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When feature information comes first! Early processing of inverted faces

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Abstract. We investigated the early stages of face recognition and the role of featural and holistic face information. We exploited the fact that, on inversion, the alienating disorientation of the eyes and mouth in thatcherised faces is hardly detectable. This effect allows featural and holistic information to be dissociated and was used to test specific face-processing hypotheses. In inverted thatcherised faces, the cardinal features are already correctly oriented, whereas in undistorted faces, the whole Gestalt is coherent but all information is disoriented. Experiment 1 and experiment 3 revealed that, for inverted faces, featural information processing precedes holistic information. Moreover, the processing of contextual information is necessary to process local featural information within a short presentation time (26 ms). Furthermore, for upright faces, holistic information seems to be available faster than for inverted faces (experiment 2). These differences in processing inverted and upright faces presumably cause the differential importance of featural and holistic information for inverted and upright faces.

1 Introduction

In the present study we investigated the early processes of face recognition. We manipulated the utility of featural and holistic features by presenting the eyes and the mouth upright or upside down in upright or inverted faces. 'Thatcherisation' of faces (Thompson 1980) originates from turning the eyes and the mouth region upside down. When thatcherised faces are inverted, the alteration is hardly detectable. As Lewis and Johnston (1997) demonstrated, inverted thatcherised faces require a very long time to be identified as odd faces in a matching task. As a result, featural and holistic information can be dissociated and specific processing hypotheses can be tested. We investigated the early processes underlying face recognition; specifically, whether face recognition is based on a holistic process or whether its nature is microgenetic.

Holistic processing is commonly defined as a mode in which different classes of information are combined in one single step without independent processing of these classes. Holistic processing enables simultaneous processing of facial features (Bradshaw and Wallace 1971), the processing of spatial relations between features (Rhodes 1988; Sergent 1984; Tanaka and Sengco 1997), as well as the recognition of low spatial frequencies (Harmon 1973). Although the holistic processing account as formulated by Tanaka and Farah (1993) proposes global processing of the whole face, this does not fully exclude additional processing of local features. As Sieroff (2001) pointed out, holistic processing does not mean that analytical processes, like the local processing of some features, could not play a role in the recognition process under some circumstances. We will focus on a very simple definition of holistic processing throughout this paper. We define holistic processing as the processing of a holistic coherent Gestalt. Thus, in holistic processing a coherent Gestalt—like an unmanipulated normal face—should be processed fast and accurately.

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Featural processing, on the other hand, refers to the processing of single features. According to the microgenetic account, features are processed as a sequence of events which are assumed to occur between the presentation of a stimulus and the formation of a single, relatively stable cognitive response (Flavell and Draguns 1957). The main idea behind this approach is that different aspects of the stimulus become perceptually available at different moments of time, while the accumulative process of perception development is still going on (Bachmann 1991). Although the perception of faces appears to be taking place at once, according to the microgenetic account, our visual representation of a scene is not achieved in one step but, rather, is built up incrementally. Marr (1982) proposed an important base for microgenesis at the psychobiological level. He demonstrated that perceptual information is carried by intensity changes which can occur at different scales and are best detected by analysing each response channel separately. According to Marr's approach, edges at intensity changes carry enough perceptual information for a first visual report for further analysis. Thus, Marr describes the location of edges in the visual scene as the first step in the decoding process. However, not all visual features will be represented in all channels. For example, small-scale channels are insensitive to gradual changes in illumination from one spatial position to another, while larger-scale channels are insensitive to fine detail, such as narrow lines and fine texture. Thus, the overall perception may be a composite of features which are separately processed at different scales, as well as features that activate channels simultaneously (Biederman and Kalocsai 1997).

Face recognition is a candidate for special processing owing to the high relevance of faces in everyday life and the number of faces which have to be differentiated at the subordinate level (Tanaka 2001). Beside holistic processing, configural processing also seems to be particularly important in face recognition (McKone et al 2001; Rhodes et al 1993; Tanaka and Sengco 1997). Leder and Bruce (2000) have shown the importance of configural processing for the recognition of faces, and how configural processing contributes to face specific effects such as the inversion effect. Moreover, they showed that distinctive configural features are somehow explicitly represented.

However, the importance of higher-order processing, like holistic or configural processing, does not rule out other types of processing. For example, an explicit representation of cardinal distinctive features, such as the nose of Gerard Depardieu or the chin of Kirk Douglas, might be particularly useful. Single features and their microconfiguration are also of great importance in social interaction. For example, the muscles around the eyes reveal the secret of true or false laughing (Ekman et al 1972) and can give us a hint about the emotional involvement and the state of health of a person (Reis and Zaidel 2001).

The eyes and the mouth play prominent roles for face recognition as well. For instance, owing to the high contrast between the white sclera and the black pupils, and their symmetric positioning, eyes are ideal indicators for both the presence of a face and the current alignment of this face. Therefore, eyes can operate as an 'artificial horizon' which facilitates the alignment of the face. This property of the eyes might be particularly advantageous for recognition of the whole face, because a valid alignment method helps to compare the visual pattern with a standardised representation and to quickly locate less dominant features. Similar methods are commonly used by face-recognition machines (Huang et al 1998; Scassellati 1998). Moreover, the advantage of a simple symmetry detector is that it does not require knowledge of the shape of the object. Nevertheless, such a device needs valid anchor points like the eye-to-eye axis or the mouth – eyes triangle. These arguments support the idea of Rakover (1998) and Rakover and Teucher (1997), who suggested that featural information is the most important class of information for face recognition, which probably should be analysed very quickly. Other findings suggest that piecemeal-feature or part-based processing also plays an important role in face recognition (Bartlett et al 2003; Biederman and Bar 1999). Furthermore, Leder et al (2001) demonstrated that even eye-distance, a relational configuration, is processed quite locally and independently of the context. Additionally, Macho and Leder (1998) showed in a forced-choice similarity decision task that facial features are processed in a noninteractive manner. In accordance with all these findings, it would not be surprising if face processing somehow started at the level of individual elements (Parks et al 1985).

