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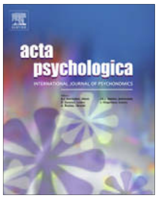

Does matching of internal and external facial features depend on orientation and viewpoint?

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ABSTRACT

Although it is recognized that external (hair, head and face outline, ears) and internal (eyes, eyebrows, nose, mouth) features contribute differently to face recognition it is unclear whether both feature classes predominately stimulate different sensory pathways. We employed a sequential speed-matching task to study face perception with internal and external features in the context of intact faces, and at two levels of contextual congruency. Both internal and external features were matched faster and more accurately in the context of totally congruent/incongruent facial stimuli compared to just featurally congruent/incongruent faces. Matching of totally congruent/incongruent faces was not affected by the matching criteria, but was strongly modulated by orientation and viewpoint. On the contrary, matching of just featurally congruent/incongruent faces was found to depend on the feature class to be attended, with strong effects of orientation and viewpoint only for matching of internal features, but not of external features. The data support the notion that different processing mechanisms are involved for both feature types, with internal features being handled by configuration sensitive mechanisms whereas featural processing modes dominate when external features are the focus.

1. Introduction

Faces are extraordinary rich sources of information, revealing a person's age, sex, personal identity, or emotional state at first glace. This is even more intriguing if one considers the many possible appearances of individual faces, and the multiple ways facial information is encoded and represented in the brain.

A useful distinction of facial information is *featural* and *configural* (Cabeza & Kato, 2000; Rhodes, 1988). Featural information comprises the attributes of isolated facial features, as given by the specific appearance of eyes, nose, mouth, ears, cheeks, skin, face outline, or hairs. Configural information, instead, concerns the relations among facial features, and, particularly, their spatial organization. Facial features have a common global arrangement, however, when judged on a finer scale, their particular spatial organization proves to be unique for each individual face (e.g., Bartlett & Searcy, 1993; Diamond & Carey, 1986; Rhodes, Brake, & Atkinson, 1993; Searcy & Bartlett, 1996; for a review, see Rakover, 2002). Both featural and configural information play a special role in face processing, however, with different relative importance depending on the viewing conditions and the visual task.

Early in the history of face perception research it was found that inverted faces are more difficult to recognize than upright faces (e.g., Goldstein, 1965; Hochberg & Galper, 1967), and that the effect of inversion is much stronger for faces than for other objects which are also usually seen upright (Yin, 1969). Subsequent studies substantiated that the face inversion effect (FIE) rests on a disruption of configural information, letting the observer rely on just featural information when viewing faces which are turned upside down (Kemp, McManus, & Pigott, 1990; Leder & Bruce, 1998, 2000; Rossion, 2008; Rossion & Boremanse, 2008; Schwaninger & Mast, 2005; Searcy & Bartlett, 1996; Young, Hellawell, & Hay, 1987). There are two basic findings which suggest that configural information enters into the processing of upright, but hardly of inverted faces. The first one is the composite effect found with chimeric faces, showing that it is difficult to identify a person when the two face halves which originate from different persons are aligned. Generally, identification of one of the two face halves is much easier when both are not aligned, or separated by a gap. In upright orientation the two halves tend to fuse, and it is difficult to say whether the one or the other half stems from another intact face seen before. However, turning chimeric faces upside down makes the task much easier. This indicates that configural fusion is strongly attenuated by face inversion, facilitating independent access to the two different halves (Carey & Diamond, 1994; Hole, 1994; Young et al., 1987). The second phenomenon bearing to

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the same point is the "Thatcher illusion". "Thatcherisation" of faces is achieved by inverting just the eyes and the mouth of a face (Thompson, 1980). A thatcherised face appears grotesque when viewed in the normal upright orientation. However, image inversion precludes to see these distortions immediately, and they become noticeable only after detailed scrutiny (Bartlett & Searcy, 1993; Carbon & Leder, 2005). The Thatcher illusion therefore indicates that there is a reduced sensitivity for configural information when viewing inverted faces, suggesting that feature-driven processing modes are predominant.

While it is generally accepted that configural information is strongly affected by inversion there is no consensus regarding the inversion effect for isolated facial features. Previous studies show a conflicting pattern of results, with alternating support of orientation-independency and orientation-dependency (Barton, Keenan, & Bass, 2001; Nachson & Shechory, 2002; Rakover & Teucher, 1997; Rhodes et al., 1993; Schwaninger, Carbon, & Leder, 2003; Valentine, 1988; Veres-Injac & Schwaninger, 2009). Although an inversion effect is reported in some of these studies, there are remarkable differences in its strength mediated by the type of facial features. While internal features, particularly eyes or mouth, were found to be orientation-sensitive, external features, such as face shape or hairs, were found to be only marginally affected by inversion (Barton et al., 2001; Malcolm, Leung, & Barton, 2005; Moscovitch, Winocur, & Behrmann, 1997; Rakover & Teucher, 1997; Rhodes et al., 1993). Apparently, the two feature classes have different relative importance for judging upright faces. Some studies show that internal features (eyes, eyebrows, nose, mouth) are particularly salient, being fixated first and attracting most of the gaze time in scan-path measurements, while external features (face and head outline, hair, ears) are seemingly not the focus of active viewing (Henderson, Falk, Minut, Dyer, & Mahadevan, 2001; Williams & Henderson, 2007). However, the same facial features were fixated in upright and inverted orientation, indicating that the face inversion effect is not a result of a different pattern of eye movements during face image inspection (Williams & Henderson, 2007). Fewer empirical data exist with respect to the effects of viewpoint. It is generally accepted that it is more difficult to judge a person's identity from two face pictures when one of the two shows another view, suggesting viewpoint-dependency of face processing (Bruce, Valentine, & Baddeley, 1987; Hill & Bruce, 1996; Liu & Chaudhuri, 2002; McKone, 2008; Newell, Chiroro, & Valentine, 1999). As a rule, performance decreases with increasing angular difference among two arbitrary views (Lee, Matsumiya, & Wilson, 2006; Liu & Chaudhuri, 2002).

In line with these observations the face adaptation effect is substantially reduced when adaptation and test faces are shown in different views (Jeffery, Rhodes, & Busey, 2006). The face adaptation effect (Webster & MacLin, 1999) is a robust perceptual phenomenon showing that face perception is strongly biased by viewing an altered or distorted image of a test face for some time. On the continuum that was manipulated the original face (i.e., the test face) appears distorted in opposite direction to the distortion applied to the adaptation face.[1] Jeffery et al. (2006) induced figural shape aftereffects at one view (3/4 left) and then tested whether there is generalization across views (3/4 left, frontal, and 3/4 right). Robust figural aftereffects were found with faces presented at the same view (3/4 left). There was a substantial reduction of the aftereffect strength for frontal and 3/4 right views, suggesting that coding of face shape is view-specific. However, since the authors adopted a rather broad definition of the term "human face shape" (Jeffery et al., 2006) it is not possible to draw conclusions from their data to the issue whether viewpoint-dependency is due to featural or configural modes of processing. In a recent study eye movements were recorded while viewing faces in frontal, 3/4, and profile views (Bindemann, Scheepers, & Burton, 2009). Despite their great variety of appearance across viewpoints eyes were found to be most likely fixated. A significant proportion of fixations were also directed to nose and mouth, suggesting that the facial features' order of saliency in scan-path experiments is independent of viewpoint. The question of whether viewpoint modulates the extent of configural processing was addressed in a recent study by McKone (2008). The composite paradigm was used to assess the amount of configural processing where subjects were trained to name the top halves of six faces in frontal, 3/4, and profile views before combining them with a series of different bottom halves. McKone obtained a composite effect of rather equal strength in all views, suggesting that configural information is involved independent of viewpoint.

