Holistic face processing is mature at 4 years of age:

Evidence from the composite face effect

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Abstract

While it is acknowledged that adults integrate features into a representation of the whole face, there is still some disagreement about the onset and developmental course of holistic face processing. We tested adults and children from 4 to 6 years of age with the same paradigm measuring holistic face processing through an adaptation of the composite face effect (Young et al., 1987). In Experiment 1, only 6-year-old children and adults tended to perceive the two identical top parts as different, suggesting that holistic face processing emerged at 6 years of age. However, Experiment 2 suggested that these results could be due to a response bias in children, which was cancelled out by always presenting two faces in the same format on each trial. In this condition, all age groups present strong composite face effects, suggesting that holistic face processing is mature as early as after 4 years of experience with faces.

Keywords

Development, children, face, holistic, composite effect.

Introduction

An important paradox characterizes the development of our face processing abilities. On the one hand, neonates tested several hours after birth already show face processing abilities, preferring to orient their attention towards face-like patterns as compared to scrambled faces (Goren, Sarty, & Wu, 1975; Morton & Johnson, 1991) or being able to differentiate their mother's face from a stranger's face (Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). However, developmental studies have shown that face processing abilities develop rather slowly and progressively (Geldart, Mondloch, Maurer, de Schonen, & Brent, 2002). For instance, children's performance in identity and facial expression processing improves tremendously between 4 and 11 years of age (Bruce, Campbell, Doherty-Sneddon, Import, Langton, McAuley, & Wright, 2000), and reaches maturity only after puberty (Carey, Diamond, & Woods, 1980; Mondloch, Le Grand, & Maurer, 2002; Chung & Thomson, 1995).

It is yet unclear whether children process faces simply less efficiently than adults (i.e. a quantitative difference) or if qualitatively different processes are used by adults and children. For instance, it is widely acknowledged that adults' face recognition does not rely only on the process of individual facial features, but also on the relationships between these features, the so-called configuration of faces (see Maurer et al., 2002, for a review). The ability of children to process faces configurally has been frequently debated in the literature (e.g. Baenninger, 1994; Brace, Hole, Kemp, Pike, Van Duuren, & Norgate, 2001; Freire & Lee, 2001; Mondloch et al., 2002; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch, Dobson, Parsons, & Maurer, 2004). The current view is that adult expertise in configural processing is especially slow to develop (Mondloch et al., 2002) even if it already emerges in infancy (Turati, Sangrigoli, Ruel, & de Schonen, 2004) and early childhood (Cohen & Cashon, 2001, Deruelle & de Schonen, 1998). To complicate matters further, the definition of ‘face configuration’ varies considerably between authors and may appear somewhat confusing in the face literature. There are at least two types of configuration that have been conceptually differentiated (see Goffaux & Rossion, in press; Maurer, Le Grand, & Mondloch, 2002; Rossion & Gauthier, 2002). First, configural information may refer to metric distances between facial features, such as the inter-ocular or eye/mouth distance for instance. These distances between facial features can be measured and manipulated on the stimulus, and the sensitivity of the face-processing system to perceive and encode this information can be tested in discrimination or recognition tasks (e.g. Haig, 1984; Freire, Lee, & Symons, 2000; Barton, Keenan, & Bass, 2001; Leder, Candrian, Huber, & Bruce, 2001). The second type of configuration is referred to as ‘holistic’ processing. It is more difficult to grasp since it refers to a way of handling a face stimulus rather than information that can be manipulated independently of the observer. The concept was probably first introduced by Francis Galton (1883), who noticed that facial features were not perceived and analyzed separately, i.e. that the face stimulus was processed as a ‘whole unit’ or as a ‘Gestalt’. Numerous phenomena exemplify this holistic processing of faces in real life situations or in the laboratory (e.g. Davidoff & Donnelly, 1990; Farah, Wilson, Drain, & Tanaka, 1998; Goffaux & Rossion, in press; Hole, 1994; Homa, Haver, & Schwartz, 1976; Sergent, 1984; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987).

Two experimental paradigms have been widely used to provide evidence for face holistic processing: the ‘composite face paradigm’ (Young et al., 1987) and the ‘whole-part paradigm’ (Davidoff & Donnelly, 1990; Tanaka & Farah, 1993). In the ‘whole-part paradigm’, participants are trained to name a series of faces, and they recognize face features (eyes, nose or mouth) better when these features are embedded in the whole face stimulus than when they are presented in isolation (Tanaka & Farah, 1993). In the initial ‘composite face paradigm’, a composite stimulus was made by joining the top half of a familiar face (cut below the eyes) with the bottom half of another familiar face. Observers were slower to name the top half of such a composite face when the top and bottom parts were vertically aligned, creating a new face stimulus, than when the same top and bottom parts were offset laterally (i.e. misaligned). Both effects have been found with unfamiliar faces in matching tasks (e.g. Endo, Masame, & Maruyama, 1989; Farah et al., 1998; Hole, 1994; Hole, George, & Dunsmore, 1999; Goffaux & Rossion, in press; Le Grand, Mondloch, Maurer, & Brent, 2004; Michel et al., 2006).