When faces are presented upside down, some information seems to be particularly disrupted. Leder and Bruce (1998) for example, have shown that configurally distinctive faces were particularly affected by inversion, but locally distinctive faces were not. Tanaka and Farah (1993) found that holistic processing also is somehow disrupted in upside-down faces. The Thatcher illusion is based on a similar dissociation: when thatcherised faces are shown in upright orientation they appear grotesque, but, when they are turned upside down, this grotesqueness disappears and they look normal (Bartlett and Searcy 1993). One prominent explanation is that the processing of configural information is disrupted in inverted faces. However, Rakover (1999) recently demonstrated that the configurational hypothesis is not adequate in explaining the Thatcher illusion. Rakover (1999) and Rakover and Teucher (1997) demonstrated that the processing of individual features is also disrupted by inversion. Another explanation for the loss of holistic information was given by Rock (1974), who claimed that the mental rotation of disorientated complex figures will overtax the cognitive apparatus. Since mental rotation is a time-consuming process (Jolicoeur 1985; Shepard and Metzler 1971), dissociate rotation of inner facial features and outer facial features seems to be ideal to test specific processing hypotheses.

1.1 *The present study*

In order to separate different kinds of facial information and to investigate their importance at different time stages in the present study, we used thatcherised faces (Thompson 1980) in a speeded identification task with limited presentation times (PTs). In experiment 1 and experiment 3, inverted normal (original) and thatcherised (Thatcher) faces were used. For inverted Thatcher faces, the eyes and the mouth region are correctly oriented with reference to the viewer's position. However, the whole Gestalt of a Thatcher face is not coherent. On the other hand, normal upside-down faces show a coherent Gestalt, but the cardinal local features (eyes and mouth) are inverted with reference to the viewer's position. Thus, by using normal (original) and Thatcher faces, featural and holistic information can be dissociated. If we assume that the early processing of (local) features is beneficial for the identification of the face, then inverted Thatcher faces should be processed faster than their original counterparts, as no mental rotation of the cardinal features—the eyes and the mouth—is required. On the other hand, if holistic processes are indeed beneficial for face recognition, then original faces have to be identified faster than Thatcher faces owing to the holistic overall coherence of the originals.

In order to test how featural and holistic information processing changes over time within the first 200 ms, the stimulus presentation was limited in different levels with a visual mask. If featural information is beneficially processed at a very early processing stage, a Thatcher advantage effect at short PTs is assumed. Alternatively, if the processing of features comes into play later, then there should be an advantage only at a later time. In all the studies presented here, only highly familiar faces were used and processing speed was measured by analysing reaction times. Moreover, sensitivity was measured by calculating A'.

In experiment 2, upright faces were used in a design similar to that in experiment 1 but, owing to the nature of the stimuli, the presentation times were much shorter.

Temporal differences in the processing of upright and inverted faces do not warrant the combination of all conditions in one experiment. Experiment 1 and experiment 2 together reveal different processing times for upright and inverted faces. Experiment 2 provides a direct test of whether holistic information is available earlier in upright faces. In experiment 3, not only whole faces (FULL faces), but also inner parts of faces (IN faces), outer parts (OUT faces), and faces rotated by 45° (R45 faces) were used. By presenting IN faces, we tested whether the processing of facial features needs contextual information or whether both kinds of information can be processed separately. With OUT faces, similar conclusions can be drawn for contextual information and their dependence from inner local features. R45 faces at short presentation times were used to test the mental-rotation hypothesis as an explanation of advantageously processed Thatcher faces.

2 Experiment 1

In experiment 1, the recognition of inverted thatcherised faces at very short presentation times was used to test whether early processing of facial features is beneficial for the whole-face recognition process.

2.1 *Method*

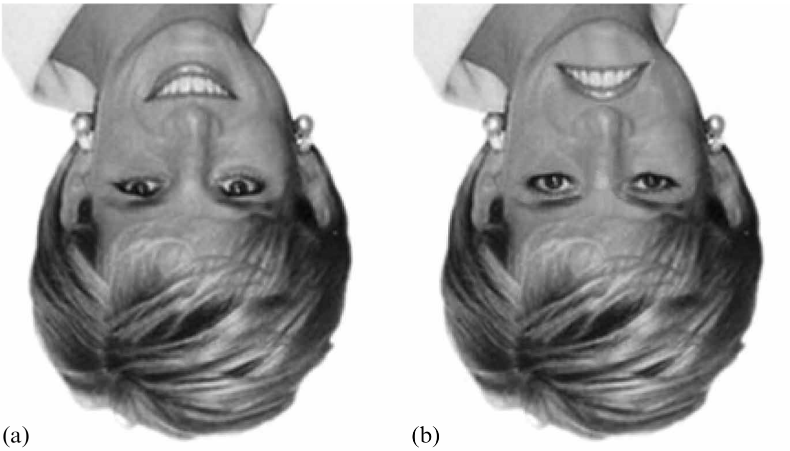
2.1.1 *Subjects.* Thirty students took part in the experiment. All participants were undergraduate students (twenty-three women, seven men) of the Freie Universität Berlin, who were given a credit to fulfil course requirements. The mean age was 24.6 years (with a range from 19 to 45 years). All participants had normal or corrected-to-normal vision abilities. The number of thirty subjects was planned a priori to allow us to test several null hypotheses with an acceptable β-failure of 0.15, which is 3 : 1 compared to a common α of 0.05 [see compromise strategy for power calculation in Erdfelder et al (1996)]. For all computations, a size effect f^2 was fixed to 0.35, which is a large effect according to the convention of Cohen (1988). Given these parameters, the power $(1 - \beta)$ for the main effects and the main interaction (both $\text{df} = 1, 29$) was 0.88.

2.1.2 *Apparatus and stimuli.* The material was constructed from the frontal photographs of nine female celebrities,[(1)] including the face from the top of the hair to the bottom of the chin. The celebrities were highly familiar to the participants. To exclude artifacts of colourisation of the pictures, all pictures were transformed into a uniformly high-colour format (2^{16} colours) with 72 pixels per inch, fitting in a graphic window size of 220×220 pixels.

Two different stimulus versions (class) of the famous faces were used. On the one hand, there was a class of original faces (original), which consisted of unmanipulated pictures of the celebrities. On the other hand, there was a class consisting of thatcherised faces (Thatcher) of the same celebrities. In Thatcher faces, the areas of the eyes and the mouth were turned by 180°. Furthermore, the resulting edges of these areas were smoothed by the image-editing software, Adobe Photoshop 4.0, to remove graphical inconsistencies and high degrees of salience in the pictures (as in Leder et al 2001). An example of a pair of a Thatcher and an original version is given in figure 1.