Based on such observations it has been claimed that configural and featural modes of processing rely on distinct cortical subsystems as their substrates (Farah, Wilson, Drain, & Tanaka, 1995; McKone, 2004, 2008; Moscovitch & Moscovitch, 2000; Moscovitch et al., 1997; Rossion et al., 2000). Moscovitch et al. (1997) studied CK, a brain-injured patient with object agnosia who cannot identify objects or written words, but can identify faces as long as they are present upright and intact. They proposed that featural processing specific for objects in all orientations as well as for inverted faces, facial parts or scrambled faces is accomplished by a system that is responsible for general object recognition. The face recognition system, on the other hand, is assumed to be stimulated by upright faces, and as being predominantly sensitive to configuration information as conveyed by internal facial features. Indeed, studies using fMRI revealed that face inversion strongly modulates responses in ventral extrastriate regions that respond preferentially to other classes of specific objects, as, for example, houses (Haxby et al., 1999). Further evidence that inverted faces do not predominantly stimulate the face recognition system, but rather mechanisms dedicated to the perception of other objects comes from studies with patients suffering from particular sensory malfunctions. In patients with prosopagnosia, which is a selective impairment of face recognition, the recognition of inverted faces can be relatively normal, suggesting that inverted face perception may be mediated by intact object perception mechanisms. In fact, some prosopagnosic patients perform worse on tasks with upright than inverted faces (Farah, Wilson, et al., 1995), suggesting that upright faces trigger erroneous processing in a damaged face perception system. McKone (2004) proposed a model of early vision that incorporates a subdivision into configuration-sensitive and feature-sensitive areas: first, the face system responsible for configural processing located in the right fusiform gyrus, and, second, various object-relevant systems involved in feature-based processing of objects, operating independent of orientation and viewpoint, nested in both hemispheres. The whole architecture is assumed to operate in parallel, generating representations of whole faces by integrating the outputs of the face and the object recognition systems.

While it is generally accepted that the identity of internal and external features as well as their spatial arrangements are relevant determinants of human face recognition performance, the possibly different roles of both types of features is an issue of current debate. Particularly, this issue arises in studies addressing the different processing schemes found for familiar and unfamiliar faces (Bruce et al., 1999; De Haan & Hay, 1986; Ellis, Shepherd, & Davies, 1979; Frowd, Bruce, McIntyre, & Hancock, 2007; Hancock, Bruce, & Burton, 2000; Hines, Jordan-Brown, & Juzwin, 1987; Jarudi & Sinha, 2003; Young, Hay, McWeeny, Flude, & Ellis, 1985). These studies indicate that internal features are most important for handling familiar faces while external features are predominantly focused when unfamiliar faces are to be recognized. Moreover, the studies

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[1] For example, after adapting to an expanded face, the original, untransformed face appears contracted; or, after adapting to a female face for a few minutes, observers tend to perceive a gender–neutral face as more likely a male.

of Moscovitch and Moscovitch (2000) and Moscovitch et al. (1997) suggest that internal and external features tap separate sensory entities, with internal features predominately affecting the face recognition system and external features predominately stimulating the object recognition system (Moscovitch & Moscovitch, 2000; Moscovitch et al., 1997).

The aim of the present study is to explore whether possible differential effects of inversion and viewpoint may render further support for the assumption of different processing routes for internal and external facial features. In two experiments we had subjects compare the same facial stimuli according to different instructions, either requiring matching of external (Experiment 1), or internal (Experiment 2) features, each in a natural and intact facial context. The facial context was arranged such that the features of the class that was not to be attended were either congruent or conflicting with the correct judgement. This scheme implies that a subject could be successful when she/he paid attention only to the relevant feature class in conflicting contexts, or when she/he focused on the relevant features and/or whole faces in congruent contexts. With this arrangement of stimulus conditions and tasks we found strong effects of orientation and viewpoint for both tasks in congruent contexts where a subject could profit from exploiting the congruence/incongruence of a whole facial Gestalt. However, in conflicting contexts, where monitoring just the task relevant features was the only way to success, strong effects of orientation and viewpoint were found for matching of internal features, but none for matching of external features. These results indicate that internal features are routed by mechanisms sensitive to configural information *per se*, while external features tap such routes only when additional features enter which enable to bind them into relevant wholes. This substantiates the distinction between configural and featural modes of processing in face perception and its close correspondence to internal and external types of features.

2. Method

2.1. Experimental outline

Two experiments with identical stimulus material but different instructions (tasks) were executed, requiring matching of either external or internal facial features. In both experiments a same/different task was used, instructing the subjects to compare two subsequently presented faces and to decide whether both were same or different with respect to the class of facial features to be attended. In each of both experiments we varied degree of congruency, stimulus orientation, viewpoint, and exposure duration.

2.1.1. Task

In the first experiment subjects were instructed to judge two facial stimuli as *same* when their external features were congruent, and as *different* otherwise (task: "same-external"). In the second experiment same-trials were defined as facial congruency in internal features (task: "same-internal"). Different subjects participated in both experiments.

2.1.2. Condition – degree of congruency

In each task facial feature congruency was realized in two degrees, *total* congruency/incongruency (the IDE condition = identical/different) and *featural* congruency/incongruency (the SISE condition = same internal/same external). In the IDE condition the two facial stimuli presented in a trial were either identical (trial type T1) or totally different faces (trial type T2). In the SISE condition two faces could be same in internal but different in external features (trial type T3) or same in external but different in internal features (trial type T4). Fig. 1 illustrates the definition of the IDE and the SISE conditions with their corresponding trial types. In the IDE condition the class of features which is not to be attended provides a consistent facial context for the target feature class, both being same for the *same* response category, and both being different when *different* is the correct response. In the SISE condition the features that are not task relevant provide a conflicting facial context, being different when the target features are same, and same when the target features are different.

2.1.3. Orientation

Facial stimuli were presented (1) in an upright orientation, with the target and test faces in their natural orientation, or (2) in an inverted orientation, where only the second presented face (test face) was rotated about 180° at the picture-plane level.