Whereas a number of developmental studies have addressed the question of the ability to perceive metric distances between facial features (e.g. Baenninger, 1994; Brace et al., 2001; Freire & Lee, 2001; Mondloch et al., 2002, 2003, 2004), few studies have directly tested holistic face processing in children. To our knowledge, only 4 studies were run using different paradigms explicitly measuring holistic face processing: the composite face paradigm (Carey & Diamond, 1994); the whole-part advantage paradigm (Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stanfield, & Szechter, 1998), and a categorization task (Schwarzer, 2002). Furthermore, there is still some disagreement about the onset and the developmental pattern of holistic face processing. On the one hand, studies using the whole-part advantage paradigm (Pellicano & Rhodes, 2003; Tanaka et al., 1998) have suggested that children of 4 and 6 years of age, process faces as holistically as adults (see also Carey & Diamond, 1994); on the other hand, Schwarzer (2002) attested that 2- to 5-year-old children prefer to categorize faces on the basis of their constituent parts (by focusing on a single attribute) more than holistically (in terms of overall similarity), suggesting that young children rely less on holistic processing than adults. Thus, the question remains as to whether young children process faces holistically, and if so whether there is sudden onset of holistic processing around a given age, between 4 and 6 years of age for instance, or a gradual developmental pattern.

In the present study, we aimed at clarifying the question of the emergence and development of holistic face processing by testing adults and children of 4, 5 and 6 years of age with the exact same paradigm. To this end, two behavioral experiments were run on adults and children, using the composite face paradigm. This paradigm is considered as providing the most compelling evidence of holistic face processing (Maurer et al., 2002), and does not present the limitations associated with the whole-part paradigm (e.g. lack of specific instructions about encoding strategy, see Goffaux & Rossion, in press; Michel et al., 2006). Here, compared to the initial study of Young et al. (1987) and subsequent experiments, different parameters were modified to accommodate young participants. First, faces were presented to the participants with no time limit. Second, they were presented simultaneously, so that there was no memory component involved in the task. Third, the upper parts of all faces were slightly colorized in red to help the youngest children performing the task adequately (see Figure 1). We reasoned that if the 'quantitative' developmental view of holistic processing (Carey & Diamond, 1994; Pellicano & Rhodes, 2003; Tanaka et al., 1998) was correct, all tested children (4-, 5-, and 6-years of age) and adults should present a composite face effect. Moreover the younger children's recognition accuracy should be poorer than that of adults (Carey et al., 1980; Geldart et al., 2002; Mondloch et al., 2002; Chung & Thomson, 1995). In contrast, according to a 'qualitative' viewpoint extended from the switch hypothesis (Carey & Diamond, 1977; Schwartzer, 2002), the composite face effect should emerge at a certain age, testifying the emergence of holistic face processing abilities.

Experiment 1

Methods

Participants

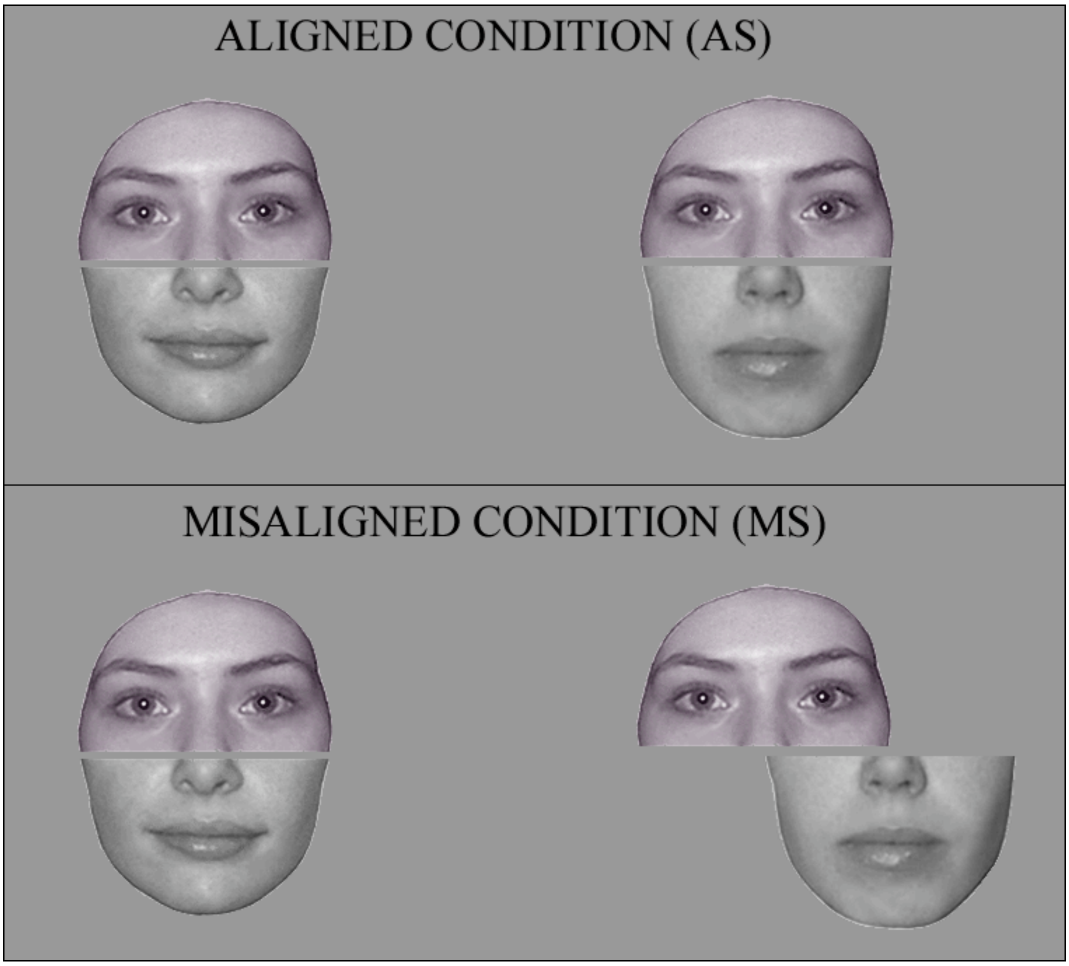
Adults. Fifteen undergraduate students (mean age: 19.07 years; 3 males) from the Department of Psychology of the University of Louvain (Belgium) received course credit for their participation to the experiment. All of them had normal or corrected-to-normal visual acuity.

