

Developmental improvement and age-related decline in unfamiliar face matching

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Abstract

Age-related changes have been documented widely in studies of face recognition and eyewitness identification. However, it is not clear whether these changes arise from general developmental differences in memory or occur specifically during the perceptual processing of faces. We report two experiments to track such perceptual changes using a 1-in-10 (Experiment 1) and 1-in-1 (Experiment 2) matching task for unfamiliar faces. Both experiments showed improvements in face matching during childhood and adult-like accuracy levels by adolescence. In addition, face-matching performance declined in adults of the age of 65. These findings show that developmental improvements and aging-related difficulties in face processing arise directly from a perceptual deficit. A clear face inversion effect was also present in all age groups. This indicates that those age-related changes in face matching reflect a quantitative effect, whereby typical face processes are engaged but do not operate at the best-possible level. These data suggest that part of the problem of eyewitness identification in children and elderly persons might reflect impairments in the perceptual processing of unfamiliar faces.

Keywords: face matching; development; aging; individual differences

Introduction

Cognition improves with development and declines with aging. This fact is reflected clearly in different memory processes. Working memory capacity and long-term memory performance, for example, improve during childhood and adolescence but then worsen severely during old age (for extensive reviews, see, e.g., Graf & Ohta, 2002; Whitbourne & Sliwinski, 2012). The experiments reported here focus on an important aspect of human social cognition that may have been conflated with such age-related cognitive differences in memory, namely the ability to process faces. Age-related changes in face recognition have already been documented extensively (for a review, see, e.g., Chung & Thomson, 1995). However, the majority of these studies have used memory-based tasks. It is now clear that performance in face identification is also a perceptual skill that is dissociable from memory processes (see, e.g., Burton, White, & McNeill, 2010; Megreya & Burton, 2008; Megreya, White, & Burton, 2011). As a consequence, it remains unresolved whether age-related changes in face recognition ability are due to general developmental differences that reflect the memory component of previous tasks or whether these changes occur also during the perceptual processing of faces.

A substantial body of work shows that face recognition accuracy improves dramatically prior to adulthood. This finding is so robust that it has been replicated with a wide variety of recognition memory tasks (see, e.g., Carey, Diamond, & Woods, 1980; Ellis & Flin, 1990; Mondloch, Geldart, Maurer, & Le Grand, 2003; Pezdek, Blandon-Gitlin, & Moore, 2003; Schwarzer, 2000) and eyewitness identification paradigms (Beal, Schmitt, & Dekle, 1995; Havard, Clifford, Memon, & Gabbert, 2010; Lindsay, Pozzulo, Craig, Lee, & Corber, 1997; Pozzulo & Balfour, 2006). However, these studies have

reported mixed results regarding the nature of this improvement. Recognition memory experiments have found age-related improvements up until the age of ten in the correct identification of previously-seen faces and also in the rejection of previously-unseen faces (for reviews and meta-analysis, see, e.g., Chance & Goldstein, 1984; Chung & Thomson, 1995; Shapiro & Penrod, 1986). However, eyewitness identification studies show that children over five years of age already produce a rate of correct person identifications that is comparable to adults (for a meta-analysis, see, e.g., Pozzulo & Lindsay, 1998) but older children continue to improve in making correct rejections (for a recent review, see Havard, 2014).

This contrast has been attributed to a key difference between face recognition and eyewitness identification tasks (Pozzulo & Lindsay, 1998). While the former typically require observers to encode and remember the faces of many individuals, the latter usually involve only a single target identity. The delayed onset of adult-like rates of correct identifications in face recognition experiments might therefore reflect the increased demands of these tasks. This points to an increase in memory load capacity with age rather than an improvement in face identification ability *per se* (Pozzulo & Lindsay, 1998).

In addition to improvements in face recognition memory during development, several studies have also shown that this ability deteriorates severely with aging. Once again, this effect has been demonstrated using tests of face memory (Bäckman, 1991; Bartlett, Strater, & Fulton, 1991; Bartlett, Shastri, Abdi, & Neville-Smith, 2009; Boutet & Faubert, 2006; Germine, Duchaine, & Nakayama, 2011; Lamont, Stewart-Williams, & Podd, 2005) and eyewitness identification (Memon, Bartlett, Rose, & Gray, 2003;

Searcy, Bartlett, & Memon, 1999; Searcy, Bartlett, Memon, & Swanson, 2001). These detrimental aging effects are manifested in the false acceptance of new faces as someone that was seen previously rather than a reduction in the correct recognition of such previously-seen targets (e.g., for reviews see Bartlett, 1993; Searcy et al., 1999, Bartlett & Memon, 2006).