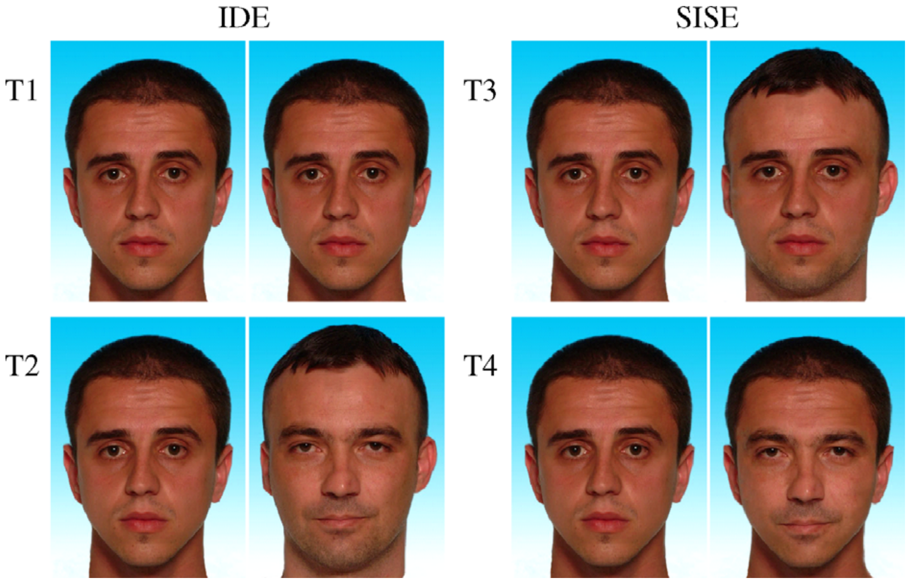

Fig. 1. Illustration of totally and featurally congruent/incongruent stimulus pairs. In trials of type T1 two same faces were shown, in trials of type T2 the two faces were completely different. T1 and T2 trials exemplify the IDE (=identical/different) condition, where faces were either totally congruent, or totally incongruent. In T3 trials the two faces had the same internal but different external features, and in T4 trials the same external but different internal features. T3 and T4 trials exemplify the SISE (=same internal/same external) condition with just featurally congruent/incongruent faces. Faces were shown in frontal and in 3/4 view.

2.1.4. Viewpoint

In a trial sequence the first face (target face) was always presented in frontal view, whereas the second face (test face) could either be in frontal or 3/4 view (45° rotation about the *y*-axis).

2.1.5. Duration

Two exposure durations, $D = \{60, 150\ \text{ms}\}$, were used as presentation times for the test faces. The presentation times for the target faces were constant at $D = 1500$ ms.

2.2. Participants

A total of 60 subjects, all of them students of psychology, participated in the two experiments, 30 in Experiment 1 (17 females), and 30 in Experiment 2 (19 females). Their mean age was 23.4 years, with a range from 19 to 28 years. All participants had normal or corrected-to-normal vision.

2.3. Stimuli

Full-color frontal and 3/4 view photographs of twelve male faces were captured in a photo studio under controlled lighting conditions. None of the models was wearing glasses or jewelry or had a beard. All had a comparable short hairstyle. Four faces were used as target faces, and were combined with appropriate 12 test faces, resulting in 96 possible pairs. Test faces could be totally congruent with the target face or just featurally congruent. Featurally congruent faces were created by manipulating faces with Adobe Photoshop 9 in order to construct sample stimuli with defined combinations of internal and external features. Internal features (nose, mouth, eyes, eyebrows) were cut out with comparable tracing lines and were placed on the second (template) face, based on the position of the internal features (Veres-Injac & Schwaninger, 2009). In Fig. 2 the four target faces, as well as an example of four possible composite test faces are shown in frontal and 3/4 view.

Stimulus images were bitmaps of 300 × 400 pixels dimension. Images were presented on a 17″ color CRT monitor. The presentation positions of target and test face image were shifted by 20 pixels away from the center in random direction in order to preclude pictorial matching strategies. The resolution of the screen was set to 1024 × 768 pixels at a refresh rate of 60 Hz. The viewing distance was approximately 60 cm.

2.4. Procedure

Each trial started with a presentation of a fixation cross located at the screen center, which was displayed for 2000 ms. Then a target face was displayed for 1500 ms, and after a blank screen of 1000 ms, a test face appeared. With 12 replications of each of the four trial types, each experiment comprises 384 trials. The target faces were always presented in frontal view and upright orientation, whereas orientation, view and exposure duration of the test faces varied randomly in each experiment. The structure of a trial is shown in Fig. 3. In order to ensure that the subjects understood the task properly, the two main experiments were preceded by a training phase. The training consisted of eight trials in both frontal–frontal (F–F) and frontal–3/4 views (F–3/4), and in both orientations (upright–upright and upright–inverted). Different facial stimuli were used in the training sessions and the main experiment. Participants were instructed to indicate whether the target and the test faces were same or different according to the feature class to be matched. In Experiment 1 faces had to be matched on

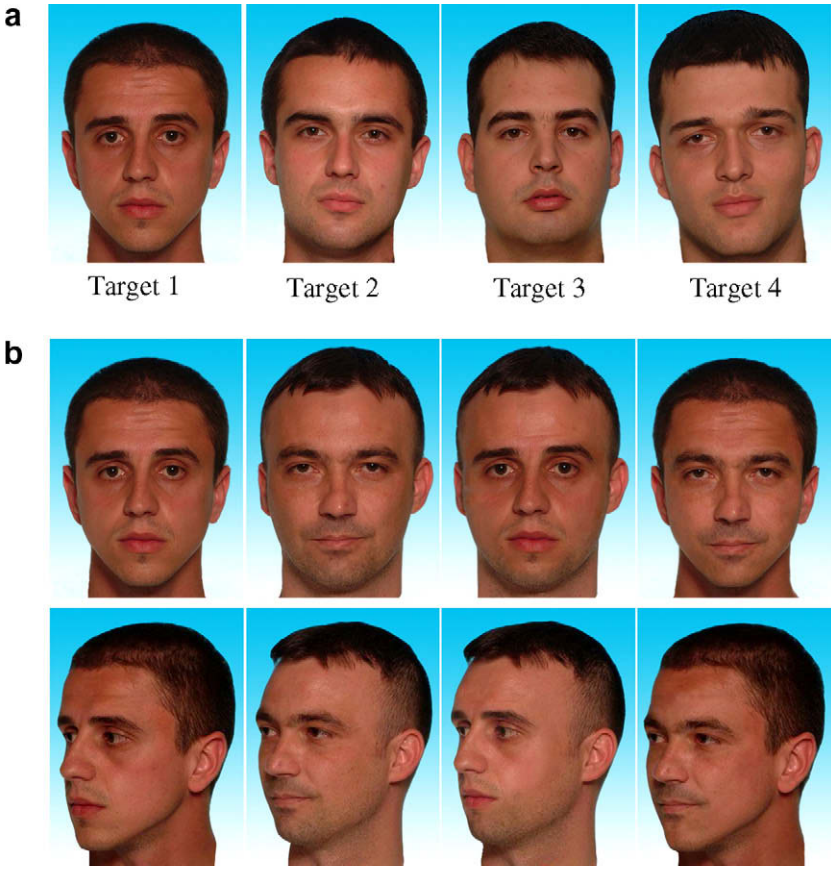

Fig. 2. The four target faces used in both experiments (set a) and possible composite test faces (set b) are shown in frontal (middle panel) and 3/4 view (lower panel).

