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Holistic face processing is mature at 4 years of age: Evidence from the composite face effect

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Abstract

Although 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, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception, 16,* 747–759]. 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 that 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 humans' face processing abilities. On the one hand, neonates tested several hours after birth already show face processing abilities, preferring to orient their attention toward face-like patterns as compared to

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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). On the other hand, 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 et al., 2000) and reaches maturity only after puberty (Carey, Diamond, & Woods, 1980; Chung & Thomson, 1995; Mondloch, Le Grand, & Maurer, 2002).

It is yet unclear whether children simply process faces less efficiently than adults (i.e., a quantitative difference) or whether qualitatively different processes are used by adults and children. For instance, it is widely acknowledged that adults' face recognition relies not only on the process of individual facial features but also on the relations between these features, the so-called configuration of faces (for a review, see Mondloch et al., 2002). The ability of children to process faces configurally has been debated frequently in the literature (e.g., Baenninger, 1994; Brace et al., 2001; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch et al., 2002). The current view is that adult expertise in configural processing is especially slow to develop (Mondloch et al., 2002) even if it already emerges during 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 to be somewhat confusing in the face literature. There are at least two types of configuration that have been conceptually differentiated (Goffaux & Rossion, 2006; Maurer, Le Grand, & Mondloch, 2002; Rossion & Gauthier, 2002). First, configural information may refer to metric distances between facial features such as the interocular or eye–mouth distance. 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., Barton, Keenan, & Bass, 2001; Freire, Lee, & Symons, 2000; Haig, 1984; Leder, Candrian, Huber, & Bruce, 2001). The second type of configuration is referred to as *holistic* processing. It is more difficult to grasp because 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, who noticed that facial features were not perceived and analyzed separately; that is, the face stimulus was processed as a whole unit or as a *Gestalt* (Galton, 1883). 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, 2006; 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, 2006; Le Grand, Mondloch, Maurer, & Brent, 2004; Michel, Rossion, Han, Chung, & Caldara, 2006).

Although 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 four studies have been conducted 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 4- and 6-year-olds process faces as holistically as adults (see also Carey & Diamond, 1994); on the other hand, Schwarzer (2002) attested that 2- to 5-year-olds 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 do 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, such as between 4 and 6 years of age, or a gradual developmental pattern.

In the current study, we aimed to clarify the question of the emergence and development of holistic face processing by testing adults and 4- to 6-year-olds with the exact same paradigm. To this end, two behavioral experiments were conducted with 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 limits associated with the whole–part paradigm such as the lack of specific instructions about encoding strategy (Goffaux & Rossion, 2006; Michel et al., 2006). In the current study, as compared with the initial study of Young and colleagues (1987) and subsequent experiments, different parameters were modified to accommodate young participants. First, faces were presented to the participants with no time limit. Second, faces 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 (Fig. 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 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; Chung & Thomson, 1995; Geldart et al., 2002; Mondloch et al., 2002). In contrast, according to a "qualitative" viewpoint extended from the switch hypothesis (Carey & Diamond, 1977; Schwarzer, 2002), the composite face effect should emerge at a certain age, testifying to the emergence of holistic face processing abilities.

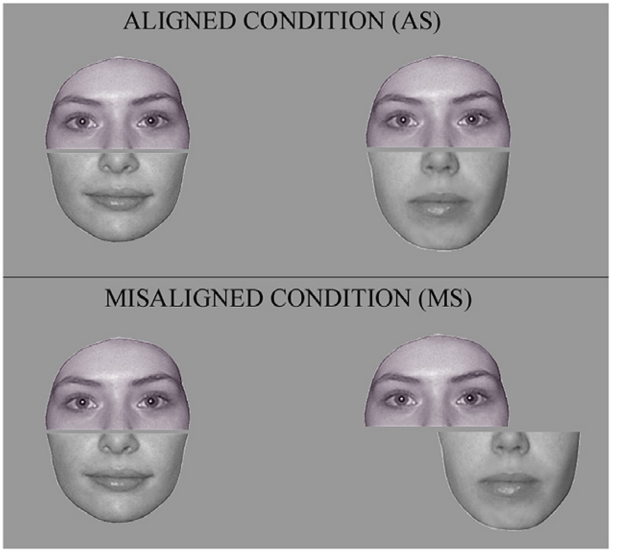

Fig. 1. Composite faces in same trials (Experiment 1).