2.1.3 *Procedure.* The experiment was conducted on an Apple iMac 350 with an integrated 15-inch CRT screen. The resolution of the monitor was 1024×768 pixels with a 75 Hz refresh rate, resulting in an averaged size of face of $6.0 \text{ cm} \times 6.0 \text{ cm}$; subjects sat about 60 cm in front of the screen, resulting in a corresponding visual angle of $5.7 \text{ deg} \times 5.7 \text{ deg}$. The luminance of the screen was 220 cd m^{-2}. The experiment was controlled by the computer program PsyScope PPC 1.25 (Cohen et al 1993), which allows the presentation

[(1)] Julia Roberts (actress), Claudia Schiffer (model), Lady Diana (royal), Marilyn Monroe (actress), Cindy Crawford (supermodel), Verona Feldbusch (national TV star), Cameron Diaz, Gwyneth Paltrow, and Pamela Anderson (actresses).



(a) (b)

Figure 1. Example of an original (a) and a Thatcher face (b) used as stimuli in experiment 1 and experiment 3—here Lady Diana. In experiment 2, upright versions of the same material were used.

of stimuli within one CRT refresh cycle. A CMU ButtonBox registered the subject's responses with a time measurement accuracy of 1 ms.

The experiment consisted of two phases, a familiarisation phase and a test phase. In the familiarisation phase, all original pictures of the celebrities were presented upright on the screen and the subjects were asked to name all faces. Each correctly named face was then faded out, leaving only the unknown faces on the screen. Only highly familiar pictures that were spontaneously named were included in the following statistical analysis.

After this initial familiarisation phase, the test phase began. Each trial started with the question: "Does the following picture show an original facial picture of ⟨forename and surname of one of the nine celebrities⟩?" All names belonged to the set of famous faces.[2]

After this initial question (2000 ms), there was a 400 ms blank screen followed by the target, which was the inverted picture of one of the nine celebrities, either in an unmanipulated (original) or a thatcherised (Thatcher) version. The participants had to answer as fast and accurately as possible whether the answer to the introductory question was "Yes" or "No". The keys belonging to the answers were alternated over the subjects. In 50% of the cases, the name in the question and the following face were compatible, ie they belonged to the same person.

Two presentation times (PTs) were used, 26 ms (short PT) and 200 ms (long PT). These values are consistent with the refresh rate of the CRT monitor used (possible PTs were multiples of $1000/75$ ms $= 13.33$ ms). The face was then followed by a 200 ms random-dotted visual mask. After a response key was pushed, the next trial started automatically. All subjects were tested individually. At the beginning, the participants ran 3 practice trials which were not included in further analyses. Then a total of 72 test-trials followed [$2 \times$ (Compatibility: same/different) $\times 2$ (Class: original/Thatcher) $\times 2$ (PT) $\times 9$ (Celebrities)].

It is important to note that the aim of the requested task was to recognise the original face. The participants were explicitly instructed to answer only with "Yes" when they were sure that it was not only the compatible face but also an unaltered face. The specific kind of question used here enabled us to test whether Thatcher faces were detected as unusual. However, the nature of the Thatcher manipulation (Thompson 1980) predicts that participants in most trials might recognise thatcherised faces as normal. Thus, it was expected that participants would notice any oddness in the thatcherised faces only rarely. The whole procedure, including instructions and a post-experimental

[2] The instructions and questions during the experiment were given in German.

interview, lasted about 25 min. The interviewer asked participants whether they had detected any anomalies in the stimuli.

2.2 *Results and discussion*

The participants reported that they did not notice any oddness for the presented stimuli. For all the following analyses, only familiar faces were included. 93.9% of all faces had been classified as familiar at the familiarisation phase at the beginning of the experiment. The average reaction time was 1042.2 ms (SD = 268.5 ms).

Furthermore, for all analyses, only 'same' pairs were used to which the participants responded with "Yes". Yes – same trials included responses to original faces as well as to Thatcher faces, and were those where original faces had been correctly identified as originals and Thatcher faces had been falsely identified as originals. Correct rejections (responding with "No" to different trials) were not included because such responses are rather problematic within this paradigm. These responses include correct rejections of different trials as well as rejections of Thatcher faces, which were identified as thatcherised. A rejection of a Thatcher face identified as thatcherised seems to be a rather different cognitive task than a rejection of non-same identities. Therefore, it is problematic to compute both measures for one single variable. However, this is not the case with yes – same trials, where Thatcher faces were not identified as being thatcherised but as undistorted ones.

In order to test the ability to detect Thatcher faces within the given narrow time span, the sensitivity measure A' was calculated for both classes and both PTs (see table 1). The A' data were submitted to a two-way repeated-measures ANOVA with Class (original versus Thatcher) and PT (short: 26 ms versus long: 200 ms) as within factors. The factor Class ($F_{1,29} = 4.63$, $p < 0.05$; $\eta_p^2 = 0.138$) as well as the factor PT ($F_{1,29} = 7.68$, $p < 0.01$; $\eta_p^2 = 0.209$) were significant. However, as table 1 reveals, the overall A' for Thatcher faces is also very high (0.919); thus it can be concluded that the participants hardly noticed anything odd in the Thatcher conditions. Moreover, none of the subjects reported to have seen any odd qualities in the Thatcher faces when queried in a post-experimental interview. In line with this finding, Lewis and Johnston (1997) demonstrated that inverted Thatcher faces require a very long time to be identified as Thatcher faces in a matching task.

Table 1. A' scores of experiment 1 for both face classes (original versus Thatcher) and both PTs (long versus short).