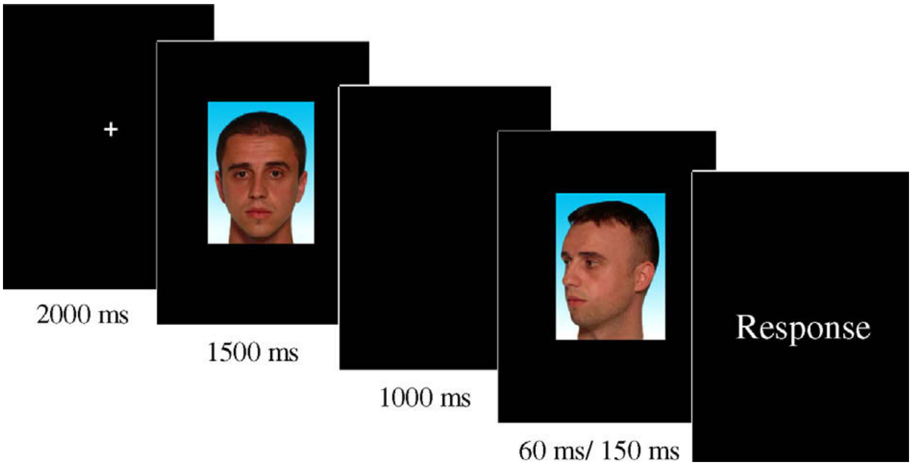

Fig. 3. Structure of a trial. A fixation cross initiated a trial sequence, followed by a target face, which was presented in upright orientation and in frontal view for 1500 ms. After an inter-stimulus interval of 1000 ms duration a test face was displayed for either 60 or 150 ms, upright or inverted, and in frontal or 3/4 view. The subject's response started the next trial instantly.

the basis of external features (task: "same-external"), and in Experiment 2 based on internal features (task: "same-internal"). Subjects responded by pressing the left or right mouse button with their preferred hand as quickly and accurately as possible. The assignment of the two response categories to the left or right mouse button was counterbalanced across participants. Both reaction time and accuracy were measured.

It is important to note that all four trial types appeared randomly intermixed in both experiments, which assures that correct decisions above chance rate could only be made if the subjects monitored the features of the class that had to be matched according to instruction.

3. Results

3.1. Reaction times

A four-way repeated measures ANOVA was used to analyze reaction times of correct answers, having task (matching of external features, matching of internal features) as a between-subject factor, and condition (IDE, SISE), orientation (U–U, U–I), viewpoint (F–F, F–3/4), and exposure duration (60, 150 ms) as within-subject factors.

Reaction times for matching of upright (U–U) faces were shorter than for inverted (U–I) faces ($F(1,58) = 5.47$, $p < .05$). Further, matching of totally congruent/incongruent faces (IDE) was completed significantly faster than that of featurally congruent/incongruent faces (SISE; main effect of condition, $F(1,58) = 49.72$, $p < .001$). Since there was a significant interaction between orientation and condition ($F(1,58) = 15.945$, $p < .001$) additional pairwise comparisons were calculated, which revealed longer reaction times for inverted faces in the IDE condition ($F(1,58) = 19.54$, $p < .001$), and no inversion effect in the SISE condition ($F(1,58) = 0.37$, $p = .54$). Moreover, the interaction among viewpoint and task reached significance ($F(1,58) = 4.73$, $p < .05$). In Experiment 1, where matching of external features was required, reaction times for matching faces from the same view (F–F) and from different views (F–3/4) were equivalent ($F(1,58) = 0.27$, $p = .60$). The viewpoint effect was significant in Experiment 2 (matching of internal features). Matching of internal facial features from different views took significantly longer than matching the same view ($F(1,58) = 6.50$, $p < .05$). Additionally, the interaction among viewpoint and condition was significant ($F(1,58) = 9.99$, $p < .01$). Pairwise comparisons revealed that reaction times for matching of featurally congruent/incongruent faces were not affected by viewpoint ($F(1,58) = .60$, $p = .44$), whereas reaction times for totally congruent/incongruent faces were significantly longer when faces were presented in different views ($F(1,58) = 12.90$, $p < .001$). The interaction among orientation and viewpoint also reached significance ($F(1,58) = 4.11$, $p < .05$). Pairwise comparisons indicated faster matching for two faces in the frontal view, compared to matching in frontal-to-3/4 view, but only for upright orientations ($F(1,58) = 4.46$, $p < .05$). Reaction times for inverted faces presented in the same (F–F) and in different views (F–3/4) were not significantly different ($F(1,58) = 0.012$, $p = .91$). Mean reaction times for Experiments 1 and 2 are shown in Fig. 4.

In summary, matching of totally congruent/incongruent faces (IDE) is faster than matching of featurally congruent/incongruent faces (SISE), implying that there are strong effects of facial context which facilitate or hamper facial feature matching. Although subjects attended the feature classes that were task relevant, conflicting and congruent contexts significantly modulated performance. This suggests that not only the features that are monitored but also their relationships to the embedding featural context matter. Additionally, reaction times were affected by inversion in the IDE condition, but not in the SISE condition. This might be expected, since inverted faces are assumed to be processed predominantly based on their featural characteristics, while use of configural information is reduced, or even completely disabled (Kemp et al., 1990; Leder & Bruce, 1998, 2000; Rossion, 2008; Rossion & Boremanse, 2008; Schwaninger & Mast, 2005; Searcy & Bartlett, 1996; Young et al., 1987). The interaction among orientation and viewpoint indicates that face matching from different views (F–3/4) is more time consuming compared to matching from the same views (F–F), but only when faces are presented upright. However, there was no difference in matching reaction times for inverted faces in the same and different views, suggesting that the asymmetry in upright orientation might be due to longer processing time of configural information for faces in different views. This notion is corroborated by the interaction among viewpoint and condition, where viewpoint affects processing time in the context of totally congruent/incongruent facial stimuli (IDE), but not if stimuli are just featurally congruent/incongruent (SISE). Additionally, matching of internal features, but not of external features, was impaired by viewpoint (interaction of viewpoint and task), suggesting that internal rather than external features serve as a source of configural information.

