

Developmental differences between young children and adults when processing internal and external information for upright and inverted faces

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幼児と成人における顔の内部的情報と外部的情報処理の発達差—正立顔と倒立顔を用いた検討—

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要約

5、6歳児と成人を対象として2つの顔刺激の同一性判断課題を行い、顔の同一性判断を行う際の、顔の内部的情報（目、鼻、口、頬等を含む顔の内部全体の情報）と外部的情報（内部的情報以外の髪型の情報）の処理の発達的变化を検討した。2種類の不一致刺激（2つの顔が同一人物で髪型が異なる刺激、2つの顔は異なる人物だが髪型が同じ刺激）と2種類の一致刺激（2つの顔が同一人物で髪型も同じ刺激、2つの顔は異なる人物で髪型も異なる刺激）を正立と倒立で提示し、2つの顔が同一人物の顔か異なる人物の顔かの判断を求め、判断時の眼球運動を測定した。5、6歳時は一致刺激よりも不一致刺激においてより大きな倒立効果がみられ、同一人物かそうでないかの判断の際に、不適切な外部的情報を含めた全体処理を行っていることが示唆された。一方、成人は、不一致刺激と一致刺激両方にわずかな倒立効果がみられ、顔の内部的情報に対する部分処理と形態処理の効率性が阻害されていることが示唆された。眼球運動のデータからは、5、6歳児も成人も、正立刺激に対しては顔の内部のみを注視しているが、倒立刺激については、成人は、倒立刺激と比較すると顔の内部への注視時間が増加したのに対して、5、6歳児は顔の外部への注視時間が増加することが明らかになった。

Key words

internal facial features, external facial features, inversion effect, eye-movement, young children

1. Introduction

Young children, compared with adults, are far more likely to misidentify people who have altered their external appearance, such as their hairstyle. Internal facial information (i.e., eyes, nose, mouth, cheeks, and chin) is important for accurate identification of faces. However, inconsistent external cues, such as hairstyle, can impair identification. Young children tend to rely on external rather than internal facial information, and this may account for their inferior facial processing ability. In this study, we investigated developmental differences in attending to and using internal and external information when processing upright and inverted faces.

A number of developmental studies have investigated facial processing in children, as there is some controversy regarding whether children process faces holistically. Many of these studies examined the “inversion effect”, first described by Yin (1969), in which the processing of inverted images of faces was impaired. The inversion effect indicates that children process facial images holistically, unlike other object images (e.g., Baenninge, 1994; Flin, 1985; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Grand, & Maurer, 2002; Pellicano &

Rhodes, 2003; Pellicano, Rhodes, & Peters, 2006; Picozzi, Casia, Turati, & Vescovo, 2009). Recently, the face inversion effect was demonstrated in children as young as 3 or 4 years (Pellicano & Rhodes, 2003; Pellicano et al., 2006; Picozzi et al., 2009) suggesting that an adult-like type of holistic processing may be present in very young children. On the other hand, a series of studies by Mondloch and his colleagues (e.g., Mondloch et al., 2004; Mondloch et al., 2002) reported that children under the age of 8 were insensitive to second-order or configural relationships among facial features, such as the space between the eyes and the space between the nose and mouth, despite their sensitivity to information about individual facial features (e.g., shape of eyes, nose, mouth) and about contour. These findings led the authors to conclude that, compared with adults, young children are less adept at face processing with respect to the second-order relationships among facial features, even though they are able to process faces holistically.

Several studies have assessed another difference in facial processing between young children and adults (or older children): reliance on internal features (eyes, nose, mouth, and cheeks) or external features (hairstyle and contour). Diamond & Carey (1977) were probably the first to report that young children exhibit a strong reliance on external cues, such as hairstyles, when identifying or recognizing faces. The subsequent stream of research investigated the developmental shift from

reliance on external to internal information during facial recognition (Campbell et al., 1999; Campbell & Tuck, 1995; Campbell, Walker, & Baron-Cohen, 1995; Ellis, Shepherd, & Davies, 1979; Young, Hay, McWeeny, Flude, & Ellis, 1985). These studies suggested that the tendency for adults to rely on internal rather than external information to recognize familiar faces, such as those of celebrities, is evidence of a developmental shift that occurs in later childhood. Several follow-up studies, however, have insisted that the previous observations of this shift were attributable to the familiarity of the faces, rather than age-related changes in facial processing (Ge et al., 2008; Megreya & Bindemann, 2009; Wilson, Blades, & Pascalis, 2007). These researchers concluded that children generally process familiar faces, such as those of their teachers and classmates, based on internal features and identify unfamiliar faces using external features. They also suggested that even very young children process familiar or unfamiliar faces in the same manner as adults.