PT	A'		Yes – same rate	
	original	Thatcher	original	Thatcher
Experiment 1: Inverted faces				
Short (26 ms)	0.925	0.904	0.822	0.739
Long (200 ms)	0.960	0.934	0.905	0.769
Experiment 2: Upright faces				
Short (26 ms)	0.970	0.866	0.927	0.528
Long (39 ms)	0.964	0.857	0.935	0.503

The main aim of experiment 1 was to investigate the early time course of recognising faces. In order to test the specific processing models, the RT of yes – same trials had to be analysed. Table 2 (section 'experiment 1') shows the RTs for yes – same targets and the Thatcher advantage effect (TAE). The TAE is the difference between the RTs for identifying original faces and Thatcher faces. Thus, as positive values, it shows an RT advantage of identifying Thatcher faces compared with original ones. In order to exclude RT outliers from the analyses, the RTs were limited in the following way. First, the RTs were limited to a static criterion of being longer than 300 ms and shorter

Table 2. RTs of experiment 1 (inverted faces), experiment 2 (upright faces), and experiment 3 (FULL faces, R45 faces) for both face classes (original versus Thatcher) and both PTs (long versus short). The RTs were limited to the RT range of ±4 SDs around the individual subject's RT average.

PT	RT (yes – same trials)/ms		SD/ms		Thatcher advantage effect (TAE)
	original	Thatcher	original	Thatcher	
Experiment 1: Inverted faces					
Short (26 ms)	1097.4	1051.6	231.4	203.2	45.7
Long (200 ms)	967.5	1052.5	287.2	332.6	−85.0
Experiment 2: Upright faces					
Short (26 ms)	1045.8	1265.1	243.3	265.0	−219.3
Long (39 ms)	1003.4	1189.6	279.6	485.9	−186.2
Experiment 3: FULL faces					
Short (26 ms)	1022.4	955.3	250.6	237.6	67.1
Long (200 ms)	949.6	967.8	215.8	242.9	−18.1
Experiment 3: R45 faces					
Short (26 ms)	902.6	868.6	310.6	194.5	34.0
Long (200 ms)	803.5	817.7	186.6	233.6	−14.2

than 3000 ms. Second, the RTs were limited to a dynamic criterion of being within the RT borders of ±4 SDs around the individual average of RTs (see Snodgrass et al 1985).

The time course of early face processing was tested by a repeated measures ANOVA with Class (original versus Thatcher) and PT (short: 26 ms versus long: 200 ms) as within factors. The dependent variable was the RT for yes – same trials.

There was no main effect of Class ($F_{1,28} < 1$; ns)(3) and PT ($F_{1,28} = 2.66$; ns). This means that there was no general difference between original and Thatcher faces or between short and long PTs. Nevertheless, an interaction between Class and PT ($F_{1,28} = 8.83$, $p < 0.01$; $\eta_p^2 = 0.240$) revealed that the factor Class had differential influence at different PTs.

As illustrated in figure 2, the RT advantage for identifying Thatcher faces under the short PT condition was reversed for the long PT condition.

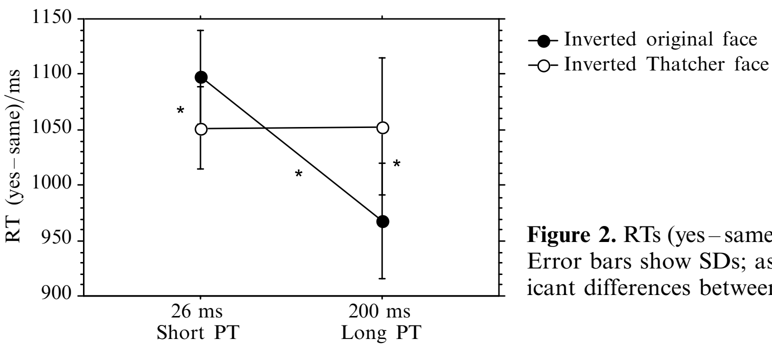


Figure 2. RTs (yes – same trials) of experiment 1. Error bars show SDs; asterisks indicate significant differences between conditions.

Moreover, the RT advantage for Thatcher faces under PT = 26 ms was found to be significant by a one-tailed t-test ($t_{29} = 1.87$, $p < 0.05$). As shown in table 2, this TAE was substantially large (45.7 ms). However, this RT advantage for the short PT changed into a disadvantage for Thatcher faces as compared to original faces when the stimuli were shown for a longer period of 200 ms (−85.0 ms). The negative TAE was also found to be significant ($t_{28} = 2.08$, $p < 0.05$).

(3) Due to some missing data of "Yes" answers to same pairs, not all RT data cells were occupied, so this analysis underwent a reduction of dfs from 29 to 28.

To ensure that this RT effect was not an artifact of using a specific RT-outlier criterion (cf Judd and McClelland 1989; Snodgrass et al 1985), cross checks with two alternative RT measures were run. With the same design as above, an ANOVA with the median as average measure revealed the same results with the only significant effect of the interaction of Class $\times$ PT ($F_{1,28} = 5.33$, $p < 0.05$; $\eta_p^2 = 0.189$) as well as an ANOVA with no RT-outlier criterion ($F_{1,28} = 6.96$, $p < 0.02$; $\eta_p^2 = 0.199$). Again, the RT results show that the lack of a main effect of Class covers up the underlying change of important face identification strategies when split up in different PTs.

The only difference between Thatcher faces and original faces is the area around the eyes and the mouth. Therefore, the reason for the change from a positive TAE value to negative must be the specific alteration in the face. The experimental strength of the Thatcher task is that variations of the stimuli are attained exclusively through the rotation, by 180°, of the cardinal facial features of the eyes and the mouth. Nothing else is changed. Moreover, even the recognition performance is nearly the same in all conditions. What might be the reason for Thatcher faces being recognised faster at shorter PTs than the originals?

The perceptual result of the Thatcher manipulation is a somewhat paradoxical configuration. For an inverted Thatcher face, the rotated features (eyes and mouth) are in an upright orientation. However, our face expertise is mainly limited to upright features and faces (Schwaninger et al 2003). Through years of practice, the face-recognition system becomes more specialised, but at the same time more constrained to processing the upright orientation, probably because of the large amount of faces seen in upright orientation. Specifically for Thatcher faces, this correct orientation comes with a resulting incoherence of the upright local features with the rest of inverted areas of the face. Owing to a significant difference for Class under the short PT, this specific rotation must be advantageous for the identification of (inverted) faces. Human face identification is optimally suited for upright faces, but for inverted Thatcher faces only the manipulated local features are recognised optimally. A TAE for briefly presented faces indicates that, within a short PT, identification of local features is advantageous for the recognition of the face. These results support the idea of early processing of local features. The disadvantage of an incoherent facial outlook does not seem to be an impediment, which indicates that for a very short PT, holistic processing is less important than featural processing. Rather, the just-in-position local features need no further rotation process—and this saves time! For the longer PT, this relation is reversed. The processing of original faces is faster than the processing of Thatcher faces. Thus, if there is enough time to process holistic information of a coherent Gestalt, then this kind of information is more efficient than featural information.