Experiment 1

Method

Participants

A total of 15 undergraduate students (3 males and 12 females, mean age: 19 years) from the Department of Psychology at the University of Louvain (Belgium) received course credit for their participation in the experiment. All of the participants had normal or corrected-to-normal visual acuity.

Children were recruited from two different schools in Brussels, Belgium. A total of 45 children participated in the study with the school's informed consent. All had normal or corrected-to-normal visual acuity. Among the child participants, 15 6-year-olds (11 males and 4 females, mean age: 80 months) completed the testing. In addition, 16 5-year-olds participated in the study, but 1 was excluded because he did not perform the task better than at chance (50%) overall; thus, the final 5-year-old sample consisted of 15 children (8 males and 7 females, mean age: 65 months). Also, 18 4-year-olds participated in the study, but 3 did not perform the task better than at chance overall; thus, the final 4-year-old sample consisted of 15 children (4 males and 11 females, mean age: 53 months).

Stimuli

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

To create the composite set of faces, the 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 (Fig. 1) to help children understand the instructions and perform the task adequately. These faces were considered as the original composite faces. Then stimuli were manipulated to create aligned and misaligned faces akin to Young and colleagues' (1987) initial experiment. The misaligned composite faces differed from the aligned ones in that the bottom segments were shifted to the extreme right side of the top segments (Fig. 1). Finally, stimuli were dispatched in pairs in four conditions: (a) the aligned–same condition, (b) the aligned–different condition, (c) the misaligned–same condition, and (d) the misaligned–different condition. In the same conditions (aligned–same and misaligned–same), top parts of the trials were identical (Fig. 1). Conversely, top segments differed from each other in the different conditions (aligned–different and misaligned–different) in that one top part was replaced by another top part of the same gender. In all pairs of faces, the bottom parts differed.

Procedure

Participants were tested individually in a two-alternative forced-choice recognition task at a distance of 70 cm from the screen of a laptop computer. Adults and children sat 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, and 20 misaligned–different). Simultaneous pairs of faces appeared on the screen. In the aligned conditions (aligned–same and aligned–different), both of the stimuli were aligned. The misaligned conditions (misaligned–same and misaligned–different) were characterized by an aligned stimulus and a misaligned stimulus (Fig. 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 difficulty in associating the response keys with their judgments, all were asked to give their responses orally and the experimenter pressed the patches for them, so that response times (RTs) were not considered for children's data.

Before starting the test trials, 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 ms, followed by a blank screen for 200 ms. 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 in which to answer, although they were orally encouraged to respond as quickly as possible during the instructions and the practice trials. The intertrial interval was 1000 ms. Following the practice trials, stimuli were displayed in four 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 the same trials between the misaligned (misaligned–same) and aligned (aligned–same) conditions reflects the composite illusion, that is, erroneous perception of different identities (Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006). Trials of aligned–different and misaligned–different conditions were considered mostly as fillers for the purpose of the experiment, although they were analyzed separately.

Results

Global performance (percentage of correct responses in the whole test) improved with age, with adults performing 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 the 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-olds, 5-year-olds, 6-year-olds, or adults) as a between-subjects factor. There was no main effect of the test condition $F(1,56) = 2.60$, $p > .10$, so that considering all groups of age, participants were not better in the misaligned-same condition than in the aligned-same condition. However there was a main effect of age, $F(3,56) = 3.75$, $p < .05$, with older participants being more accurate than younger participants overall. Most important, the critical interaction between test condition and age was significant, $F(3,56) = 3.81$, $p < .05$. The difference in accuracy between the two conditions (aligned–same and misaligned–same) changed across the four age groups (Fig. 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, $t(14) = 4.55$, $p < .01$, and $t(14) = 2.98$, $p = .01$, respectively (for means and standard deviations, see Table 1). There was no face composite effect for 4- and 5-year-olds, $ts(14) < 1$ (for means and standard deviations, see Table 1).