Although several studies have reported an adult-like use of information by young children during facial processing (Ge et al., 2008; Megreya & Bindemann, 2009; Wilson et al., 2007), the authors discussed methodological problems: the lack of comprehensive facial configurations, and separation between internal and external facial areas. In most previous studies, internal facial areas were presented in the absence of external areas, and vice versa. This enabled researchers to individually examine the effect of these facial components (e.g., Ge et al., 2008; Mondloch et al., 2002). However, from a practical perspective, the individual presentation of external or internal facial stimuli does not reflect real-life facial processing, because people do not see internal face features and external features such as hairstyles separately (Sugimura, 2013). In addition, experiments using isolated stimuli may have led to overestimations of facial recognition ability in children. For example, in a study by Gilchrist and McKone (2003), in which internal facial stimuli were shown without external facial stimuli, the authors found a pattern of sensitivity to second-order relationships in the 7-year-old participants that was similar to that in adults. However, in a study by Baudouin, Gallay, Durand, and Robichon (2010), 7-year-olds did not show the aforementioned adult-like sensitivity to second-order relationships when identifying natural faces. Indeed, accounting for the interaction between internal and external facial areas is central to clarifying the developmental differences in facial processing.

Recent studies (Meinhardt-Injac, Persike, & Meinhardt 2014; Sugimura, 2013) have shown that children are more likely than adults to depend on external information in same-different matching tasks in which external information affects the processing of internal features. These studies asked children and adults to make same-person or different-people decisions for four different stimuli type: two incongruent stimuli, in which the two images contained either the same internal features (i.e., same person) with different hairstyles or two different sets of

internal facial features (i.e., different people) with the same hairstyle, and two congruent stimuli, in which the two images showed either the same face and hairstyle or two different faces and hairstyles. Meinhardt-Injac et al. (2014) used sequential matching tasks in which the presentation time ranged from 50 to 700 msec. The researchers found that 8- to 10- year-olds performed poorly compared with adults when viewing incongruent stimuli. Sugimura (2013) used a simple matching task in which two faces were presented simultaneously to 5- to 6-year-olds and adults, with no time restrictions. They found that young children performed poorly when viewing incongruent stimuli, while adults exhibited a ceiling effect. These results indicate that external features are much more important for facial processing in children, and that they rely on information from the external area when the internal information conflicts with the external information.

However, eye tracking studies have found that, in the case of such discrepancies, children only focus on the internal area, and do not attend to the external hairstyle (Sugimura, 2011, 2013). Sugimura (2013, Experiment 3) examined the eye-movements of 5- to 6-year-olds and adults while they performed a same-different matching task comprising congruent and incongruent stimuli. They found that both the children and adults spent more time looking at the internal features and allocated little attention to the external hairstyles. This was the case for all the types of stimuli tested, even though the children were more likely to make decisions that depended on the external information of the hairstyle. Sugimura (2011) also analyzed eye movements during gender-discrimination tasks with incongruent stimuli (e.g., a male with long hair in a feminine style). They found that, unlike adults, children mainly based their judgments about gender on the external cues given by hairstyle. However, both children and adults spent more time looking at internal facial features. These eye-tracking studies indicate that, although both children and adults attend to the same area of faces (i.e., internal area), they process information used for judgments or identification of faces in different ways.

What processing differences between young children and adults account for the differences in their judgments about incongruent stimuli? Sugimura (2011, 2013) explained that children lack the ability to disregard inappropriate information located in their peripheral vision. Thus, in a facial identification task, children might base their responses on external cues, such as hairstyle. In other words, children might process incongruent stimuli holistically, including the external facial area, which contains irrelevant information. Conversely, adults are able to selectively or locally process relevant internal information. As evidenced by eye-tracking studies, eye movements only reflect foveal vision, which is a small part of a visual scene with a high resolution (Armann & Bülhoff, 2009). A holistic processing approach is useful for managing information with a low spatial frequency, in which foveal vision is not required (Henderson,

Williams, & Falk., 2005). That is, while the local and analytical aspects of facial processing are reflected in eye-movement behavior, this method does not reflect the holistic processing of faces. Therefore, it is possible that holistic processing in children involves irrelevant external information, and is not reflected in eye movement.

In this study, we examined the possibility that young children process incongruent stimuli holistically, and that they may include irrelevant external information in doing so. Previous research has considered holistic processing, or representation, for example, to be the act of recognizing the components of a template (Tanaka & Farah, 1993) or gluing together features into a gestalt (Maurer, Le Grand, & Mondloch, 2002). These “holistic” areas are limited to the central part of the face. However, holistic processes occur not only among the internal features but also between the internal features and external contour (Maurer et al., 2002). In addition, as shown in studies investigating the composite effect (Richler, Mack, Gauthier, & Palmeri, 2009, Richler, Tanaka, Brown, & Gauthier, 2008), the holistic process signifies an inability to selectively attend to one part or to ignore the irrelevant parts of a face. Therefore, it is likely that young children, who process incongruent stimuli holistically without ignoring irrelevant external cues, such as hairstyles, would show the inversion effect. In contrast, adults process locally relevant cues about internal features, and therefore, their performance is not likely to be affected by the orientation of stimuli.