This logic is based on the findings on mental rotation. It has often been demonstrated that RTs linearly increase with increasing rotation of objects from their familiar viewpoint (Cooper 1976; Cooper and Shepard 1973; Jolicoeur 1985; Shepard and Metzler 1971; Tarr and Bülthoff 1995). Interestingly, Tarr et al (1998), who studied the recognition of single geons from Biederman and Gerhardstein's (1993) experiment 4 with line drawings, found that rotation rates for such stimuli ranged from approximately $750^\circ\ s^{-1}$ for a naming task to $3600^\circ\ s^{-1}$ for a match-to-sample task with a go/no-go response. This corresponds to a total time of 50–240 ms for a full 180° rotation, which is approximately within the range of the TAE demonstrated above (cf table 2). This projection, of course, must not be taken literally. From a view-based perspective, a rotation of 180° would be expected to produce enormous rotation costs relative to slight rotation angles. Biederman et al (1999) found the opposite: mirror reflections incur no cost in priming (cf Biederman and Cooper 1991), or less effort than angles of about 90° for some other tasks (Valentine and Bruce 1988, figure 5).

Nevertheless, the advantage of early local featural processing does not rule out the possibility that at the same time contextual featural processes may already be in progress, for instance the processing of the outline given by the hair and the chin. Indications for the involvement of such processing were found in the post-experimental interviews with many participants, who reported that they sometimes had only seen outlines or contours of some faces. These results are in accordance with Phillips (1979), who found that inversion affects recognition of the internal features of the face (eyes, nose, mouth) more than recognition of the external features (hair, chin). Using a matching task, Young et al (1985, experiment 2) found that external-feature matches were much faster than internal-feature matches. Moreover, it was proposed that 'global configurations' are crucial in activating stored object representations (Boucart et al 1995).

Experiment 1 cannot rule out a contextual feature precedence, because only a further reduction of PT could have the power to reveal the nature of this supposed outline identification process. Another possibility would be to test the RT data for faces exclusively with contextual information in comparison to both normal faces and faces without any context information. This is done in experiment 3. Therefore, for experiment 1, it remains unsolved whether contextual featural and local featural processes occur simultaneously, or whether one of the processes precedes the other. Nevertheless, it was shown that local feature identification processing is important at a very short PT of only 26 ms. Furthermore, the benefit of early local feature analysis seems to be greater than the cost of incoherence between the local parts and the disoriented whole, presumably because the different processing levels (local and contextual) are not yet bound together. This is an indication that holistic processing, in which it is not details that are parsed but the whole (coherent) Gestalt, is not available within such restricted time resources.

However, the RT results for the original faces indicate that the coherent Gestalt of a face was beneficial for recognition when more time resources were available. An expansion of PT from 26 ms to 200 ms reduced the RT of identifying original faces apparently by 129.8 ms (one-tailed t-test with $t_{29} = 3.43$, $p < 0.001$). Nevertheless, Thatcher faces seem to be processed in a comparable way in the short PT and the long PT condition, which is indicated by nearly identical RTs at both PTs (difference: 0.9 ms; $t_{28} < 1$; ns). Thus, given more time resources the early identification of local features still seems to be important, but holistic processes seem to be even more influential. Such holistic processes are most probably template-like matching routines that compare the face with stored face representations that are organised holistically rather than featurally.

For the Thatcher faces used in this experiment, it is, of course, not clear whether the mouth and/or the eyes are responsible for the TAE, because both areas were always changed concurrently. From the arguments presented above, the eyes region seems to be the more prominent candidate, but also the upright mouth, with its high physical distinctiveness and its high amount of meaningful social information (Parks et al 1985), seems plausible. However, the goal of experiment 1 was not to analyse this in particular, but to demonstrate the existence of early local processing in general.

Our object in experiment 2 was to investigate whether the early time course of face processing is different when faces are presented upright and, therefore, to compare the effects of upright and inverted faces.

3 Experiment 2

The aim of experiment 2 was to provide a direct comparison of the early processing of inverted and upright faces. We investigated whether upright Thatcher faces are also identified as odd faces, even in a very early stage of processing, or whether this identification performance is only mediated through later processes. This allows a better understanding of whether binding of internal (local featural) and external (contextual featural) structures is possible within the first milliseconds of face processing.

In view of our expertise with upright faces, we predicted that upright Thatcher faces will be easily recognised as distorted (Schwaninger et al 2003). This is tested by two analyses. On the one hand, the discrimination performance (A') of Thatcher faces and original faces is investigated. According to Thompson (1980), upright Thatcher faces should be detected very accurately as being odd, even after a very brief presentation. Moreover, upright Thatcher faces are more difficult to identify, owing to their grotesqueness and the incoherence of the local features and the contextual information. This should result in longer RTs compared with original faces.

3.1 *Method*

3.1.1 *Subjects.* Thirty undergraduate students (twenty female, ten male) of the Freie Universität Berlin participated. They were given a credit to fulfil course requirements. Their mean age was 26.1 years (ranging from 19 to 39 years). None of the subjects had taken part in experiment 1.

3.1.2 *Apparatus and stimuli.* The same stimuli as in experiment 1 were used, but were presented in an upright orientation.

3.1.3 *Procedure.* Pre-studies revealed that even under short PTs, subjects were able to notice the inconsistencies of upright Thatcher faces. Therefore, the long PT condition of experiment 1 was reduced from 200 ms to 39 ms in order to prevent floor effects of the yes – same rate of thatcherised faces. The other procedural parameters were the same as in experiment 1.

3.2 *Results and discussion*

As in experiment 1, only familiar faces were included in the subsequent analyses. 91.8% of all faces were recognised as being familiar. The average reaction time was 1124.3 ms (SD = 344.5 ms). The RT data of yes – same pairs were investigated in the following tests (see table 2) with the same outlier criterion as in experiment 1. RT data were submitted to a repeated-measures ANOVA with two within factors: Class (original versus Thatcher) and PT (short: 26 ms versus long: 39 ms). The significant main effect of Class ($F_{1,27} = 14.07$, $p < 0.005$; $\eta_p^2 = 0.343$) revealed a substantial difference between RTs of Thatcher and original faces of 202.7 ms (1227.4 ms versus 1024.6 ms, respectively).