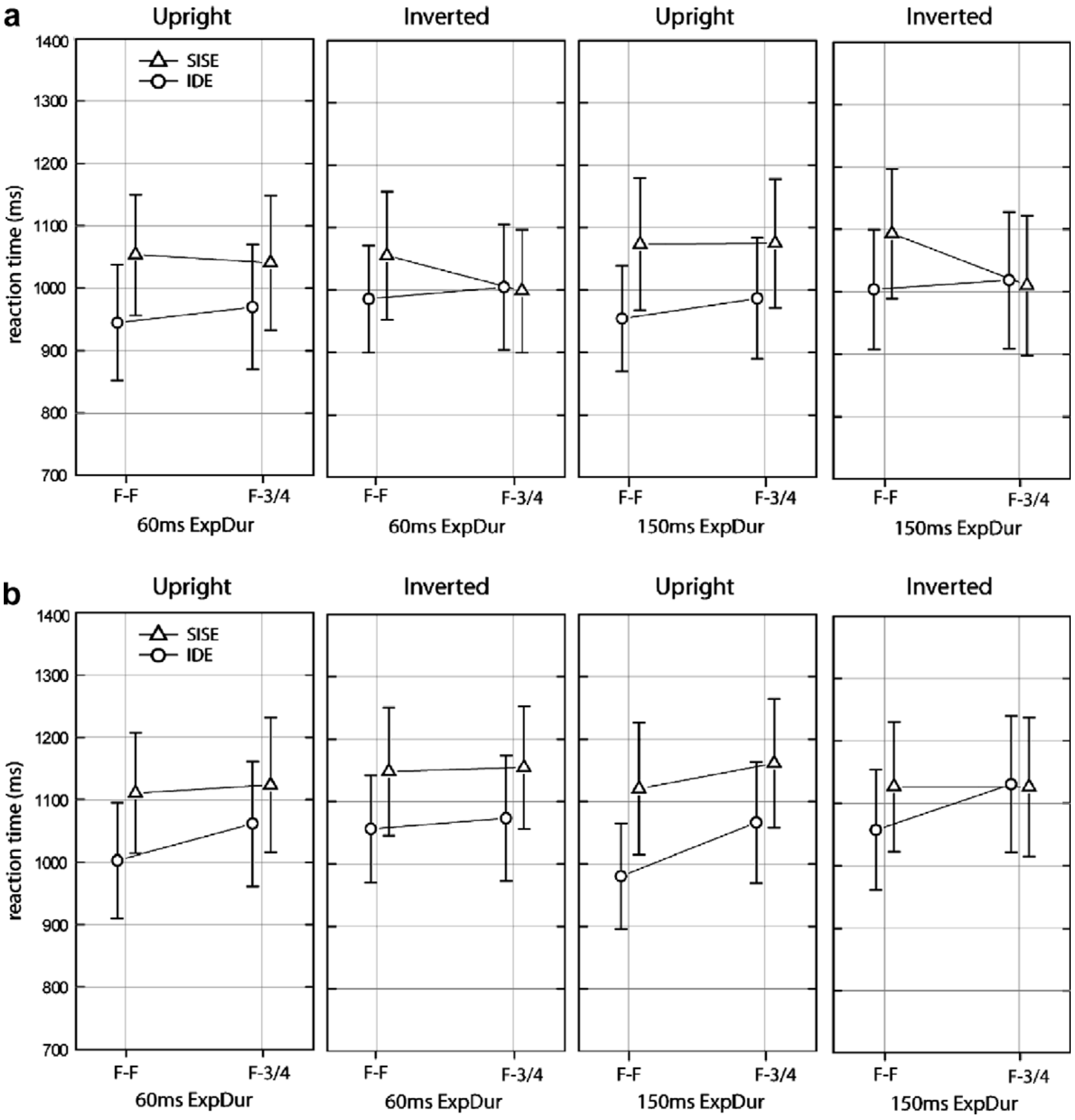

Fig. 4. Mean reaction times obtained for matching of external features (set a), and for matching of internal features (set b). In each data panel reaction times are plotted for the two different viewpoint conditions. Error bars indicate 95% confidence intervals of the means, based on the standard errors of measurement.

3.2. Error rates

Error rates were assessed with the same statistical procedures as the reaction times of correct answers. All four main effects were statistically significant: main effect of exposure duration ($F(1, 58) = 10.27$, $p < .01$) – matching was more accurate within 150 ms than within 60 ms of exposure duration; main effect of orientation ($F(1, 58) = 88.17$, $p < .001$) – upright faces were matched more accurately than inverted faces; main effect of viewpoint ($F(1, 58) = 83.06$, $p < .001$) – faces in the same and frontal view (F–F) were matched more accurately than faces in different views (F–3/4); main effect of condition ($F(1, 58) = 127.63$, $p < .001$) – matching in congruent feature contexts (IDE) was better than in conflicting feature contexts (SISE). The mean matching error rates are shown in Fig. 5. The main effects of orientation and viewpoint were modulated by the task, as indicated by significant orientation × task ($F(1, 58) = 20.24$, $p < .001$) and viewpoint × task ($F(1, 58) = 20.91$, $p < .001$) interactions. The effects of orientation and viewpoint were larger for matching of internal (Experiment 2) than for matching of external facial features (Experiment 1). The orientation × exposure duration interaction also reached significance ($F(1, 58) = 4.16$, $p < .05$). Pairwise comparisons revealed that a decrease of exposure duration from 150 to 60 ms increased the number of matching errors in both tasks, but only if faces were presented inverted ($p < .05$, for both tasks). If presented upright, face matching remained unaffected by shorter presentation. This effect is in line with previous studies suggesting that image inversion affects early stages of face processing, which are involved at brief timings below 160 ms (Jacques, d'Arripe, & Rossion, 2007; Veres-Injac & Meinhardt, 2008; Veres-Injac & Schwaninger, 2009).

The three-way interactions were highly statistically significant: orientation × condition × task – $F(1, 58) = 15.05$, $p < .001$; viewpoint × condition × task – $F(1, 58) = 16.22$, $p < .001$; and orientation × viewpoint × condition – $F(1, 58) = 4.6$, $p < .05$. Further pairwise comparisons were calculated.

3.2.1. Interaction among orientation, condition, and task

A significant increase of matching errors for inverted faces was found for both tasks in the IDE condition (both with $p < .001$). Further, inversion impaired matching accuracy for matching of inter-