Several theories have been proposed that aim to integrate the developmental and aging aspects of face recognition performance. On one hand, children's face recognition immaturity has been linked to their inability to process configural information, whereby faces cannot be perceived as integrated holistic percepts of separate visual facial features (e.g., the eyes, nose, and mouth) in the way that adults do (see, e.g., Freire & Lee, 2001; Mondloch et al., 2003; Mondloch, Le Grand, & Maurer, 2002). On the other hand, aging-related increases in false identifications are thought to reflect deficits in recollecting context and an increased reliance on a *sense* of familiarity, rather than explicit conscious memories for a face, in making identification decisions (see, e.g., Searcy et al., 1999). In support of this reasoning, a positive association has been found in older adults only between familiarity ratings for unfamiliar faces and the correct and incorrect identification rates for these stimuli as "known" (see, e.g., Barton & Fulton 1991; Edmonds, Glisky, Bartlett, & Rapcsak, 2012; Rhodes, Castel, & Jacoby, 2008).

An important question for the interpretation of these age-related effects is whether these differences arise during the memorial or perceptual processing of faces. A few studies have already examined this question using the Benton Face Recognition Test (BFRT; see Benton, 1980; Carey, Diamond, & Woods, 1980; de Heering, Rossion, & Maurer, 2012; Searcy et al., 1999). This neuropsychological test requires observers to

match a face target to a six-person line-up, which contains either an identical image of the target (BFRT part 1) or three different images of the same target, which vary in viewpoint and lighting (BFRT part 2). In a pioneering study, Carey et al. (1980) reported continuous developmental improvements on this test from 68% to 84% accuracy with eight groups of children and adolescents, which were aged between 7 and 16. In a more recent study, de Heering et al. (2012) presented a computerized version of the BFRT to middle- or late-aged children (~ 7 – 10 years of age), early adolescents (~ 10-12 years of age), and young adults (19 years of age). de Heering et al (2012) also reported reliable improvements between middle- and late-aged children and between adolescents and early adults, but not between late-aged children and adolescents. In addition, some studies on aging also show that late adults (~ 70 years of age) score poorer than early adults (~ 24 years of age) on the BFRT (Benton, Eslinger, & Damasio, 1981; Searcy et al., 1999).

While these findings are informative, the effects of development (de Heering et al., 2012) and aging (Searcy et al., 1999) have not been compared directly with the BFRT. However, the BFRT also might not be suited best to capture age-related changes in perceptual processing of faces. Previous research in face recognition and eyewitness identification has shown inflated rates of false positive for children and late adults (e.g., for reviews, see Bartlett & Memon, 2006; Chung & Thomson, 1995; Havard, 2014; Pozzulo & Lindsay, 1998). The BFRT does not include target-absent trials, in which the targets are not present in the corresponding identity lineups, and that are crucial for measuring false positives. An alternative assessment that can capture such identification errors is the 1-in-10 task (Bruce, Henderson, Greenwood, Hancock, Burton & Miller, 1999). In this task, observers are presented with target faces, which have to be selected

from corresponding ten-face identity lineups (for an example, see Figure 1). Crucially, the target can be present or absent from the identity lineups, thus allowing for the measurement of correct identifications in the presence of the target and of false positives in its absence.

This task is considered a best-case scenario for measuring face perception as all images are matched for viewing angle, lighting and pose, and the targets and their counterparts in the lineup were photographed only a few minutes apart. Despite this, performance on the 1-in-10 task is surprisingly poor (Bruce et al., 1999). When the target is present in a lineup, it is identified correctly only on approximately 70% of trials, whereas absent responses occur on 20% and mistaken identifications, of other lineup members, on 10% of trials. Similarly, the targets' absence from the lineups is noted about 70% of the time while false identifications of other lineup members occur on 30% of trials.