Children were recruited from two different schools in Brussels (Belgium). Forty-five children participated in the study with the school's informed consent. They had normal or corrected-to-normal visual acuity. Fifteen 6-year-old children completed the testing (mean age: 80 months; 11 males). Sixteen 5-year-old children participated in the study but one was excluded because he did not perform the task better than at chance (50%) overall. Thus the final 5-year-old sample consists in 15 children (mean age: 65 months; 8 males). Eighteen 4-year-olds participate in the study but three did not perform the task better than at chance overall so that the final 4-year-old sample consisted in 15 children (mean age: 53 months; 4 males).

Stimuli and Materials

The original sample was constituted of 100 hairless Caucasian full-front greyscale faces posing with neutral expression (50 males; 50 females). All the faces, whose global luminance was equalized, were placed on a uniformly grey background. Their sizes subtended approximately 7.8 x 5.8 of visual angle.

To create the composite set of faces, faces were divided into a top and a bottom segment by slicing them off in the middle of the nose using Adobe Photoshop 7.0. Each top part was slightly colorized in red (see Figure 1) in order to favor children understanding the instructions and performing the task adequately. These faces were considered as the original composite faces. Then stimuli were manipulated to create aligned and misaligned faces in reference to the initial Young et al.'s (1987) experiment. The misaligned composite faces differed from the aligned ones in that their bottom segment was shifted to the extreme right side of the top segment (see Figure 1). Finally, stimuli were dispatched in pairs in four conditions: (1) the 'aligned-same' condition; (2) the 'aligned-different' condition; (3) the 'misaligned-same' condition and (4) the 'misaligned-different' condition. In 'same' conditions ('aligned-same' and 'misaligned-same'), top parts of the trials were identical (see Figure 1). Conversely, top segments differed from each other in the 'different' conditions ('aligned-different' and 'misaligned-different') since one top part was replaced by another top part of the same gender. In all pairs of faces, the bottom parts differed.



<u>Figure 1</u>: Composite Faces in Same trials (Experiments 1).

Procedure

Participants were tested individually in a two-alternative forced-choice recognition task at a distance of 70 cm of the screen of a laptop computer. Adults and children seated in a quiet room. Stimuli were presented and responses were collected using E-Prime 1.1. software.