The data sampled in the yes – same measure include cases in which original faces were correctly identified as being of a famous person plus cases in which Thatcher faces were misinterpreted as being normal originals. Consequently, the values cannot simply be classified as being 'correct' because of the specific interrogative form. It is important to note that RT data for thatcherised yes – same trials were the RTs of undetected Thatcher faces. It seems that the participants were not just processing the context of the faces which were the same in both versions. This can be ruled out because in this case the identification speed would have been the same as the identification speed for original faces. Rather, there was an averaged difference of 202.7 ms between Thatcher faces and original faces. Thus, even for the misclassified Thatcher faces that were found not to be original faces, the coherence of the whole facial Gestalt had been processed. Indication for such holistic processing was not found in the RT data of the short PT condition of experiment 1, where inverted faces were used. It seems that the recognition of briefly presented inverted faces is primarily based on local featural processing. Moreover, a parallel ongoing identification of the outline of the face had been assumed for experiment 1. For the short PT condition there was no sign of an integration of these two different processes. For upright faces, this seems to be quite different. Here, the inverted eyes and mouth region interfered with the processing of the whole.

Thus, it has to be assumed that higher-order and more-integrative early processing is involved in the face recognition of briefly presented upright faces. In contrast, inverted faces are processed first and foremost locally. Similar results have been found in several studies of orientation sensitive face-recognition effects (Leder et al 2001; Mondloch et al 2002; Robbins and McKone 2003). In experiment 3, the role of contextual feature processing in relation to local-feature and holistic processing was further analysed.

4 Experiment 3

Experiment 3 was concerned with three general questions. First, we aimed to replicate the findings of experiment 1 with an alternative interrogative sentence at the beginning of each trial, using the same material as in experiment 1 (condition: FULL). Second, to further analyse the influence and importance of the processing of contextual structures, two additional stimulus conditions (IN and OUT) were realised. Third, the mental-rotation hypothesis, propagated as the cause of the TAE, was directly addressed by an additional stimulus condition called R45, in which stimuli were presented in a 45° orientation.

In the IN condition, the outline of the face was cut from the face, only the inner parts of the faces were presented. This condition will reveal whether the processing of local features can also be advantageous for face recognition without the processing of contextual structures. In this case, the TAE should even be increased, because the omission of outlines emphasises the distinctiveness and processing of the inner parts of the face (Bruce et al 1994; Leder and Bruce 1998). Alternatively, if the separate processing of local features is not possible without the recognition of contextual structures, any TAE effect should vanish and the identification rate of IN faces should decrease.

In the OUT condition, only outlines of faces were presented. Contextual structures, like the hair region, are coarse and possess a relatively low informational content. Therefore, they sometimes have been predicted to be processed faster than more detailed structures which contain more information (Hughes et al 1984; Paquet and Merikle 1984). However, it has to be analysed whether the processing of exclusive contextual information is also sufficient to recognise a face within the given time constraints.

Moreover, in experiment 3 we tested whether mental rotation was a valid explanation for the TAE in experiment 1. In the discussion of experiment 1, we assumed that the RT advantage for the thatcherised faces might be caused by beneficial early local-feature analyses. If the TAE is based on the additional mental rotation of the cardinal local features of original faces compared to those of Thatcher faces, then the RT advantage of Thatcher faces should be decreased by rotating the stimulus material by 45°. In this case, according to the mental-rotation hypothesis (Shepard and Metzler 1971), not only the local features of original faces but also those of Thatcher faces have to be rotated mentally. Therefore, we expect an overall decrease of TAE.

4.1 *Method*

4.1.1 *Subjects.* Participants were thirty undergraduate students (twenty-five female, five male) of the Freie Universität Berlin, who were given credit to fulfil course requirements. Mean age was 25.9 years (ranging from 19 to 42 years). None of the subjects had taken part in experiment 1 or experiment 2.

4.1.2 *Apparatus and stimuli.* The material was based on the stimuli of experiment 1, in which original faces as well Thatcher faces were used in an inverted orientation. There were four different conditions used in experiment 3. Figure 3 and the following description give an overview of this material.

FULL IN OUT R45

Figure 3. Stimulus material used in experiment 3 (only shown for original faces, not for Thatcher faces). From left to right: the unmanipulated face from test block 1 (condition FULL), the inner-face version (IN) from test block 2, the outer-part version (OUT) from test block 3, and the 45°-rotated version (R45) from test block 4.

The four different face conditions were tested in four different succeeding test phases. The basic material came from experiment 1 and was used in the first block as the FULL condition. For the IN condition, only the inner parts of the faces were present. This was achieved with a standardised oval, which overlays the FULL faces. The advantage of using standardised ovals against the commonly used method of sharply cutting the hair is that there is then no information available about the form and Gestalt of the contours and the hairstyle (cf Liu and Chaudhuri 1998). In the OUT condition, just the opposite of the IN manipulation was realised. Here, only the parts excluded by the IN condition were apparent. Additionally, in the R45 condition the basic faces of the FULL versions were presented in a 45°-rotated fashion. Every block consisted of 3 practice trials and of 72 test-trials as in experiment 1 and experiment 2 [$2 \times$ (Compatibility: same/different) $\times 2$ (Class) $\times 2$ (PT) $\times 9$ (Celebrities)].

4.1.3 *Procedure.* The time course of each trial was the same as in experiment 1. The experiment consisted of four different blocks (referred to henceforth as tasks) separated by short breaks, during which specific instructions about the nature of the stimuli were given. The first block (block 1: FULL) dealt with full faces, the same as in experiment 1. Then followed a block with IN faces (block 2: IN), after that came a block with OUT faces (block 3: OUT), and last a block with R45 faces was presented (block 4: R45). Only the OUT condition deviated from the common logic of the other blocks. Because of the omission of the inner features in OUT faces, the stimuli could not differbetween Thatcher and original faces. Thus, OUT faces did not belong to a special face Class. Each block contained the same number of trials: three preceding practice trials were followed by 72 test trials. The whole experiment consisted of $4 \times 72 = 288$ total test trials and lasted about 45 min. Afterwards, the participants were interviewed about their perceptual experiences during the experiment.