In addition, we examined differences in eye movement between young children and adults while they identified upright and inverted faces. Several studies (Williams & Henderson, 2007; Sekuler, 2004), which examined adult eye movements when viewing upright vs. inverted faces, showed that participants looked at both upright and inverted faces in the same manner. For example, Williams & Henderson (2007) conducted a facial recognition task and found that the eyes were more frequently attended to than the nose and mouth for both upright and inverted stimuli. They concluded that the inversion effect is not the result of different eye movement patterns. On the other hand, Xu & Tanaka (2013) used a sequential same-different identification task and found that eye-fixations were most frequent in the eye and nose regions in upright faces, but in the nose and mouth regions in inverted faces. Despite the above-mentioned literature, few studies have examined developmental differences in eye-movements when viewing facial stimuli. Although Sugimura (2013) showed that 5-year-olds and adults exhibited the same eye-movement patterns, specifically, they attended only to internal features for both congruent and incongruent stimuli, the researchers only examined upright faces. Therefore, we compared eye-movements for upright and inverted stimuli between 5-year-olds and adults. To this end, we used a same-different matching task previously described by Sugimura (2013).

2. Methods

2.1 Participants

Sixty preschool children (32 boys and 28 girls, aged 5:0-6:11 years, $M = 6:0$ years) at a Japanese kindergarten and 64 Japanese undergraduate students (32 men and 32 women, aged 18:11-23:8 years, $M = 18:11$) participated in this experiment. For the children, the purpose and method of the study were explained to the head administrators and class teachers of their school, as well as to the parents of the children, who gave permission for participation. The adults participated in the experiment as a part of a psychology class. They were given an explanation about the purpose of the experiment after participating.

2.2 Materials

The stimuli were created in almost the same way as in Sugimura (2013). Figure 1 contains examples of the stimuli. The stimuli were presented as an image on a screen that was 984×693 pixels in size (about 32×24 cm on the display). Two facial images were placed side-by-side. Each face was approximately 300×400 pixels (10×14 cm), and the distance from the center of one face to the center of the other face was 600 pixels.

We prepared four kinds of stimuli (i.e., two incongruent and two congruent): the SD (same face - different hair) stimuli, in which the two images contained the same face (i.e., identical person) but different hairstyles, the DS (different face - same hair), in which the two images contained different faces (i.e., different people) with the same hairstyle, the SS (same face - same hair), in which the two images were completely identical (i.e., same face and hairstyle), and the DD (different face - different hair), in which the two images were completely different (i.e., different faces and hairstyles). We constructed a set of male stimuli and a set of female stimuli. Each set included 16 stimuli: four SD, four DS, four SS, and four DD. In addition, we created a training set, which consisted of four different types of stimuli, for use in the training session.

To create the male set of stimuli, we captured 30 color photographs of Japanese undergraduate males (18–24 years old). The photos were taken from the shoulders up, and contained front views of the individuals with neutral facial expressions and hair concealed with a black headband. The neck and shoulders of the individuals were removed from the photos using Photoshop. We used 8 of the 30 faces for the 8 same-face stimuli (i.e., SD and SS), 16 faces for the 8 different-face stimuli (i.e., DS and DD), and the other 6 faces for training stimuli. We used an identical procedure to create the female images.

We used I-Style (Infinisys, Sendai, Japan), which is a type of software that can be used to simulate different hairstyles, to create various hairstyles for our face stimuli. For the same-hair stimuli (i.e., DS and SS), we composed images containing different or identical faces with the same hairstyle (see Figure 1). For the different-hair stimuli (i.e., SD and DD), we composed images containing identical or different faces with different

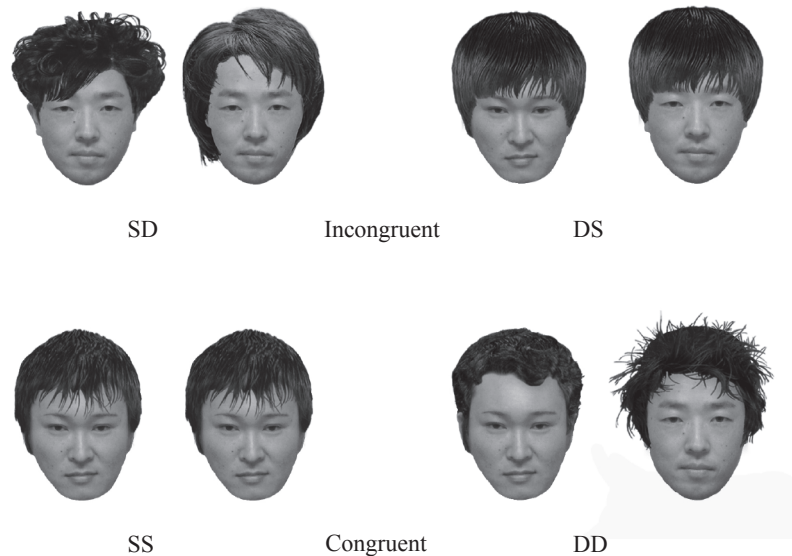


Figure 1: Sample stimuli used in this experiment

Notes: SD: same face - different hair, DS: different face - same hair, SS: same face - same hair, DD: different face - different hair

hairstyles (e.g., long hair vs. short hair, straight hair vs. wavy hair). We used 96 hair patterns (i.e., 48 for the male and 48 for the female images) to create the stimuli.