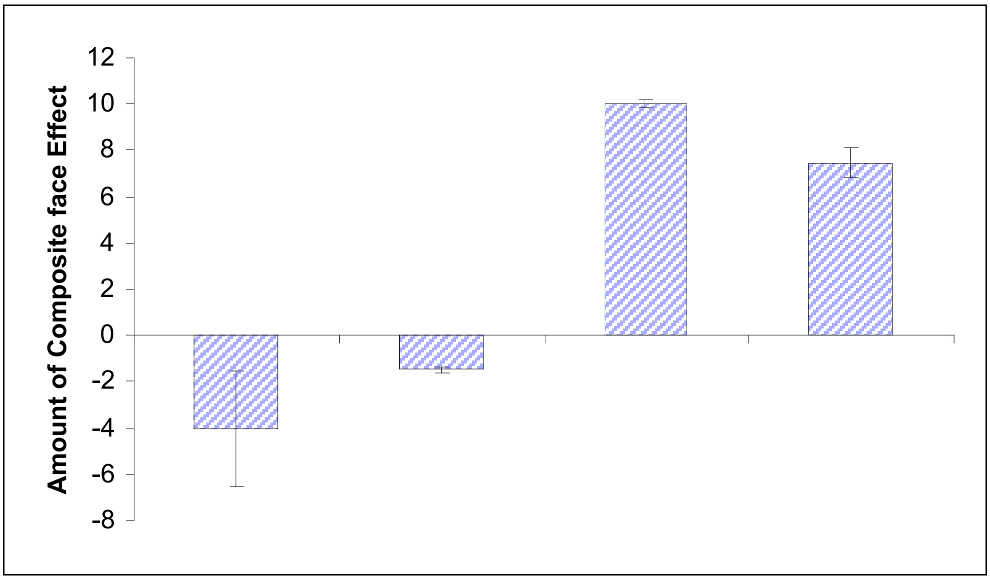
The experiment consisted of 100 experimental trials (30 'aligned-same'; 20 'aligned-different'; 30 'misaligned-same'; 20 'misaligned-different'). Simultaneous pairs of faces appeared on the screen. In aligned conditions ('aligned-same' and 'aligned-different'), both the stimuli were aligned. The misaligned conditions ('misaligned-same' and 'misaligned-different') were characterized by an aligned and a misaligned stimulus (see Figure 1). Adults were asked to focus on the colorized upper parts of the faces and to press as accurately and as fast as possible a green patch on the keyboard if these were identical ('aligned-same' and 'misaligned-same') or a red patch if they were different ('aligned-different' and 'misaligned-different'). Because younger children had extra difficulties associating the response keys with their judgments, all were asked to give their response orally and the experimenter pressed the patches for them, so that response times were not considered for children's data. Before starting the experiment, each participant performed 17 practice trials to become familiarized with the stimuli and the procedure. Feedback was provided on the practice trials but not on the experimental trials. Each trial started with a fixation-cross presented in the middle of the screen for 300 msec followed by a blank screen for 200 msec. Then a pair of composite faces randomly extracted from one of the four conditions ('aligned-same', 'aligned-different', 'misaligned-same' or 'misaligned-different') appeared on the screen. Participants had no time limit to answer even if they were orally encouraged to respond as quickly as possible during the instructions and the practice trials. The inter-trial interval was 1000 msec. Following the practice trials, stimuli were displayed in 4 blocks of 25 trials. Aligned and misaligned trials were presented randomly within the blocks. A fixed same/different ratio of trials (30/20) was used to increase the proportion of trials relevant for the analysis. Indeed, only the difference of performance for 'same' trials between the misaligned ('misaligned-same') and the aligned ('aligned-same') conditions reflects the composite illusion (i.e. erroneous perception of different identities; see Le Grand et al., 2004; Goffaux & Rossion, in press; Michel et al., 2006). Trials of 'aligned-different' and 'misaligned-different' conditions were mostly considered as fillers to the purpose of the experiment, even though they were analyzed separately.

Results

Global performance (percentage of correct responses in the whole test) improved with age: adults performed better (*M* = 85%, *SD* = 9) than preschool children (6-year-olds: *M* = 78%, *SD* = 10; 5-year-olds: *M* = 73%, *SD* = 8; 4-year-olds: *M* = 78%, *SD* = 9).

For 'same' response trials, we performed an analysis of variance (ANOVA) on participants' response accuracy (percentage of correct responses on same trials) with test condition ('aligned same' vs. 'misaligned same') as a within-subjects factor, and age (4-year-old, 5-year-old, 6-year-old children and adults) as between subjects factor. There was no main effect of the test condition ($F(1,56) = 2.598$, ns) so that considering all groups of age, participants were not better in the misaligned ('misaligned-same') condition than in the aligned ('aligned-same') condition. However there was a main effect of age ($F(3,56) = 3.752$, $p = .016$), older participants being more efficient than younger participants overall. Most importantly, the critical interaction between test condition and age was significant ($F(3, 56) = 3.81$, $p = .015$), the difference between the performances for the two conditions ('aligned-same' and 'misaligned-same') changed across the four age groups (see Figure 2). This was confirmed by subsequent paired t-tests that revealed a significant composite effect only for two age groups. Both adults and 6-year-olds showed a composite effect on Accuracy ($t(14) = 4.549$, $p = .000$ and $t(14) = 2.976$, $p = .01$, respectively) (see means and standard deviations in

Table 1). There was no face composite effect for 5-years and 4 years-old children (t(14) = .596, ns and t(14) = .810, ns, respectively) (see means and standard deviations in Table 1).



<u>Figure 2</u>: Amount of Composite face Effect

('misaligned-same' Accuracy (percentage) – 'aligned-same' Accuracy (percentage)) (Experiment 1).

Response times of the 'same' trials were only collected and analyzed for adults who did not showed any composite effect on RTs, t(14) = .983, ns.