In experiment 1 and experiment 2 participants were instructed to react to original faces and Thatcher faces in a different way, although the faces belong to the same person. This might have led the participant to use an artificial response strategy. Rather than recognising faces, participants might have focused on facial manipulations. In order to test whether the TAE is also found with a more common instruction, an alternative interrogative form was used in experiment 3. Subjects were asked whether the name and the succeeding face were compatible (ie the same), while any detected oddity had to be ignored. This instruction did not allow the determination whether the participants recognised any odd qualities in the faces. But, as this had already been checked in experiment 1, the new interrogative form had the advantage of being much more intuitive, because the percentage correct could be easily calculated. Thus, the results are more comparable with most empirical work that uses similar interrogative forms.

4.2 *Results and discussion*

Again, only familiar faces (93.7% of all faces) were included in the subsequent analyses. To test whether the participants fulfilled the different tasks in an adequate way, the yes–same rates were analysed (see table 3). After a PT of only 26 ms, the participants performed the FULL and the R45 tasks with correct identification rates of above 0.8. This high performance was not found for the OUT task, and totally broke down for the IN face task.

Table 3. Yes–same rates of experiment 3 for each face-stimulus task. The distinction between Thatcher and original versions was only available for FULL, IN, and R45 faces owing to the omission of the inner facial region in the OUT version.

PT	FULL		IN		R45		OUT
	original	Thatcher	original	Thatcher	original	Thatcher	
Short (26 ms)	0.805	0.772	0.587	0.528	0.862	0.846	0.727
Long (200 ms)	0.947	0.906	0.869	0.746	0.978	0.924	0.933

The weak performance of identifying IN faces at a very brief PT was found to be not significantly different from the base rate of 0.5 ($t_{29} = 1.89$; ns). Therefore, the RT data of the IN face condition could not be evaluated in the following analyses. Nevertheless, this is strong evidence against pure local feature processing at an early stage. The participants somehow seemed to need a reference to contextual facial structures to successfully use local feature information within such brief presentation times. However, contextual information on its own at this time stage also seemed insufficient to identify faces accurately. This can be seen in the yes–same rate for OUT faces, which was only medium high (72.7%). Nevertheless, the recognition of OUT faces was very fast (at short PT: 961.3 ms; at long PT: 863.3 ms). In sum, the data for OUT faces indicate that although contextual structures are successfully recognisable, even at such an early time stage, the processing of pure contextual information is not very reliable.

To test specific processing hypotheses, the RT data of the single tasks were further analysed (see table 2). However, these excluded the IN face condition owing to its weak identification rates at the chance level. As in all preceding experiments, the RT data were limited as already described for experiment 1.

One of the additional goals of experiment 3 was to test whether the TAE, demonstrated in experiment 1, also occurred with a different instruction. A repeated-measures two-way ANOVA was conducted with the within-subjects factors Class (original versus Thatcher) and PT (short: 26 ms versus long: 200 ms), and with RT data of FULL faces as dependent variables. The only significant effect was the interaction between Class and PT ($F_{1,29} = 6.35$, $p < 0.02$; $\eta_p^2 = 0.180$), which showed the same pattern as in experiment 1 (see figure 4).

A deeper analysis of the TAE indeed revealed a significant difference of 67.1 ms between original condition and Thatcher condition under the short PT for FULL faces (one-tailed $t_{29} = 2.54$, $p < 0.01$).

In experiments 1 and 2, with the specific interrogative form used, only yes–same trials were analysed. With the question used in experiment 3, it was plausible to analyse RTs for correct trials. A two-way repeated-measures ANOVA with Class and PT as within-subjects factors revealed a pattern of results similar to the ANOVA with RTs of yes–same trials. Again, the only significant effect was the interaction between Class and PT ($F_{1,29} = 6.32$, $p < 0.02$; $\eta_p^2 = 0.179$). Beside this interaction, the TAE was again significant ($t_{29} = 1.96$, $p < 0.05$), with a value of 39.0 ms. Thus, with an alternative instruction, experiment 3 replicated a TAE.

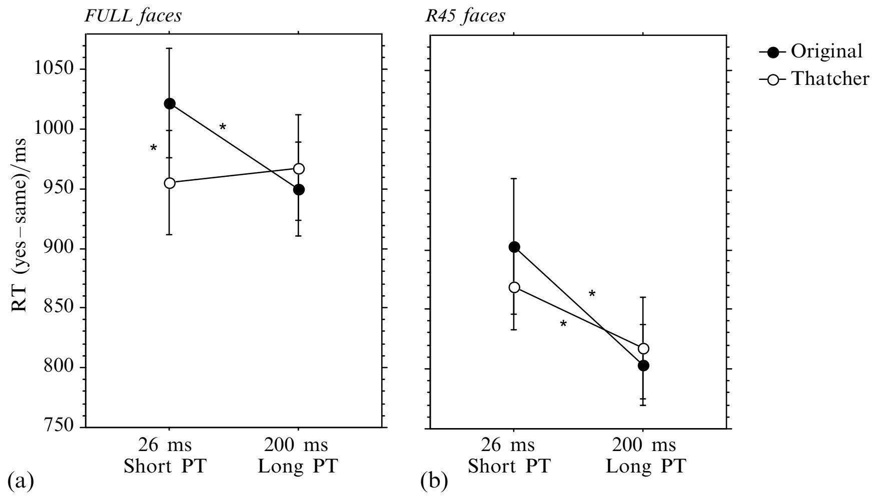


Figure 4. RTs (yes – same trials) of experiment 3 for (a) FULL faces and (b) R45 faces. Error bars show SEs; asterisks indicate significant differences between conditions.

The RT data for R45 faces were analysed in order to test the mental-rotation hypothesis as an explanation for the TAE. For inverted Thatcher faces, the local features—eyes and mouth— do not have to be rotated mentally because they are already in an upright orientation. Therefore, a reduction in TAE was predicted when faces deviated by 45° from full inversion in condition R45. To probe this hypothesis, the TAE for short PTs was calculated for FULL as well as for R45 faces by subtracting the RT data of thatcherised faces from those for original faces. The TAE was indeed reduced and turned out to be numerically negative. This is in accordance with the mental-rotation hypothesis. Although this decrease of TAE does not constitute direct evidence for the early local-feature-analysis hypothesis, it indicates, in combination with the RT data discussed above, that local features are processed advantageously, yet at a very early processing stage.