2.3 Procedure

Our procedure was identical to that used by Sugimura (2013) except that we also presented inverted stimuli. Participants were shown two facial images and asked to decide whether they depicted the same person or two different people. Each participant saw both the male and female set of stimuli (i.e., 16 male and 16 female stimuli) and half of the stimuli (i.e., 8 male and 8 female stimuli) were shown upright while the rest were inverted. Half of the participants were given the male set first and the other half were given the female set first. Whether the stimuli appeared upright or inverted was counterbalanced and the presentation order was randomized for each participant.

All stimuli were presented using a Tobii T60 eye tracker (Tobii Technology, Stockholm, Sweden), with Tobii Studio 2.1 software for managing experiments and collecting data. The stimuli were displayed at a resolution of 1024×768 pixels on a Tobii T60 17-in. monitor. Participants were seated such that the monitor was approximately 60 centimeters from their eyes. We used a five-point calibration for the eye tracking system, in which the participants were required to attend sequentially to animation character pop-ups at five different locations (the four corners and center) on the monitor.

After successful calibration, the female experimenter gave the following instructions while showing one of the stimuli used in the training session. “Now, I am going to show you some pictures of two faces side-by-side. Please tell me whether the two faces are the same person or different people. Sometimes two faces have different hairstyles even though they are the same

person [presenting SD stimuli]. Sometimes two faces have the same hairstyle even though they are different people [presenting DS stimuli]. So, please attend to internal facial features, not to external hairstyles. Also, be careful not to be misled by hairstyles when deciding whether the two faces are the same person or different people. If you cannot decide whether the faces are the same or different people, don’t be too shy to say “I don’t know.” Let’s try this one [presenting one of the stimuli for the training session]. Are these faces the same person or different people?” After four trials had been conducted in the training session, participants were given 32 trials in the test session. They were permitted to take as much time as they wished to make their choices.

The fixation duration prior to the reaction was measured by the experimenter, who pressed one of the reaction keys assigned to *same*, *different*, or *I don’t know* as soon as a participant made a verbal response. We used this procedure because young children are known to have difficulty operating reaction keys.

3. Results

3.1 Accuracy of identification task

For all responses, one point was assigned to each correct response and 0 points to incorrect and “I don’t know” responses. Correct responses were “same” for the SD and SS stimuli and “different” for the DS and DD stimuli. The summed score for each of the four types of stimuli (maximum = 4, two male stimuli and two female stimuli) was the basic unit for further analyses.

Table 1 (Figure 2) shows the mean number of correct responses as a function of age, orientation and stimuli type. We performed a three-way (two age groups \times two orientations \times four stimuli types) ANOVA on the mean scores. The main ef-

Table 1: Mean number of correct responses as a function of condition and stimuli type

| Orientation | Stimuli type | <i>M</i> (<i>SD</i>) | Children (<i>n</i> = 60) | | Adults (<i>n</i> = 64) | | | |
|-------------|--------------|------------------------|---------------------------|-----------|-------------------------|-------------|------|------|
| | | | 95% CI | | 95% CI | | | |
| | | | <i>LL</i> | <i>UL</i> | <i>LL</i> | <i>UL</i> | | |
| Upright | Incongruent | SD | 1.65 (1.55) | 1.37 | 1.93 | 3.95 (0.28) | 3.68 | 4.22 |
| | | DS | 2.67 (1.43) | 2.39 | 2.95 | 3.80 (0.65) | 3.52 | 4.07 |
| | Congruent | SS | 3.45 (1.17) | 3.24 | 3.66 | 4.00 (0.00) | 3.80 | 4.20 |
| | | DD | 3.45 (0.83) | 3.30 | 3.60 | 3.95 (0.21) | 3.81 | 4.10 |
| Inverted | Incongruent | SD | 1.37 (1.54) | 1.08 | 1.65 | 3.81 (0.47) | 3.53 | 4.09 |
| | | DS | 1.33 (1.32) | 1.02 | 1.64 | 3.14 (1.11) | 2.84 | 3.44 |
| | Congruent | SS | 3.38 (1.21) | 3.17 | 3.60 | 4.00 (0.00) | 3.79 | 4.21 |
| | | DD | 3.28 (1.03) | 3.07 | 3.50 | 3.69 (0.64) | 3.48 | 3.90 |

Note: CI = confidence interval; *LL* = lower limit, *UL* = upper limit.