For different trials, there was a significant main effect of test condition ('aligned different' vs. 'misaligned different', F(1,56) = 6.083, p = .017). This reflected the fact that participants were better at recognizing top parts of faces in the 'aligned-different' condition as compared to the 'misaligned-different' condition (see Table 1). There was no main effect of age (F(3,56) = 1.9, ns) even if 4 and 5 years old tended to perform at a lower level than the 6 years old and the adults, and no interaction between age and test condition (F(3, 56) = .311, ns).

In order to compare the size of their composite effect, we determined a 'composite size' coefficient for each participant by subtracting their accuracy rates in the 'aligned-same' and 'misaligned-same' condition respectively ('misaligned-same' accuracy score – 'aligned-same' accuracy score) (see Table 1 and Figure 2). Comparing the 'composite size' coefficients of adults (*M* = 7; *SD* = 6) and 6-year-old children (*M* = 10; *SD* = 13) who showed a composite face effect, we did not obtain any significant difference between the two groups.

	4-years old		5-years old		6-years old		Adults	
	A	M	A	M	A	M	A	M
Same	**83***(11)*	**79***(21)*	**71***(19)*	**71***(18)*	**71***(14)*	**81***(15)*	**83***(12)*	**90***(9)*
Different	74*(14)*	72*(13)*	80*(18)*	72*(20)*	84*(19)*	80*(15)*	87*(12)*	81*(14)*

Table 1: **Participants' accuracies** (percentage of correct responses) *(standard deviations)* for 'Same' and 'Different' trials in Aligned (A) and Misaligned (M) Conditions (Experiment 1).

Discussion

Overall, the results of Experiment 1 suggested that 6-year-old children formed holistic representations of faces, as manifested by their significant differential ability to compare the upper parts of the faces in the misaligned ('misaligned-same') vs. aligned ('aligned-same') condition. Conversely, before that age, there was no evidence in this task that children processed faces holistically, as it was previously suggested (Schwartzer, 2002). This stood in contradiction with the observations of Pellicano and Rhodes (2003) of holistic abilities since 4 years of age.

The discrepancies observed in the developmental literature about the onset and developmental course of holistic face processing have been previously discussed on the basis of different arguments. Whereas some authors suggested that the inconsistencies are due to the type of stimuli or to the paradigm measuring holistic face processing (e.g. whole-part advantage vs. composite effect), others invoke the variability of definitions of holistic/configural processing (Schwartzer, 2002). Experiment 1 had the advantage of testing different age groups with the same paradigm, the composite face effect, considered as the most compelling demonstration of holistic processing in the literature (Maurer et al., 2002). Yet, they are different ways to implement this paradigm, which may explain the results observed here. The design of Experiment 1 was similar to recent experiments performed by our group (see Michel et al., 2006): whereas two aligned stimuli are used in the 'aligned' condition, only one of the stimuli is a face with the two misaligned parts in the 'misaligned' condition (see Figure 1). However, 2 misaligned face stimuli could also have been used (Legrand et al., 2004; Goffaux & Rossion, in press). Moreover, we observed that younger children's performance was quite low in the misaligned condition with same and different trials (see Table 1). We reasoned that they might have erroneously answered 'different' on a number of same trials presenting an aligned and a misaligned face stimulus, perhaps making their decision on the format of the stimuli rather than on their identity. If so, this might have possibly cancelled out any advantage for the misaligned ('misaligned-same') over the aligned condition ('aligned-same'). To clarify this point, we ran a novel experiment with other groups of 4-, 5- and 6-year-old children and adults. In Experiment 2, both composite faces of the misaligned conditions were misaligned (see Figure 3).

Experiment 2

Methods

Participants

Adults. Fifteen undergraduate students (mean age: 19.7 years; 5 males) from the Department of Psychology received course credit for their participation to the experiment. All of them had normal or corrected-to-normal visual acuity.

Children were recruited from two different schools in the surroundings of Brussels (Belgium). Forty-five children participated in the study with the school's informed consent. They all had normal or corrected-to-normal visual acuity. Fifteen 6-year-olds (mean age: 77 months; 6 males), 15 5-year-olds (mean age: 69 months; 9 males) and 15 4-year-old children (mean age: 55 months; 8 males) complete the testing.

Stimuli and Materials

Stimuli and materials were similar to Experiment 1.

Procedure

Procedure was similar to the one used in Experiment 1. Yet, we changed the combination of composite face stimuli composing the pairs presented to the participants. In this way, both faces appearing on the screen were either aligned in the aligned conditions ('aligned-same' and 'aligned-different') or misaligned in the misaligned conditions ('misaligned-same' and 'misaligned-different') (see Figure 3).