This low level of performance has now been replicated many times (Konar, Bennett, & Sekuler, 2010; Megreya & Bindemann, 2013; Megreya & Burton, 2006a, 2007, 2008; Megreya, White, & Burton, 2011). In most of these studies, the targets are presented immediately prior to the identity lineups. Crucially, however, the same performance pattern also holds when memory demands are eliminated by presenting the photographs of target faces simultaneously with the corresponding lineups (Bindemann, Sandford, Gillatt, Avetisyan, & Megreya, 2012; Megreya & Burton, 2006b) and even when live targets are shown alongside the lineup displays (Megreya & Burton, 2008). This indicates that the 1-in-10 task provides a good test of face perception for conditions in which the influence of memory factors should be minimized.

The 1-in-10 task also appears to be a good index of an individual's face identification ability. For example, performance in this task can be used to estimate the identification accuracy of individual eyewitnesses (e.g., Bindemann, Brown, Koyas, & Russ, 2012) and correlates with aspects of personality, such as anxiety (Megreya & Bindemann, 2013). This sensitivity to individual differences suggests that the 1-in-10 task is also an appropriate test for studying different age groups. The present study therefore sought to assess age differences in face identification with the 1-in-10 task. We compared seven different age groups, comprising young children, adolescents, and young, middle-aged and older adults to chart both the development and decline of facial identification.

Experiment 1

This experiment examined age differences in face perception using the 1-in-10 matching task for unfamiliar faces (see Bruce et al., 1999). In each trial of this task, observers were shown a target face and a concurrent lineup of ten faces, in which the target could be present or absent. Observers had to decide whether the target is present, and if so, indicate who it is. This matching task provides a useful test of individual differences (see, e.g., Bindemann, Brown, et al., 2012; Megreya & Bindemann, 2013; Megreya & Burton, 2006). In contrast to previous studies on age differences in facial identification, this matching task also minimizes memory demands (c.f., e.g., Bäckman, 1991; Bartlett et al., 1991; Germine et al., 2011; Lamont et al., 2005) and allows for the measurement of false positives (Carey et al., 1980; de Heering et al., 2012; Benton et al.,

1981; Searcy et al., 1999). Experiment 1 compared seven age groups with this task, ranging from 7 to 65 years of age.

Method

Participants

A total of 330 Egyptian participants volunteered for this experiment. These consisted of children, adolescents and young, middle-aged, and older adults. The children and adolescents were recruited from primary and secondary schools in Menoufia, Egypt, whereas young adults were recruited from Menoufia University. Parental consent for participation for child and adolescent participants was obtained prior to the experiment. The middle-aged adults were teachers at the primary and secondary schools where all children were recruited or were employees at Menoufia University. The oldest age group consisted of retired adults. These participants were assigned to seven groups, with mean ages ranging from 7 to 65 years. Details of these age groups are provided in Table 1. All participants had normal or corrected to normal vision and self-reported to be in good health.

Stimuli

The stimuli consisted of 50 target-present and 50 target-absent face-matching arrays (see Figure 2). These arrays were taken from an Egyptian database (see Megreya & Burton, 2008), which was constructed from facial photographs of university students. Each of these arrays consisted of a still image of an unfamiliar face target, which was recorded with a video camera. In each stimulus display, an identity line-up was shown

below this target image. This consisted of photographs of ten faces, which were taken with a digital camera. All of these face images were presented in good resolution (72 ppi) at a size of approximately 7 x 10 cm and were matched in viewpoint, lighting, and facial expression.

For each of the stimulus displays, a target-present and a target-absent line-up were constructed. In target-present arrays, the photograph of the target face and its counterpart in the lineup were recorded on the same day to eliminate transient differences in, for example, hairstyle, health, weight, or age. The lineup location of the targets was also counterbalanced so they were equally likely to appear in each of the ten lineup locations. The target-absent displays were identical to target-present stimuli, with the exception that the target faces were replaced in the lineups with a foil. For further details, see Megreya and Burton (2008).

Procedure

Participants were tested individually. The experimental materials were presented in booklets at a rate of one stimulus display per page. Two booklets were constructed to counterbalance the presence and absence of targets, so that the same target was never encountered twice (i.e., in a target-present and a target-absent display) by the same participant. However, over the course of the experiment, each target face was seen equally often in a target-present and a target-absent array.