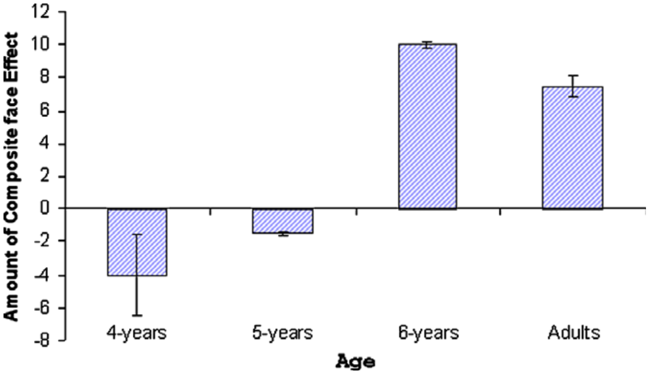

Fig. 2. Amounts of composite face effect (misaligned–same accuracy minus aligned–same accuracy) (Experiment 1).

Table 1
Percentages of correct responses (and standard deviations) for same and different trials in aligned and misaligned conditions (Experiment 1)

	4-year-olds		5-year-olds		6-year-olds		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)

Note. A, aligned; M, misaligned. Standard deviations are in parentheses.

RTs of the same trials were collected and analyzed only for adults, and they did not showed any composite effect, $t(14) < 1$.

For different trials, there was a significant main effect of test condition: aligned–different versus 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 than in the misaligned–different condition (Table 1). There was no main effect of age, $F(3,56) = 1.90$, $p > .10$, and no interaction between age and test condition, $F(3,56) < 1$.

To compare the sizes of participants' composite effects, we determined a composite size coefficient for each participant by subtracting his or her accuracy rates in the aligned–same and misaligned–same conditions (Table 1 and Fig. 2). Comparing the composite size coefficients of adults ($M = 7$, $SD = 6$) and 6-year-olds ($M = 10$, $SD = 13$) who showed a composite face effect, we did not obtain any significant difference between the two groups.

Discussion

Overall, the results of Experiment 1 suggested that 6-year-olds formed holistic representations of faces, as manifested by their significant differential ability to compare the upper parts of the faces in the misaligned–same condition versus the aligned–same condition. Conversely, prior to that age, there was no evidence in this task that children processed faces holistically as has been suggested previously (Schwarzer, 2002). This conflicts with the observations of Pellicano and Rhodes (2003) of holistic abilities from 4 years of age.

The discrepancies observed in the developmental literature about the onset and developmental course of holistic face processing have been discussed previously on the basis of different arguments. Whereas some authors have 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 have invoked the variability of definitions of holistic/configural processing (Schwarzer, 2002). Experiment 1 had the advantage of testing different age groups with the same paradigm, with the composite face effect being considered as the most compelling demonstration of holistic processing in the literature (Maurer et al., 2002). Yet there are different ways to implement this paradigm, and this may explain the results observed here. The design of Experiment 1 was similar to recent experiments performed by our group (Michel et al., 2006) although 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 (Fig. 1). However, two misaligned face stimuli could also have been used (Goffaux & Rossion, 2006; Le Grand et al., 2004). Moreover, we observed that younger children's performance was quite low in the misaligned condition with the same and different trials (Table 1). We reasoned that younger children might have erroneously answered "different" on a number of same trials presenting an aligned and a misaligned face stimulus, perhaps making their decisions on the format of the stimuli rather than on their identity. If so, this might have cancelled out any advantage for the misaligned condition (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-olds and adults. In Experiment 2, both composite faces of the misaligned conditions were misaligned (Fig. 3).

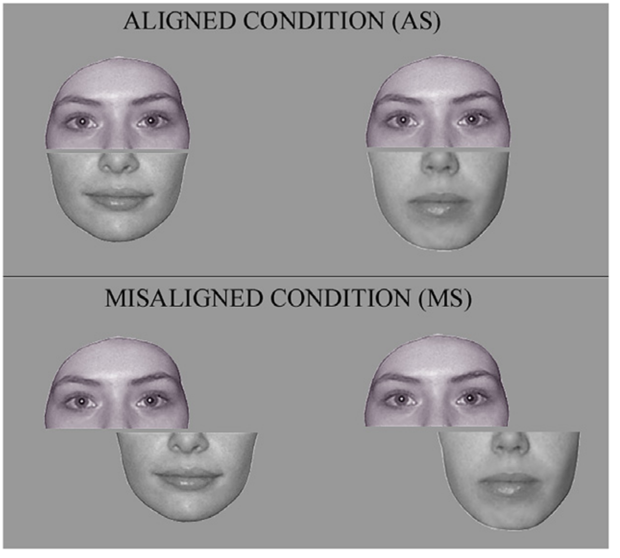

Fig. 3. Composite faces in same trials (Experiment 2).