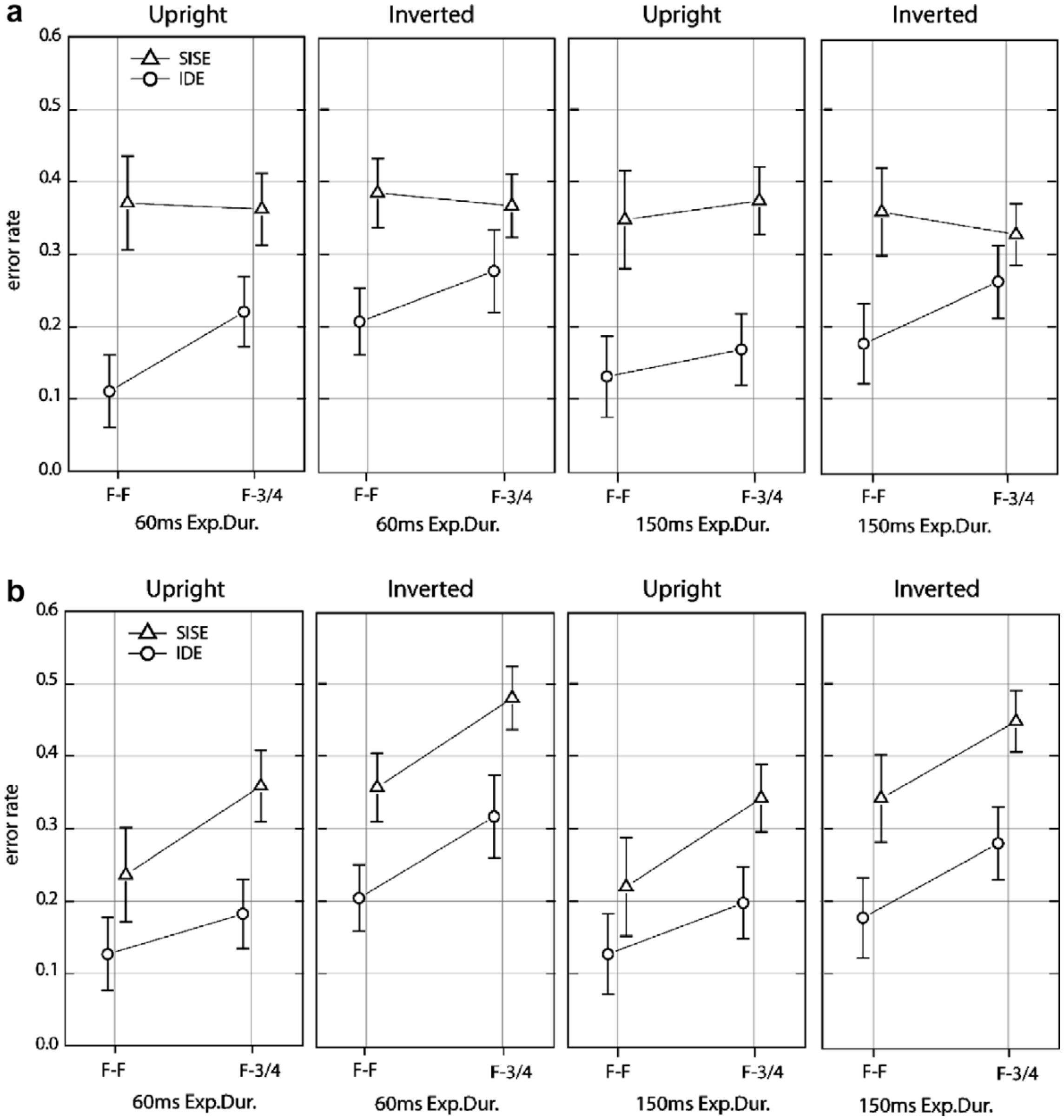

Fig. 5. Mean error rates obtained for matching of external (set a) and internal features (set b). Conventions as in Fig. 4.

nal features in the SISE condition, with a highly significant increase of matching errors for inverted stimuli ($F(1, 58) = 62.73$, $p < .001$), whereas matching of external features was not affected by inversion (Experiment 1, $F(1, 58) = .004$, $p = .83$). Hence, the data reflect an asymmetrical effect of inversion for external and internal facial features, with matching of internal features being strongly affected by inversion, while matching of external features is not. The results for the accuracy measure are in line with the data obtained for reaction times, and suggest that internal features are an important source of configural information in faces, whereas external features comprise featural characteristics of information.

3.2.2. Interaction among viewpoint, condition, and task

We found a significant effect of viewpoint in the IDE condition for both tasks, where the mean number of matching errors was larger for faces presented in different views (both $p < .001$). In contrast, viewpoint effects in the SISE condition were found only in Experiment 2, where internal facial features had to be matched ($F(1, 58) = 51.67$, $p < .001$). Matching of external facial features in conflicting internal feature context (the SISE condition in Experiment 1) was not affected by viewpoint, with similar accuracy levels in F–F and F–3/4 views ($F(1, 58) = 0.22$, $p = .63$). Again, as for the inversion effect, there is a pronounced asymmetry for matching of internal and matching of external facial features, mediated by viewpoint. While matching of external features is equivalent independent of the views in which the faces appear, matching of internal features is much better if faces appear in the same and frontal view (F–F) than in different views (F–3/4). Here we would like to stress that absolutely the same pattern of results was obtained for orientation and viewpoint effects (see Section 4).

3.2.3. Interaction among orientation, viewpoint and condition

Viewpoint effects were pronounced and equivalent in size when faces were upright, for both the IDE and the SISE conditions ($F(1, 58) = .02$, $p = .87$). For inverted faces the strength of the viewpoint effect was dependent on condition, being stronger for the IDE condition than for the SISE condition ($F(1, 58) = 7.11$, $p < .001$). Moreover, in the IDE condition viewpoint effects were generally stronger for inverted faces, while in the SISE condition just the opposite holds, i.e., we obtained stronger viewpoint effects for upright than for inverted faces (see Fig. 6b). At this point it is important to stress that the general viewpoint effect in the SISE is a conglomerate of two sources, namely, external and internal features, which are clearly processed differently, as our previous data show.

Comparing the results obtained for the two dependent measures it becomes clear that the error rates reveal stronger effects, particularly of orientation and viewpoint. More specifically, the dependency of orientation and viewpoint effects on the class of features to be attended is more pronounced for the error rates than for the reaction times. Within conflicting feature contexts (the SISE condition), where only monitoring the relevant feature class leads to success, matching of external facial features was not affected by orientation and viewpoint, with a constant level of matching accuracy in both upright and inverted orientations, and in the same and different views (Experiment 1). On the contrary, matching of internal facial features was strongly impaired by orientation and viewpoint variation in the SISE condition (Experiment 2). Moreover, the effects of both factors add together, leading to performance close to chance level with inverted faces shown in different views. The

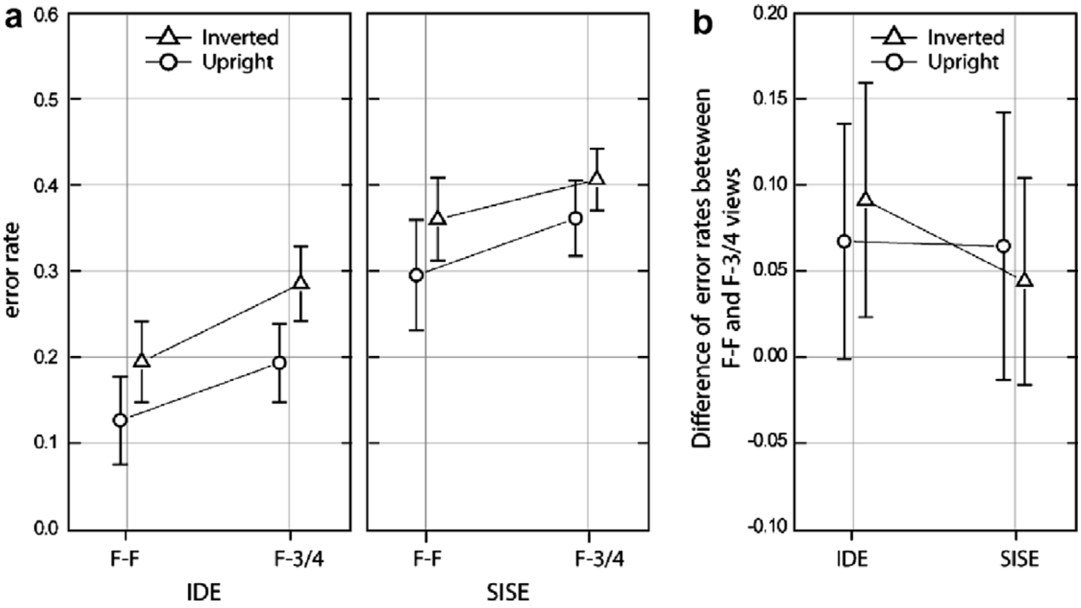

Fig. 6. Mean error rates for the IDE and the SISE conditions, agglomerated over task, and plotted for the two viewpoint conditions (set a), and the viewpoint effect for the IDE and the SISE conditions (b). Error bars indicate 95% confidence intervals of the means.

