation reduces the importance of configural information – but turning the face upside-down increases this disruption, thus disrupts any kind of configural processing even more. However, configural processing that is based on a facial prototype (Goldstein & Chance, 1980) should still be possible from line drawings (in which all local elements are at the same place as in the corresponding photographs), thus plausibly this kind of configural information might be preserved while the formation of an overall impression is disrupted as it might rely on more face specific e.g. three-dimensional information. On the other hand, the difficulty to recognise inverted faces might have to do with the difficulty to preserve relations during the process of mental rotation, while some general impression may be easily recovered from inverted faces (e.g. a long pale face remains blond and pale in inversion).

It was already known that more than one kind of configural processing is involved in face recognition. Carey & Diamond (1994) reported that at least two sources of configural information have to be considered: one which is involved in the face inversion effect (Yin, 1969) and one which causes the composite effect (Young et al., 1987). Carey & Diamond (1994) present findings which show that both effects show different time courses during early development. Thus the story of configural information is yet not fully understood and far from being simple.

There is also other evidence for the more general conclusion that transforming a face to a line representation and turning a face upside down affects different processes. First, when the processing of upright presented line drawings was compared to upright presented photographs then the sensitivity to detect swapped features (such as a new nose or mouth) did not differ between line drawings and photographs (Leder, 1996a). Rhodes et al. (1993) used a similar procedure to investigate the source of the inversion effect. Detecting swapped features in their study produced strong inversion effects.

A second source of evidence about the use of different information in recognising inverted and line drawn faces stems from research on the effect of “transformation to a photonegative” on face recognition. Face processing of photographs faces is strongly disrupted by negation (Phillips, 1972). But when faces were presented without texture (Bruce & Langton, 1994) then negation is no longer so disruptive. On the other hand if high-pass components which are very similar to line drawings are set into photo negative, their recognition is hardly affected (Hayes, Morone & Burr, 1986). Together these findings also support the idea of different information being used in the processing of inverted and line based representations of faces.

The effects found in the present studies are consistent with this general hypotheses, however, there were differences in the outcomes of the different experiments. Thus, a further aspect of the present paper is concerned with methodological consequences from the use of familiar and unfamiliar faces and from matching and identification tasks. These aspects are discussed in the final section.

Methodological aspects

The combined effect of line transformation and inversion was in no case less than additive. Despite the consistency of these findings there are methodological aspects to consider which have to do with other variables in the experiments.

Familiarity

When familiar and unfamiliar faces are compared then some points can be observed: using unfamiliar faces reduced the effect of inversion when face internal features were used (Experiment 2). However, a comparison between the results of unfamiliar and familiar faces did not reveal great differences – in both cases matching of the face internal features was more difficult than matching
complete faces. This is not surprising taken the importance of hair and chin region for the processing of faces (Shepherd et al., 1981). From the present results the use of unfamiliar faces is not critical.

It has been argued that internal features are more important in the processing of familiar than of unfamiliar faces. The comparison of complete faces and internal features only reveals that the latter was generally more difficult. However, in the present study this aspect is confounded with the amount of information and therefore conclusions should not be drawn.

Matching versus identification

Deciding whether two sequentially presented pictures depict the same or different persons requires less memory load than the identification of a picture of a face from memory. Valentine (1988) argued that the occurrence of an inversion effect might require a memory component. There was a large inversion effect in experiment 5 while the inversion effects in the matching tasks were less reliable which might underline Valentines hypothesis and which is in accordance with the finding the certain processing deficits of inverted faces emerge in sequential but not simultaneous matching tasks (Leder, 1999).

The effects of transformation into a line drawing and inversion were more profound in the identification task. In the matching tasks participants might have used strategies that are successful in matching and which might be more efficient than the strategies that apply in everyday face recognition, where a face is matched against “older” memory contents. Thus plausibly the use of an identification task allows a broader generalisation. However, the general finding was not affected by the different tasks, thus matching might be a valuable tool especially when the use of known – thus identifiable – material is excluded and the behaviour under observation needs to be well controlled.

References

Appendix

Mean error rates (SD) in Experiment 1–4 for both ORIENTATIONS (upright versus inverted) and both MODES (photo versus line) in “same” and “different” trials.

<table>
<thead>
<tr>
<th>MODE</th>
<th>ORIENTATION</th>
<th>same</th>
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<th>different</th>
<th>same</th>
<th>inverted</th>
<th>different</th>
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<td>.188 (.13)</td>
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