Experiment 2

Method

Participants

A total of 15 undergraduate students (5 males and 10 females, mean age: 19,7 years) from the Department of Psychology received course credit for their participation in the experiment. All of them had normal or corrected-to-normal visual acuity.

Children were recruited from two different schools in the surrounding area of Brussels. A total of 45 children participated in the study with the schools' informed consent. All had normal or corrected-to-normal visual acuity. Among the child participants, 15 6-year-olds (6 males and 9 females, mean age: 77 months), 15 5-year-olds (9 males and 6 females, mean age: 69 months), and 15 4-year-olds (8 males and 7 females, mean age: 55 months) completed the testing.

Stimuli

Stimuli and materials were similar to those used in Experiment 1.

Procedure

The procedure was similar to the one used in Experiment 1 except that 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) (Fig. 3).

Results

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

As in Experiment 1, we performed an 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-olds, 5-year-olds, 6-year-olds, or adults) as a between-subjects factor. For the same trials, we found a highly significant main effect of the test condition, $F(1,56) = 85.58$, $p < .01$, such that participants showed better results in the misaligned condition (misaligned–same) than in the aligned condition (aligned–same). The main effect of age was also significant, $F(3,56) = 5.72$, $p < .01$, with older participants performing better overall. The significant Age × Test Condition interaction, $F(3,56) = 3.37$, $p < .05$, also revealed that the participants' matching of upper parts varied as a function of their age. Post hoc t tests showed a significant composite effect for each age group (all ps < .002) (for means and standard deviations, see Table 2), but it was larger for each group of children (ps < .001) than for adults (Fig. 4). Even though adults presented a smaller composite effect in accuracy, it also had a significant effect on RTs, with participants responding faster on misaligned trials than on aligned trials, $t(14) = 2.252, p = .041$.

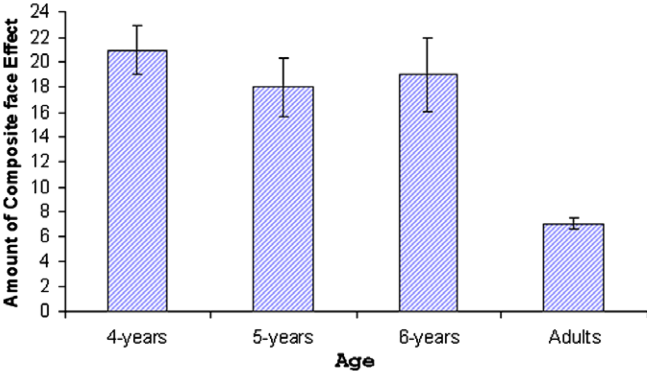

Fig. 4. Amounts of composite face effect (misaligned–same accuracy minus aligned–same accuracy) (Experiment 2). Note that there was also a significant effect on RTs for adults who showed a smaller composite effect in accuracy, with participants responding faster on misaligned trials than on aligned trials (see text).

Table 2
Percentages of correct responses (and standard deviations) for same and different trials in aligned and misaligned conditions (Experiment 2)

	4-year-olds		5-year-olds		6-year-olds		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)

Note. A, aligned; M, misaligned. Standard deviations are in parentheses.

We did not find any main effect of test condition on different trials, $F(1, 56) < 1$. There was a main effect of age, $F(3, 56) = 2.813$, $p < .05$, with older participants performing better, but the interaction was not significant, $F(3, 56) = 1.123$, $p > .10$.

The composite size coefficients (misaligned–same scores minus aligned–same scores) described in Experiment 1 (Table 2 and Fig. 4) were significantly different when comparing the adult group ($M = 7$, $SD = 7$) to all of the child groups (6-year-olds: $M = 19$, $SD = 18$; 5-year-olds: $M = 18$, $SD = 13$; 4-year-olds: $M = 21$, $SD = 13$) ($ps < .05$), although no difference was found among the child groups ($ps > .05$). In fact, the main effect of age, $F(2, 42) < 1$, and the significant Age × Test Condition interaction, $F(2, 42) < 1$, vanished when comparing children only.