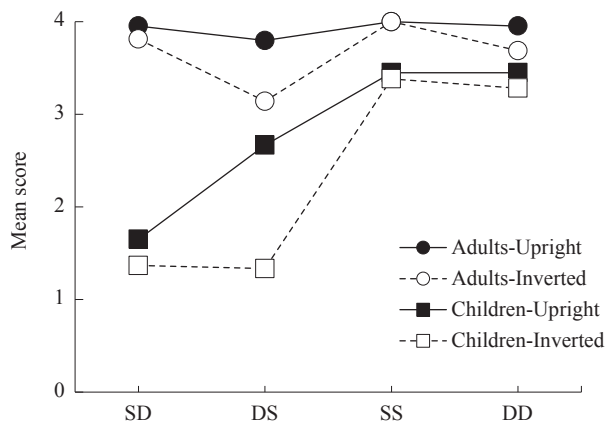


Figure 2: Mean scores of the correct responses as a function of age, orientation and type of stimuli

effect of age was significant, $F(1,122) = 222.30$, $\eta^2 = .646$, $p < .01$, indicating that the mean score obtained by the children was lower than that obtained by the adults. The main effect of orientation was significant, $F(1,122) = 91.72$, $\eta^2 = .429$, $p < .01$, indicating that task performance for the inverted faces was lower than that for the upright faces. The main effect of stimuli type was also significant, $F(3,336) = 46.42$, $\eta^2 = .276$, $p < .01$.

We found significant interactions between age and stimuli type, $F(3,366) = 31.36$, $\eta^2 = .205$, $p < .01$, and orientation and stimuli type, $F(3,366) = 39.19$, $\eta^2 = .243$, $p < .01$. The interaction among age, orientation, and stimuli type was also significant, $F(3,366) = 5.99$, $\eta^2 = .047$, $p < .01$. We found the following simple main effects. In children, the score for inverted images was lower than that for upright images in the SD condition, $F(1,488) = 8.08$, $\eta^2 = .016$, $p < .01$, and DS condition, $F(1,488) = 178.96$, $\eta^2 = .268$, $p < .01$, although we found no difference between the SS and DD conditions. In adults, the score for inverted images was lower than that for upright images in the DS condition, $F(1,488) = 43.35$, $\eta^2 = .082$, $p < .01$, and DD condition, $F(1,488) = 7.10$, $\eta^2 = .014$, $p < .01$.

.01, and we found no difference between the SD and SS conditions. The multiple comparisons revealed the following. When the children viewed the upright stimuli, the ascending order of the scores was $SD < DS < DD = SS$, such that the score for the SD condition was lower than that for the DS condition ($p < .01$) and the score for the DS condition was lower than that for the DD condition ($p < .01$). When the children viewed the inverted stimuli, the ascending order of the scores was $DS = SD < DD = SS$, such that the score for the SD condition was lower than that for the DD condition ($p < .01$). When the adults viewed the upright stimuli, we found no difference among the four conditions. When the adults viewed the inverted stimuli, the ascending order of the scores was $DS < DD = SD = SS$, such that the score for the DS condition was lower than that for the DD condition ($p < .01$).

The response data revealed the following. Overall, the children exhibited difficulties when identifying incongruent stimuli (i.e., SD, DS) and performed particularly poorly in the SD condition, even when viewing the images in the upright orientation. We observed the inversion effect in the responses of the children when viewing the incongruent stimuli, and this effect was large in the DS condition. On the other hand, the responses of the adults revealed almost perfect scores when viewing the images in the upright orientation, however, adults also exhibited a small inversion effect for the DS and DD conditions, in which a “different” response is correct.

3.2 Eye movement behavior

We omitted the data from 6 children and 14 adults because their gaze data were not fully recorded. We used Tobii Studio 2.1 software to compute fixation durations for each of seven areas of interest (AOIs), which included the internal area (eyes, nose, mouth, cheeks, and chin) and external area (hair and forehead). We defined AOIs in the facial area using a similar template as that used in previous eye-tracking studies examining facial recognition (Armann & Bühlhoff, 2009; Goldinger, He, & Papesh,

Table 2-1: Mean fixation duration as a function of age, orientation, and stimuli type (Internal area)

| Orientation | Stimuli type | Children (n = 54) | | | | Adults (n = 50) | | | |
|-------------|--------------|-------------------|-------------|------|--------|-----------------|------|------|--|
| | | M (SD) | 95% CI | | M (SD) | 95% CI | | | |
| | | | LL | UL | | LL | UL | | |
| Upright | Incongruent | SD | 4.23 (2.16) | 3.73 | 4.72 | 3.34 (1.34) | 2.83 | 3.86 | |
| | | DS | 3.71 (1.53) | 3.34 | 4.08 | 2.90 (1.13) | 2.52 | 3.28 | |
| | Congruent | SS | 3.25 (1.83) | 2.85 | 3.66 | 2.32 (0.99) | 1.90 | 2.74 | |
| | | DD | 3.65 (1.71) | 3.26 | 4.04 | 2.62 (1.09) | 2.21 | 3.03 | |
| Inverted | Incongruent | SD | 3.48 (1.97) | 3.01 | 3.95 | 3.55 (1.42) | 3.06 | 4.04 | |
| | | DS | 3.24 (2.72) | 2.64 | 3.85 | 3.77 (1.48) | 3.15 | 4.40 | |
| | Congruent | SS | 2.83 (1.99) | 2.38 | 3.27 | 2.79 (1.14) | 2.33 | 3.26 | |
| | | DD | 3.47 (2.52) | 2.93 | 4.01 | 3.27 (1.14) | 2.71 | 3.83 | |

Note: CI = confidence interval; LL = lower limit, UL = upper limit.