However, the fast identification of local features during brief presentation seems to need contextual facial structures, probably as a perceptual anchor. In the experimental situation with a simple yes/no task as used here, it was even possible that participants sometimes recognised faces relatively accurately and quickly solely on the basis of the recognition of the outer parts. This is revealed by the data for OUT faces.

We interpret these findings in the following way. On the one hand, contextual structures seem to be important and effective for simple face-recognition tasks. On the other hand, local feature analysis is also available very early on in face processing. Using inverted faces for which feature processing was thought to be particularly important (Leder and Bruce 2000; Rakover 2002), we found that feature processing provides a processing advantage in terms of RTs. This was found to be especially true when time resources were very limited. However, identification of local features presumably requires the presence of contextual cues.

5 General discussion

Three experiments with thatcherised faces (in inverted and upright orientation) revealed that the processing of local facial features can precede the processing of holistic face structures. As perceivers did not notice that the local features in inverted versions were in the usual upright position, it was shown how the use of thatcherised faces can dissociate featural and holistic processing.

Experiment 1 revealed that inverted thatcherised faces (Thatcher faces) presented for only 26 ms were recognised faster than inverted normal faces (original faces). This TAE is due to beneficial early processing of local features. Experiment 1 also demonstrated that holistic face processes seem to be dominant when more time resources are available (realised by a presentation time of 200 ms).

In experiment 2, thatcherisation in upright orientation was detected after a presentation of only 26 ms. Early holistic face processing was assumed to be the cause of this high performance.

In experiment 3, the results of early local feature processing found in experiment 1 were further investigated. In the FULL condition, the findings of experiment 1 were replicated with an alternative interrogative form but with identical procedure and material to experiment 1. Again, a significant TAE was found. Moreover, by presenting gross outer features (hair, chin, etc) only (OUT condition), a strong influence of contextual information for the early processing of faces was revealed. The recognition of these features was found to be very fast and still accurate.[(4)] Thus, for simple recognition tasks the contextual features seem to be sufficient to recognise famous faces.

Pure contextual structures were sufficient for simple face recognition. However, additional local feature analyses were needed for further recognition processing. This was the case in the FULL condition. Therefore, the assumption of a general contextual precedence was not supported, but was refined by a non-holistic processing mode in which contextual and local features presumably were processed separately. Thus, the results support an interaction between task and type of stimuli in respect of precedence of type of processing. These data are also compatible with the concept of Rakover's (2002) "task-information approach". However, as we only varied the length of presentation time here, we favour an explanation on the grounds of microgenetic processing with differential meaning of facial information over time.

Furthermore, the results of the 45° rotation conditions provided evidence that mental rotation is a valid explanation for the TAE.

The finding that local feature analyses were beneficial under very restricted presentation times are in accordance with the findings of Cooper and Biederman (1993). In a yes – same decision task they found that feature changing had a greater salience over metric, ie configural, properties (see also Biederman et al 1999). Moreover, in our study there was not only evidence of a general precedence of featural-to-holistic or holistic-to-featural information, but also a time-dependent importance of both classes of information. While featural information was effective at an early stage, this advantage decreased at a later processing stage. Furthermore, featural information without surrounding contextual features was not sufficient, as indicated by recognition rates at chance level in the IN conditions of experiment 3.

In the present study, we showed a processing advantage for inverted Thatcher faces. Inversion is thought to reduce configural processing (Bartlett and Searcy 1993; Leder and Bruce 2000). Therefore, it might be argued that local feature analyses would be advantageous a priori in the processing of inverted faces, because recognition had to be based on the quality of the remaining information. This might be the case to some degree. However, we were not interested whether local feature analyses are available in early face processing for the further face recognition, but whether their processing can be beneficial. This was confirmed in experiment 1 and experiment 3, where Thatcher faces were recognised faster than original faces. When IN and OUT conditions were compared, local feature analysis was indeed an important component of early face processing, but not when local information was presented without contextual structures.

[(4)] We think that contextual information (hair and chin area) as used here also belong to the class of facial features (cf Rakover 2002).

However, this need for global or contextual information does not imply that the ongoing processing is holistic in the sense that several kinds of information are integrated into a coherent representation. Because Thatcher faces were recognised faster than original faces at short PTs, a holistic or template-like processing mode seems not to be available at such an early time stage. When the PT was extended to 200 ms, the local-feature advantage vanished. For experiment 1 and experiment 3, it was argued that under these circumstances holistic processing would emerge. Although local feature analyses might still be present, a holistic recognition mode of original faces is even more advantageous. This concept of holistic processing differs from the original formulation by Tanaka and Farah (1993). In the original view, holistic processing meant that parts are not represented explicitly. The present studies indicate that in a first stage, contextual and local feature information are processed separately and later are combined into a holistic representation.

The supposition that the integration of several information qualities is established rather late is not new. In Marr's theory of vision (Marr 1982) or the cascade processing model of Humphreys et al (1988) similar ideas are proposed. Interestingly, Humphreys and Riddoch (1987) have also demonstrated that clinical cases of visual object agnosia were unable to combine visual information to complete objects. For these cases, the essential step for binding several information qualities was apparently not achievable at all. Furthermore, Brooks et al (1997) have assumed that local as well as holistic types of processing are each specialised for different face-recognition strategies. According to Brooks et al, holistic processing is well suited for face-matching tasks, whereas local processing might be optimal for recognising face details.

The present results revealed different face-processing strategies and their differential temporal importance depending on the orientation of the faces. Exploiting a specific property of inverted Thatcher faces to investigate early processes in face recognition, we have shown how the temporal analysis of the microgenesis of a cognitive process allows us to identify the different components that are involved. The differential benefit of recognition processes from featural and holistic information for different time stages in the recognition of faces might be the basis of the finding that holistic information is impeded by inversion. Although we showed that holistic information is also beneficially processed for inverted faces, the high importance of local features at an early time stage seems to be dominant for the further recognition process.

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