Discussion

Contrary to Experiment 1, the results depicted a composite effect across all age groups tested (4-year-olds, 5-year-olds, 6-year-olds, and adults); that is, performance was more accurate in the misaligned condition (misaligned–same) than in the aligned condition (aligned–same) for the same trials. Furthermore, there was no difference among 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 RTs. The smaller effect in accuracy suggested that adults were better able to inhibit a wrong response (pressing the "different" key when two top parts were 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 in accuracy rates, in response times, or in both (Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006; Young et al., 1987). However, for adults, the effect on accuracy was smaller in the current study than in previous studies, when stimuli were presented for a limited time (Goffaux & Rossion, 2006; Le Grand et al., 2004; Michel et al., 2006, for evidence that holistic processing is most evident when presentation times are very short [80 ms], see Hole, 1994). Here, given that the stimuli were presented for an 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). But most important, the presence of a strong face composite effect in all child groups shows that they processed faces holistically on the task.

These results failed to support the switch processing hypothesis (as suggested by Experiment 1) of a qualitative difference in the ways in which young participants (4- and 5-year-olds) and older participants (6-year-olds and adults) process faces. Moreover, the comparison of participants' results on the same trials (aligned–same and misaligned–same) between Experiments 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 face and one misaligned face).

Children might have erroneously judged two upper parts as different in same trials when an aligned face and a misaligned face were presented in the misaligned conditions of Experiment 1, making their decisions 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 children are not flexible enough to adapt to an unnatural experimental situation (Piaget & Inhelder, 1966).

General discussion

The current study investigated the development of holistic face processing. To this end, we tested adults and 4-, 5-, and 6-year-olds using the composite face paradigm, which is a classic face paradigm demonstrating that participants 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], and categorization task [Schwarzer, 2002; Schwarzer, Huber, & Dümmler, 2005]) and have not fully resolved the question of the onset and developmental course of holistic face processing. It is also worth noting that developmental studies usually do not distinguish clearly between holistic and configural face processing (e.g., Schwarzer, 2002). The current study was built within a theoretical framework considering that holistic face processing is a subtype of configural processing (Goffaux & Rossion, 2006; Maurer et al., 2002) because features interact with each other during their processing. Other studies have focused more on the perception of spatial relations (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 4 years of age or perhaps earlier (Pascalis, de Haan, Nelson, & de Schonen, 1998). This is in agreement with previous findings of an adult-like composite face effect at 6 years of age (Carey & Diamond, 1994) and a whole–part advantage effect at 4 years of age (Pellicano & Rhodes, 2003) and 6 years of age (Tanaka et al., 1998). Moreover, the contrast between the results of Experiments 1 and 2 illustrate that simple changes in experimental designs that have little effect on adults' performance can have a dramatic impact on the performance of children and thus on the conclusions that one can reach.

Given that in the current experiment, as in previous studies, the youngest tested group is already characterized by the experimental effect (Carey & Diamond, 1994; Pellicano & Rhodes, 2003; Schwarzer, 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-olds process faces holistically even if the paradigm used by these authors, the *switched design,* 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 with it 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 processing. However, this is complicated because newborns, infants, and children have different visual, motor, and cognitive abilities; thus, different experimental techniques (e.g., visual preference, matching tasks) would need to be used with different age groups. This could make the results uninterpretable 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 current study because a simple change of format between Experiments 1 and 2 led to different conclusions. The strength of this 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 the use of different paradigms. For instance, Pellicano and Rhodes (2003) used photographs of faces and the whole–part paradigm, whereas Schwarzer (2002) used schematic faces and a categorization task and found that children of that age were 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 who were born with bilateral congenital cataracts, and who were deprived of early visual input, presented permanent visual deficits even when their cataracts were surgically removed at approximately 2 months of age. Recent studies have shown that such patients tested during 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 in the 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). Thus, it may 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 three-dimensional individual facial representations, allowing the recognition of faces across viewpoint changes and the extraction of metric distances between features (Goffaux & Rossion, 2006; Michel et al., 2006).

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