Table 2-2: Mean fixation duration as a function of age, orientation, and stimuli type (External area)

| Orientation | Stimuli type | Children (n = 54) | | | | Adults (n = 50) | | | |
|-------------|--------------|-------------------|-------------|------|--------|-----------------|-------|------|--|
| | | M (SD) | 95% CI | | M (SD) | 95% CI | | | |
| | | | LL | UL | | LL | UL | | |
| Upright | Incongruent | SD | 0.44 (0.52) | 0.34 | 0.55 | 0.13 (0.15) | 0.02 | 0.24 | |
| | | DS | 0.37 (0.39) | 0.29 | 0.45 | 0.07 (0.14) | -0.02 | 0.15 | |
| | Congruent | SS | 0.40 (0.36) | 0.32 | 0.48 | 0.11 (0.18) | 0.03 | 0.20 | |
| | | DD | 0.34 (0.37) | 0.26 | 0.42 | 0.10 (0.22) | 0.01 | 0.18 | |
| Inverted | Incongruent | SD | 0.95 (0.72) | 0.79 | 1.12 | 0.28 (0.45) | 0.11 | 0.45 | |
| | | DS | 1.23 (1.00) | 1.01 | 1.44 | 0.28 (0.48) | 0.06 | 0.51 | |
| | Congruent | SS | 0.99 (0.85) | 0.82 | 1.17 | 0.19 (0.32) | 0.01 | 0.38 | |
| | | DD | 0.95 (0.93) | 0.76 | 1.15 | 0.23 (0.34) | 0.03 | 0.43 | |

Note: CI = confidence interval; LL = lower limit, UL = upper limit.

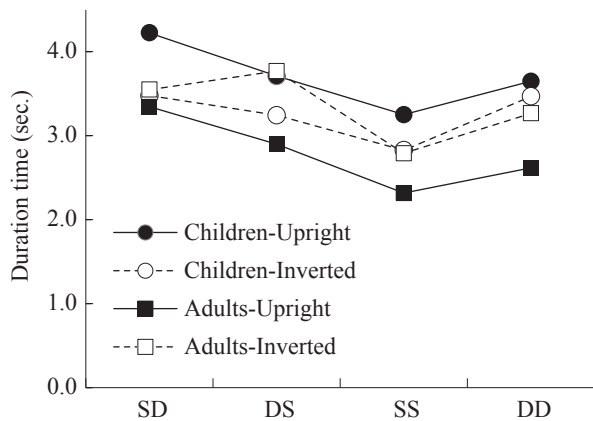


Figure 3-1: Mean fixation duration as a function of age, orientation, and stimuli type (Internal area)

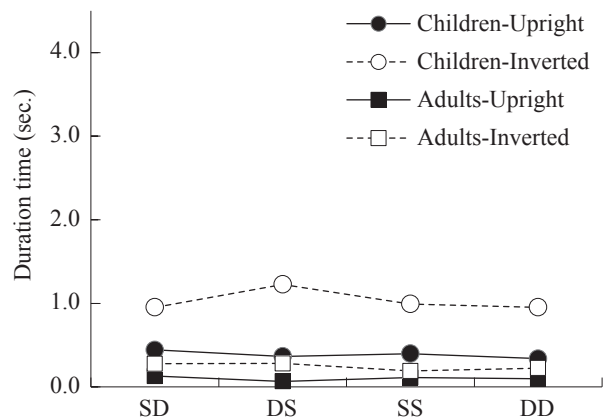


Figure 3-2: Mean fixation duration as a function of age, orientation, and stimuli type (External area)

2009; Henderson, Falk, Minut, Dyer, & Mahadevan, 2001; Williams & Henderson, 2007).

Table 2 (Figure 3) shows the mean fixation duration as a function of age, orientation, stimuli type, and area. We conducted a four-way (two age groups × two orientations × four stimuli × two areas) ANOVA on the mean durations. The main

effects of age, $F(1,102) = 9.58, \eta^2 = .086, p < .01$, orientation, $F(1,102) = 33.68, \eta^2 = .248, p < .01$, stimuli type, $F(3,306) = 15.74, \eta^2 = .134, p < .01$, and area, $F(1,102) = 483.34, \eta^2 = .826, p < .01$, were significant. The interactions between stimuli type and area, $F(3,306) = 21.03, \eta^2 = .171, p < .05$, and be-

tween age and orientation, $F(1,102) = 10.90$, $\eta^2 = .097$, $p < .05$, were significant, which indicated that the children spent the same amount of time looking at the upright and inverted stimuli, while adults spent more time looking at the inverted stimuli compared with the upright stimuli.