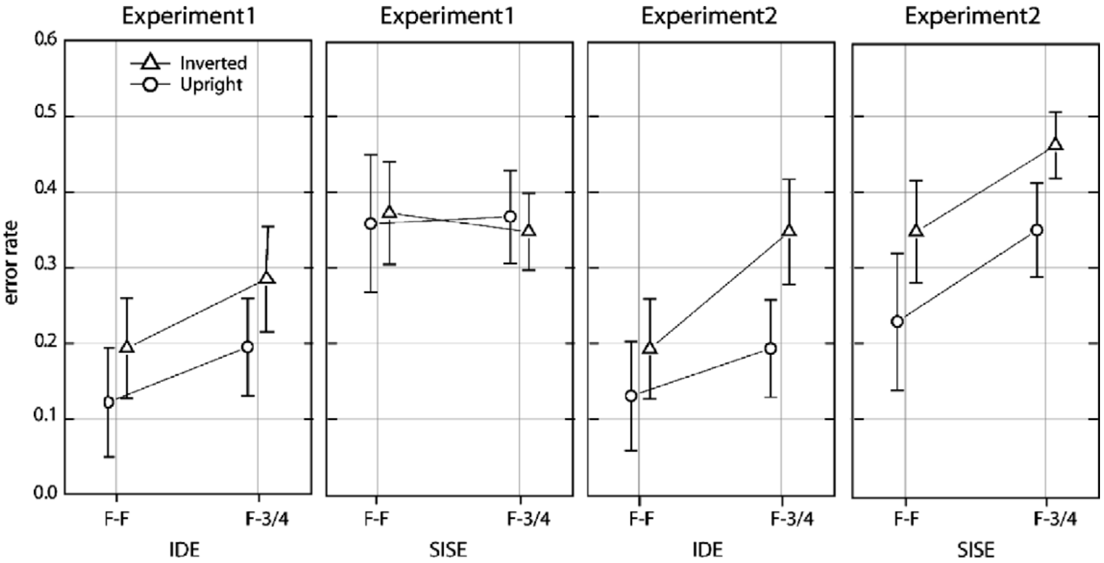

Fig. 7. Mean error rates, pooled across the two exposure durations, and plotted for both viewpoints in each panel. The left two panels show the data for matching of external features (Experiment 1), the right two panels for matching of internal features (Experiment 2). There are strong viewpoint effects independent of the featural context (IDE, SISE) when matching internal features, whereas when matching external features, viewpoint effects only exist for congruent feature contexts (IDE), but not for conflicting feature contexts (SISE).

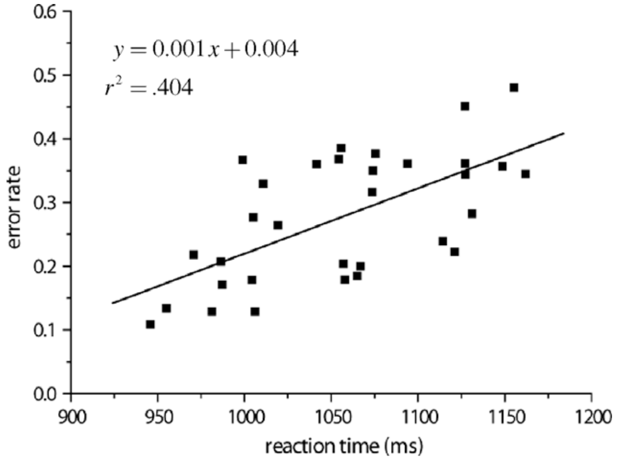

Fig. 8. Linear regression of error rates on reaction times.

finding of inversion and viewpoint effects in the IDE condition, independent of instruction, suggests that face processing is subject to variation of orientation and viewpoint whenever (1) configural information comes into play, which is provided by congruent contexts in the IDE condition, and (2) when monitoring of just internal features leads to task success (see Fig. 7).

3.3. Speed-accuracy trade off

To make sure that both measures, reaction time and error rate, are not mutually dependent in the sense of a speed-accuracy trade off we calculated the regression of error rates on reaction times on the cell means level of the ANOVA (32 cells). As shown in Fig. 8, longer reaction times are associated with more errors, which means that both measures reflect increasing task difficulty. The Pearson correlation among reaction time and error rate is $r = .635$, which is highly significant ($t = 4.51$, $p < .001$).

4. Discussion

In previous studies it was demonstrated that internal and external features contribute to the recognition of familiar and unfamiliar faces to different degrees (Bruce et al., 1999; De Haan & Hay, 1986; Ellis et al., 1979; Frowd et al., 2007; Hancock et al., 2000; Hines et al., 1987; Jarudi & Sinha, 2003; Young et al., 1985). Moscovitch and Moscovitch (2000) and Moscovitch et al. (1997) maintain a rigorous view of the underlying sensory routes, claiming that internal features, and their configural content, are predominantly processed by the face recognition system, while external features are assumed to predominantly stimulate the object recognition system. The face recognition system is taken to be responsible for extracting configural properties of faces, as given in upright intact face stimuli. On the other hand, the object recognition system is supposed to be activated by objects, and by inverted and scrambled faces, since their recognition relies much stronger on featural modes of processing (Farah, Wilson, et al., 1995; McKone, 2004; Moscovitch & Moscovitch, 2000; Moscovitch et al., 1997; Rossion et al., 2000).

Since former studies demonstrated that it is possible to draw conclusions about featural and configural modes of processing in face perception by testing orientation and viewpoint effects (e.g., Farah, Tanaka, & Drain, 1995; Leder & Bruce, 2000; Leder, Candrian, Huber, & Bruce, 2001; McKone, 2008; Rhodes et al., 1993; Young et al., 1987) we tested whether a differential pattern of inversion and viewpoint effects is obtained when internal or external features have to be attended to for task success, and in contexts which could provide either helpful and congruent or conflicting facial feature information.

4.1. Internal and external facial features involve different processing mechanisms

The results of the present study indicate that internal and external facial features are not handled by the same sensory routines, since effects of viewpoint and inversion strongly depend on the feature class to be attended. Generally, orientation and viewpoint effects were strong, suggesting that internal and external features transmit, in principle, both configural and featural facial information, but to a very different extent, and dependent on the embedding featural context. Matching of internal facial features was strongly affected by variations of orientation and viewpoint, with the strongest modulation found for the accuracy measure. These effects were moderate, and in some conditions missing, when external features had to be focused. As it has been previously demonstrated, inversion impairs processing of configural rather than featural facial properties (Leder & Bruce, 1998, 2000; Rossion, 2008; Rossion & Boremanse, 2008; Searcy & Bartlett, 1996). In line with these results, our findings suggest that focusing on internal feature lays more weight on configural properties of the stimulus, and less weight on purely featural attributes (e.g., nose shape or eyes shape). This is consistent with our finding that when focusing on external features, effects of inversion and viewpoint were found only in the IDE condition, where consistent internal feature information supports face matching, but are not found in the SISE condition, where the correct judgment hinges on a correct comparison of external features only. For matching of internal features, however, effects of inversion and viewpoint were strong in the IDE and the SISE conditions, suggesting that configural information enters when just internal features, and intact wholes, enter the comparison. This pattern of results does not rule out that also featural modes of processing apply for internal features, but suggests that distortions of configural information are mainly responsible for the poorer performance in matching across views or orientations. Hence, the finding that matching of external facial features was not modulated by orientation and viewpoint in the SISE condition indicates that here, predominantly featural modes of processing apply. The finding of inversion and viewpoint effects for external features in the IDE condition is consistent with the notion that there, configural information enters by congruent feature contexts with internal features, enabling holistic matching strategies.