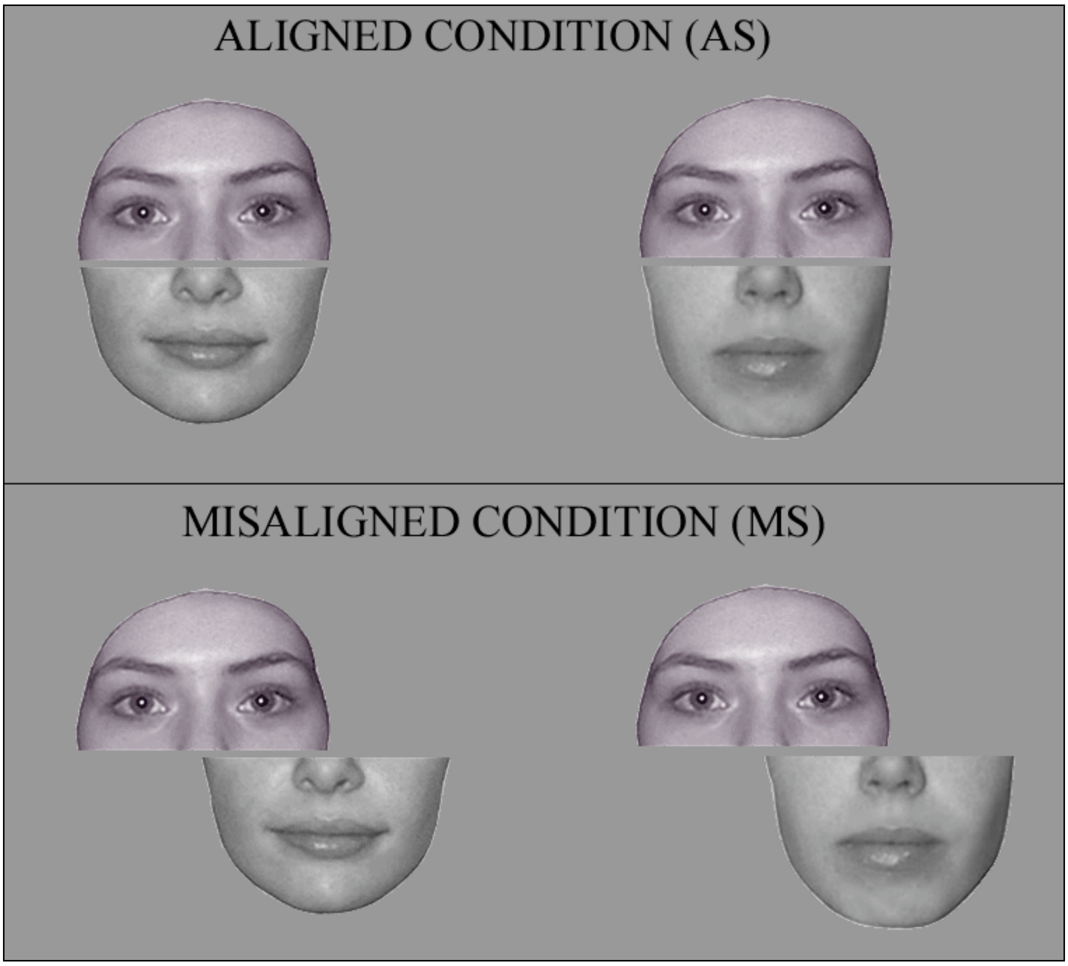
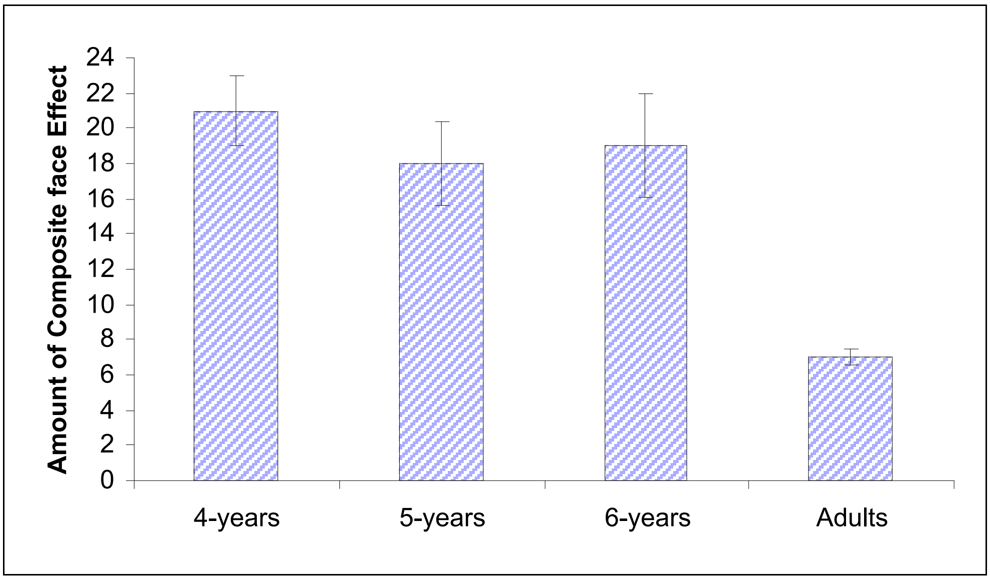


Figure 3: **Composite Faces in Same trials** (Experiment 2).