The interaction between age, orientation, and area, $F(1,102) = 30.55$, $\eta^2 = .230$, $p < .01$, was also significant. We found the following simple main effects. The children spent longer looking at the internal facial area in the upright stimuli compared with the adults, $F(1,408) = 18.11$, $\eta^2 = .043$, $p < .01$, and the children spent longer looking at the external facial area in the inverted stimuli compared with the adults, $F(1,408) = 13.42$, $\eta^2 = .032$, $p < .01$. The children spent longer looking at the internal facial area in the upright stimuli compared with the inverted stimuli, $F(1,204) = 16.95$, $\eta^2 = .077$, $p < .01$, and they spent longer looking at the inverted stimuli compared with the upright stimuli, $F(1,204) = 34.12$, $\eta^2 = .143$, $p < .01$. The adults spent more time looking at the internal facial area in the inverted stimuli compared with that in the upright stimuli, $F(1,204) = 24.84$, $\eta^2 = .109$, $p < .01$, and we found no difference between the amount of time the adults spent looking at the external facial area in the upright and inverted stimuli.

We obtained the following results from eye movement data. Overall, both the children and adults spent more time attending to the internal vs. external facial area. We found no difference in the amount of time that the children spent looking at the upright compared with the inverted stimuli, however, the adults spent more time looking at the inverted stimuli. When the children viewed the inverted stimuli, the amount of time spent looking at the internal facial area decreased while that of the external facial area increased. The adults spent more time looking at the internal facial area in the inverted stimuli compared with that of the upright stimuli. However, we found no difference in the amount of time the adults spent looking at the external facial area between the upright and inverted stimuli.

4. Discussion

Unlike adults, young children exhibited overall difficulties identifying incongruent stimuli, specifically, a pair of identical faces with different hairstyles or a pair of different faces with identical hairstyles. Thus, for children, the external hairstyles in our stimuli appear to have impeded the processing of the internal face features. In particular, children had difficulty identifying two identical sets of internal face features with different external hairstyles, even when viewing the stimuli in the upright orientation. These results correspond to those reported by Sugimura (2013). Similar results were also described by Knowles & Hay (2014), who used sequential matching tasks. In their experiment, both 6-year-olds and 10-year-olds tended to use external cues (hairstyles) to identify incongruent stimuli. These results confirmed that, unlike adults, children frequently use information from external areas for facial processing when internal informa-

tion conflicts with external information.

We observed inversion effects in the responses of the children to incongruent stimuli. This indicates that children process incongruent stimuli holistically, that is, they process whole faces, including irrelevant information from external areas, when identifying faces. Previous studies (e.g., Picozzi et al., 2009; Pellicano & Rhodes, 2003; Pellicano et al., 2006) have investigated the age at which children first show holistic or configural processing when external areas of a face are systematically excluded. These authors considered holistic processing to be a more proficient and adult-like strategy for facial processing. However, when presented with entire faces, including external information given by hairstyles, holistic processing may be seen as an immature processing strategy that is chosen by individuals who are unable to selectively attend to the internal area of a face or to ignore irrelevant information contained in the external area.

The adults in our study obtained nearly perfect response scores in the upright condition. However, contrary to our expectation, they exhibited a small inversion effect for the DS and DD stimuli, in which a “different” response is correct. This small inversion effect probably occurred not because adults process face holistically (i.e., by including irrelevant information of the external area), but because the inverted stimuli impaired their efficiency with respect to encoding both featural and configural information contained in the central area of the face. As several studies have demonstrated, inverted faces impair efficiency for encoding featural information as well as configural information (Mondloch et al., 2002; Riesenhuber, Jarudi, Gilad, & Sinha, 2004; Yovel & Kanwisher, 2004). The inversion effects observed in adults might reflect a decrease in the efficiency of extraction of all of the relevant featural and configural cues.

That we found a larger inversion effect for children than for adults signifies that the framework of holistic processing must be reconsidered. Facial processing can be divided into two categories: featural processing and configural processing. There is a general consensus in the literature regarding featural processing: it is the componential, piecemeal, analytic, or part-based processing of a single facial attribute, such as the eyes or nose. Configural processing, in contrast, has a much more comprehensive definition. According to Maurer et al. (2002), configural processing can be divided into three categories: sensitivities to first-order relationships (i.e., seeing a basic arrangement, such as two eyes located above the nose), sensitivities to second-order relationships (i.e., perceiving the spatial relationship among features, such as the distance between the eyes), and holistic processing (i.e., gluing together the features into a gestalt). Although the “featural”, “first”, and “second-order” aspects clearly refer to the processing of internal facial areas, which types of processing occur “holistically”, that is, by only referring to internal areas or including external areas (such as hairstyles), is not clear. Therefore, two types of holistic processing must

be clarified: holistic processes that occur among the internal features and those which occur between the internal features and external features, as suggested by Maurer et al. (2002). The latter type of holistic processes may have led to the larger inversion effect observed in children.