Hence, our results corroborate the claim of Moscovitch and Moscovitch (2000) and Moscovitch et al. (1997) that optimal recognition of faces depends on interactions among the face and the object recognition system. The face recognition system forms holistic representations of faces based on configurations, where spatial relations among internal features, and among internal and external features in congruent feature contexts, play a major role. The object recognition system integrates information about individual features and global structural descriptions, and is predominantly involved when external features are processed. Spatial relations among internal features are crucial for face recognition, and are strongly orientation-specific. Recent ERP studies support the idea that internal features reflect configural information processing, provided that ERPs modulations are reflected by the N170, whereas external facial features carry some kind of structural or global information necessary for stimulus categorization (“it is a face”), which is related to ERP modulations of the P150 (Eimer, 1998, 2000; Olivares & Iglesias, 2008). The global analysis works as a guideline, directing successive featural processing of more detailed aspects, whereas both global and featural processes work in parallel in order to garner further information about a face (Bruce, 1988; Moscovitch et al., 1997; Olivares & Iglesias, 2008; Singer & Sheinberg, 2006; Sugase, Yamane, Ueno, & Kawano, 1999).

4.2. The whole is more than the sum of the parts – internal and external features interact in representations of holistic faces

Representations of holistic faces rely on both configural and featural face properties. Presumably, they are generated by integrating the outputs of different sensory processing systems dedicated to each class of information. Our study does not provide evidence that only configural or only featural facial properties might play a dominant role in the face processing. Rather, the strong context effects obtained here imply that the integration of information in a complex facial representation occurs automatically, and cannot completely be switched off by conscious processes following task demands. In both experiments presented here matching was slower and less accurate for the SISE condition compared to the IDE condition. These findings are consistent with previous studies showing a whole-to-part advantage in matching of isolated facial features (Tanaka & Farah, 1993; Tanaka & Sengco, 1997), and in matching of misaligned compared to aligned composite faces (Hole, 1994; Hole, George, & Dunsmore, 1999; Young et al., 1987). Holistic or configural mechanisms that might be responsible for the results reported in these studies may also apply to processing of internal and external facial parts. Fusion of both into a facial whole makes matching of isolated features a difficult task in conflicting contexts, or makes it easy when a congruent facial context supports the correct judgment about the features to be compared. The rather efficient matching in the IDE condition was reduced with inverted orientations, resulting in a significant decrease of accuracy and in longer reaction times. This is in line with previous findings elaborating the inversion effect in face perception (e.g., Carey & Diamond, 1994; Farah, 1996; Hole, 1994; Tanaka & Farah, 1993; Young et al., 1987). Additionally, viewpoint effects were also significant, with shorter reaction times and fewer errors obtained for matching of two faces which were presented in the same view (F–F), compared to faces presented in two different views (F–3/4). The viewpoint effect was pronounced in both upright and inverted orientations, which might be expected only if configural properties of upright faces remain to be important input information, independent of the angular difference between two faces which are to be matched (McKone, 2008). The efficiency in encoding configural facial properties, however, is much higher if target and test faces are presented in the same view than in different views, indicating view dependency in processing of configural facial information.

4.3. Processing of configural facial information is impaired by orientation and by viewpoint

The data of the present study clearly demonstrate that variations of orientation and viewpoint affect matching performance in a similar way, both being significant for matching of totally congruent/incongruent faces and internal features, but not of external features. Moreover, effects of viewpoint and orientation add in impairing matching accuracy, suggesting that mechanisms involved in the processing of configural facial information are affected by both sources. In previous studies the inversion effect was demonstrated in memory and matching tasks for faces presented in views other than frontal (17°, 3/4, profile views), which might be taken as evidence for configural processing across different views (Hill, Schyns, & Akamatsu, 1997; Moses, Ullman, & Edelman, 1996). By using the composite paradigm and a peripheral inversion task McKone (2008) arrived at exactly this conclusion, pointing out the importance of configural processing modes for recognition of known faces in frontal, 3/4 and profile views. Additionally, it has been proposed that the amount of configural processing is view-independent, and that only image-plane orientation (upright vs. inverted) affects processing of configural facial information. On the other hand, it should be noted that an overall disadvantage in identifying *profile* faces (but not faces in 3/4 view) would indicate view-dependent processing of facial features. Configural information is therefore crucial for reliable identification of faces despite the large variability in the appearance of facial features (McKone, 2008).

Although the conclusions of the present study seem to contradict those of McKone (2008), there are some substantial differences in the methodological approaches that need to be discussed. In the study by McKone (2008) subjects were trained to learn top halves of six faces shown in frontal, 3/4, and profile views, and were required to recognize them in composite test faces, whose lower part stemmed from another person. Since extensive experience with a face promotes emphasis on configural modes of face perception (Buttle & Raymond, 2003; Megreya & Burton, 2006; Veres-Injac & Persike, 2009), the conclusion of McKone is expected, i.e., in her task configural information is preferred, rather than featural information, since it is a recognition task with known faces. It has been shown that a variation of viewpoint affects matching of familiar faces much less than that of unfamiliar faces (Bruck, Cavanagh, & Ceci, 1991; Davies & Milne, 1982; Hill & Bruce, 1996). This is probably the reason why in the study of McKone (2008) no differences were found for identifying faces in frontal and 3/4 view, whereas in our study face matching was clearly impaired when target and test face appeared in different views. The other important difference to the study of McKone (2008) is that there was no use of external features at all, while the differential effects of inversion and viewpoint on processing of internal and external features were explicitly tested here.

Despite these differences, the existing data on the effects of inversion and viewpoint in face perception bolster the notion that configural facial information plays a role for processing faces in frontal, but also in other views, and particularly in 3/4 view. Moreover, the present study provides evidence that viewpoint effects most likely occur at the stage of configural processing, but not at the stage of purely featural processing, where global shape information is extracted. Recent fMRI studies (Andrews & Ewbank, 2004; Fang, Murray, & He, 2007) support that the substrate of the viewpoint adaptation effect is most likely located in the fusiform face area (FFA), which is known to be highly sensitive for configural information. On the other hand, no activity related to viewpoint adaptation was found in the lateral occipital complex (LOC), which is known to be a shape-sensitive area (Altmann, Bülthoff, & Kourtzi, 2003; Kourtzi & Kanwisher, 2000). These findings support that there is a strong link of viewpoint-dependent and configural information processing in the mechanisms of face perception.

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