Results

A general improvement in performance (percentage of correct responses in the whole test) was observed with age: adults performed better (*M* = 91%, *SD* = 6) than preschool children (6-year-old: *M* = 87%, *SD* = 5; 5-year-old: *M* = 86%, *SD* = 7; 4-year-old: *M* = 81%, *SD* = 8).

As in Experiment 1, we performed an analysis of variance (ANOVA) on participants' response accuracy (percentage of correct responses on same trials) with test condition ('aligned same' vs. 'misaligned same') as within-subjects factor, and age (4-year-olds, 5-year-olds, 6-year-olds and adults) as between subjects factor. Response times of same trials were only collected and analyzed for adults. In this experiment, we found for 'same' trials a highly significant main effect of the test condition (F(1,56) = 85.584, p = .000) so that participants showed better results in the misaligned ('misaligned-same') compared to the aligned condition ('aligned-same'). The main effect of age was also significant (F(3,56) = 5.719, p = .002), older participants performing better overall. The significant age x test condition interaction (F(3, 56) = 3.365, p = .025) also revealed that the participants' matching of upper parts varied as function of their age. Post-hoc t-tests showed a significant composite effect for each age group (all ps < .002, see means and standard deviations in Table 2), but it was larger for each group of children (ps < .001) than for adults (see Figure 4). Even though adults presented a smaller composite effect in accuracy, it was also significant on response times, participants responding faster for misaligned than aligned correct trials, t(14) = 2.252, p = .041.



<u>Figure 4</u>: Amount of Composite face Effect

('misaligned-same' Accuracy (percentage) – 'aligned-same' Accuracy (percentage)) (Experiments 2). Note that there was also a significant effect on response times for adults who showed a smaller composite effect in accuracy, participants responding faster for misaligned than aligned correct trials (see text).

We did not find any main effect of test condition on different trials, so that participants were not better in the aligned than in the misaligned condition (see Table 2), F(1,56) = .312, ns. There was a main effect of age (F(3,56) = 2.813, p = .047), older participants performing better but the interaction was not significant (F(3,56) = 1.123, ns).

The 'composite size' coefficients ('misaligned-same' score – 'aligned-same' score) described in Experiment 1 (see Table 2 and Figure 4) were significantly different comparing the adult (*M* = 7; *SD* = 7) group to all the children's groups (6-years: *M* = 19; *SD* = 18; 5-years: *M* = 18; *SD* = 13; 4-years: *M* = 21; *SD* = 13) (ps < .05) although no difference was found between children's' groups (ps > .05). In fact, the main age effect (F(2,42) = .695, ns) and the significant age x test condition interaction (F(2,42) = .201, ns) vanished when comparing children only.

	4-years old		5-years old		6-years old		Adults	
	A	M	A	M	A	M	A	M
Same	**69***(15)*	**90***(7)*	**74***(16)*	**92***(7)*	**73***(16)*	**92***(5)*	**88***(8)*	**95***(6)*
Different	87*(15)*	82*(14)*	90*(9)*	90*(7)*	94*(7)*	93*(8)*	90*(9)*	*92(11)*

Table 2: **Participants' accuracies** (percentage of correct responses) *(standard deviations)* for 'Same' and 'Different' trials in Aligned (A) and Misaligned (M) Conditions (Experiment 2).

Discussion

Contrary to Experiment 1, the results depicted a composite effect across all age groups tested (4-, 5-, 6-year-old children and adults); that is, better performance in the misaligned ('misaligned-same') as compared to the aligned ('aligned-same') condition for 'same' trials. Furthermore, there was no difference between children's age groups in the amount of composite face effect. There was a smaller composite face effect in adults, but they also showed an effect on response times. The smaller effect in accuracy suggested that adults were better able to inhibit a wrong response (pressing the 'different' key when two top parts are identical and aligned), but then took longer to respond in the aligned condition. Previous studies showed that the composite face effect can be observed in adults either in accuracy rates or response times, or both (Goffaux & Rossion, in press; Le Grand et al., 2004; Michel et al., 2006; Young et al., 1987). However, for adults, the effect in accuracy is smaller in the present study than in previous studies, when stimuli were presented under limited time (Goffaux & Rossion, in press; Le Grand et al., 2004; Michel et al., 2006; see Hole, 1994 for evidence that holistic processing is most evident when presentations times are very short (80ms)). Here, given that the stimuli were presented for unlimited time to accommodate young participants; this may also have reduced the amount of face composite illusion in adults (Hole, 1994) and favored featural analysis (Celani, Battachi & Arcidiacono, 1999). Yet, most importantly, the presence of a strong face composite effect in all child groups shows that they processed faces holistically in the task.