Holistic processes used by young children who are not capable of disregarding irrelevant external information must be distinguished from the holistic processes used by adults. Previous studies, in which the influence of the external facial area was controlled, have demonstrated the presence of adult-like holistic processing in an early stage of development that occurs around 4 years of age (e.g., de Heering, Houthuys, & Rossion, 2007; Pellicano & Rhodes, 2003, Picozzi et al., 2009). However, these studies may not have considered the qualitative difference between holistic processing in adults and children in real life situations, such as instances where irrelevant information about external hairstyle can interfere with the identification of internal facial features. Young children tend to process entire faces (i.e., internal and external area) non-selectively. On the other hand, adults are likely to only process the internal area holistically, or to shift to featural processing for internal parts when a target face includes irrelevant information (i.e., external hairstyles).

Overall, we found that both children and adults spent a larger amount of time attending to internal vs. external facial areas. This result corresponded with the results of Sugimura (2011, 2013), in which face matching by children, unlike adults, was likely to be based on the external cue of hairstyle, even though the children mainly attended to internal facial features. In other words, children and adults appear to process information about faces in different ways when making judgments or identifications, even though they attend to the same area of faces.

In children, we found no difference in the amount of time spent looking at upright and inverted faces. However, adults spent more time looking at inverted compared with upright stimuli. This result corresponds to the findings of previous developmental studies (Mondloch et al., 2004; Mondloch et al., 2002) that examined differences in reaction time when identifying upright and inverted faces. For example, in a study by Mondloch et al. (2004), 8-year-old children and adults were asked to make same or different judgments about upright and inverted faces that had facial features with varied spacing. They found that the inversion increased the reaction time in adults but had little or no effect on that in children. That adults had a longer reaction time might have reflected a difference in the types of processing used by children and adults to interpret inverted stimuli. Adults often quickly and automatically generate a whole face representation (Knowles & Hay, 2014) but may change their processing strategy from holistic to featural representation when inversion disrupts holistic or configural information contained in internal facial features. This shift to featural processing, in which the internal features are individually inspected, might increase the length of time taken to identify the face. Indeed, children prob-

ably do not notice the disadvantages of using holistic processing to process both upright and inverted faces. If they use the same type of processing in both cases, this would explain why we did not see a difference in the amount of time taken to process the upright and inverted stimuli.

Our eye-movement data also indicated that the children and adults in our study attended to the inverted stimuli in different ways: In the children, the duration of time spent looking at the internal area decreased and that of the external area increased, while in adults the duration of time spent looking at the internal area increased. These results indicate that, although the developmental difference in processing the upright stimuli was not reflected in the eye-movement but in the response data, that for the inverted stimuli was reflected in both the eye-movement and response data. Given that the featural or analytical aspects of facial processing are likely to be reflected in eye-movement behavior, children might process the combined internal and external areas holistically for upright faces, but only the external area analytically for inverted faces. More precisely, the reaction time might reflect a trade-off between holistic processing of the combined areas and analytical processing of the external area. The poor performance exhibited by the children for the inverted faces in the incongruent condition may be partly due to the increased time required to conduct analytical processing of irrelevant external information, i.e., hairstyles. On the other hand, adults spent more time inspecting the internal area without shifting their attention to the external area. Similar tendencies in adults were observed by Williams & Henderson (2007). These results suggest that adults are able to maintain their focus on an internal area that is relevant for identifying faces, even when an inversion disrupts the overall structure of facial stimuli.

To the best of our knowledge, no studies have compared eye movements in young children while viewing upright and inverted faces. However, a recent study with infants produced results that were similar to ours. Gallay, Baudouin, Durand, Lemoine, & Lécuyer (2006) showed that 4-month-old infants spent more time viewing an external facial area when the face was shown inverted vs. upright. The authors suggested that, in this population, viewing inverted faces results in a transfer from time spent looking at the nose/mouth to exploration of the external area. These results suggest that an increase in the analytical processing of irrelevant external information for inverted faces is an immature strategy that is observed in both young children and infants. However, more data would be required to conclude that this shift to analytical processing of the external area is a general tendency observed at an early developmental stage.

In this study, we examined differences in young children and adults in terms of facial processing of internal and external areas while identifying upright and inverted faces. Our results indicate that young children process whole faces (i.e., internal and external areas) non-selectively, even though external areas contain irrelevant information for identifying faces. In contrast,

adults were more likely to process only internal areas holistically or to shift to featural processing of internal parts. Our eye-movement data indicated that both children and adults attended to mainly internal areas when viewing upright faces, however, when shown inverted stimuli, children tended to shift their attention to external areas. On the other hand, adults spent more time inspecting internal areas that were relevant for identifying faces, even when inversions disrupted the overall structure of the facial stimuli. Further studies are needed to clarify the emergence of mature holistic processing, in which an individual selectively focuses on relevant information contained in the internal facial area. Additionally, instead of the traditional view, centered on a dichotomic developmental shift from featural to holistic processing, future research should consider the development of flexibility in selecting a processing strategy (i.e., holistic or featural) when obtaining information for the effective identification of faces.

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Note

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