These results failed to support the switch processing hypothesis (as suggested by Experiment 1) of a qualitative difference in the way young (4- and 5-year-old children) and older (6-year-old children and adults) participants process faces. Moreover, the confrontation of participants' results on same trials ('aligned-same' and 'misaligned-same') between Experiment 1 and 2 suggested a response bias: children's performance seemed to be extremely sensitive to the absence of format coherence between two stimuli presented at the same time, e.g. one aligned and one misaligned face.

Taken together, children might have erroneously judged two upper parts as 'different' in same trials when an aligned and a misaligned face were presented in the misaligned conditions of Experiment 1, taking their decision on the difference of format of the composite stimuli rather than on a difference of identity. This might be due to the fact that before a certain age the child's mind is not flexible enough to adapt to an unnatural experimental situation (Piaget & Inhelder, 1966).

General Discussion

The present study investigated the development of holistic face processing. To this end, we tested adults and 4-, 5- and 6-year-old children using the composite face paradigm known as one of the classical face paradigms testifying that participants are able to extract a robust holistic representation from face stimuli. Previous studies measuring holistic face processing in children have used different paradigms ('composite effect', Carey & Diamond, 1994; 'whole-part advantage', Pellicano & Rhodes, 2003; Tanaka et al., 1998; categorization task, Schwartzer, 2002; Schwartzer, Huber, & Dümmler, 2005) and did not fully resolve the question of the onset and developmental course of holistic face processing. It is also worth noting that developmental studies do not usually distinguish clearly between 'holistic' and 'configural' face processing (e.g. Schwartzer, 2002). The present study was built within a theoretical framework considering that holistic face processing is a subtype of configural processing (Goffaux & Rossion, in press; Maurer et al., 2002) because features interact with each other during their processing. Other studies focus more on the perception of spatial relationships (i.e. metric distances) between features (e.g. Carey & Diamond, 1977; Cohen & Cashon, 2001; Deruelle & de Schonen, 1998).

Overall, our results support the view that children process faces holistically by the age of 4, perhaps earlier (see Pascalis, de Haan, Nelson, & de Schonen, 1994). This is in agreement with previous findings of adult-like composite face effect at 6 years of age (Carey & Diamond, 1994) and whole-part advantage effect at 4 (Pellicano & Rhodes, 2003) and 6 years of age (Tanaka et al., 1998). Moreover, the contrast between the results of Experiment 1 and 2 illustrate that simple changes in experimental designs, which do not affect much the data on adult populations, can have a dramatic impact on the performance of children, and thus on the conclusions that one can reach.

Given that in the present experiment, as in previous studies, the youngest tested group is already characterized by the experimental effect (Carey & Diamond, 1994; Pellicano & Rhodes, 2003; Schwartzer, 2002; Tanaka et al., 1998), the question of the age of emergence of holistic face processing remains unsolved. Consequently, it is possible that holistic face processing appears much earlier during development. For instance, Cohen and Cashon (2001) found data suggesting that 7-month-old infants process faces 'holistically' even if the paradigm used by these authors ('switched design', see Cohen & Cashon, 2001) may have more to do with the configuration of the face, i.e. the spatial relations between both internal and external features of the face, than to his perception as a 'whole'. Ideally, one would need to perform a systematic investigation of holistic face processing from birth to adolescence (Carey et al., 1980) to clarify the developmental course of process. However, this is complicated because newborns, infants and children have different visual, motor and cognitive abilities, and thus different experimental techniques (e.g. visual preference, matching tasks) would have to be used with different age groups. This could make the results uninterpetable because factors such as the homogeneity between tasks and stimuli are known to be relevant to compare collected data (Pellicano & Rhodes, 2003). The importance of task/stimuli homogeneity was in fact well illustrated in the present study, because a simple change of format between Experiment 1 and 2 led to different conclusions. The strength of the present study lies in the fact that the same paradigm was used for all age groups, whereas previous disagreements in the literature could be due to use of different paradigms. For instance, Pellicano and Rhodes (2003) used photographs of faces and the whole-part paradigm, whereas Schwartzer (2002) used schematic faces and a categorization task and found that children of that age are processing the faces by taking single facial attributes into account.

The ability to perceive faces holistically at 4 years of age may be critical and essential for the extraction of other information in a face stimulus. For instance, infants born with bilateral congenital cataracts, who are deprived of early visual input, presented permanent visual deficits even when their cataracts were surgically removed around two months of age. Recent studies have shown that such patients tested in adulthood perform in the normal range for matching facial local features but do not process faces holistically in the composite paradigm (Le Grand et al., 2004). Moreover, they remain below normal range for extracting metric distances between facial features (Le Grand, Mondloch, Maurer, & Brent, 2001) and are impaired on matching individual faces across viewpoints despite normal performance in eye gaze and facial expression processing, as well as lip reading (Geldart et al., 2002). It may thus be that the ability to process faces holistically, which we suggest to be mature at 4 years of age, is a necessary step during development to build long term 3D individual facial representations, allowing recognizing faces across viewpoint changes and extract metric distances between features (see Goffaux & Rossion, in press; Michel et al., 2006).

Authors' note

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