Each participant completed 50 trials (25 target-present and 25 target-absent), which were presented in a random order. The participants were asked to match the identity of the target face to its counterpart in the 10-face line-up. They were instructed

that the target might be present or absent in each display. Participants recorded their responses on an answer sheet by writing the number of the lineup face that was identified as the target or by marking the target as absent. The task was self-paced and participants were encouraged to perform as accurately as possible. All children between 7 and 10 years of age were given five practice trials for which feedbacks was provided.

Results

Performance for target-present and target-absent lineups reflects dissociable abilities (Megreya & Burton, 2007), so these conditions were analyzed separately. For target-present and target-absent lineups, the percentage of correct identifications of the target and the incorrect acceptance (false positives) of lineup faces as the target were calculated, respectively. This data is provided in Table 2. A series of independent-samples t-tests did not find sex differences in any of the age groups (all $t_s \leq 1$, all $p_s > 0.05$). In addition, a series of one-sample Kolmogorov-Smirnov tests revealed that participants' performance was distributed normally around the group means (Z_s ranged from 0.54 to 1.2, all $p_s > 0.05$). Finally, a series of one-sample t-tests showed that correct identifications of the target and correct rejections of target-absent lineups (i.e., the complement of FPs) in all age groups were higher than a chance level of 10%, all $t_s > 17.15$, all $p_s < 0.01$.

To compare the age groups directly, two one-way between-subjects Analyses of Variance (ANOVAs) were conducted to analyze performance for target-present and target-absent trials. These ANOVAs showed a main effect of age for correct identifications, $F(6,323) = 44.66, p < 0.001, \eta_p^2 = 0.55$, and false positives, $F(6,323) =$

11.23, $p < 0.001$, $\eta_p^2 = 0.17$. To analyse performance for different ages, Tukey HSD tests were conducted to compare adjacent age groups (see Table 3). These comparisons showed that hit rates increased between the ages 7 and 16, were equivalent for the 16-, 19- and 35-year age groups, and then declined in adults aged 65. In contrast, false positives decreased until the age of 10, then remained constant until the age of 30, but increased again in 65-year-olds.

Discussion

This experiment explored age-related changes in face matching using the 1-in-10 task. There were remarkable increases in correct target identifications through the ages of 7 to 16 years. Thereafter, the percentage of correct identifications did not differ between the ages of 16, 19 and 30. A similar, but not identical, pattern was observed for target-absent lineups. For this measure, false positives decreased between 7 and 10 years of age, but then remained stable until the age of 30. Thus, performance for target-absent lineups reached adult-like levels earlier than correct identifications, at 10 compared to 16 years of age. Finally, between the age of 35 and 65, correct identifications declined and false positives increased, but the increase in the latter (23.6%) exceeded the decrease in the former (12.1%).

These age-related changes in face matching ability converge with studies of face recognition memory, which have also shown improvements in correct identifications and a decrease in false positives with development (e.g., Chance & Goldstein, 1984; Chung & Thomson, 1995; Shapiro & Penrod, 1986) and a reverse of this trend during later adulthood (Bäckman, 1991; Bartlett et al., 1991; 2009; Boutet & Faubert, 2006; Germine

et al., 2011; Lamont et al., 2005). While these effects may reflect developmental improvements and a later decline in *memory*, a similar pattern has been found for correct identification with the BFRT, which provides a more direct test of *face* perception (Carey et al., 1980; de Heering et al., 2012; Searcy et al., 1999). Experiment 1 replicates these findings with another direct test of face matching, in which memory factors are minimized, and extends previous results to target-absent trials.

Experiment 2

Experiment 1 shows a developmental improvement in face matching during childhood and a decline in later adulthood. A possible explanation for these effects may lie in the difficulty of the task, which might put a particular strain on younger and older age groups. This difficulty arises in part from the number of comparisons that are required to contrast a target with each of the ten lineup faces as accuracy improves with reduced lineups of five faces (see Bindemann, Sandford, Gillatt, Avetisyan, & Megreya, 2012; Megreya, Bindemann, Havard, & Burton, 2012). Performance is even better when this task is reduced to a simple pair-matching scenario, in which observers have to decide whether two concurrent faces depict the same person or two different people (Megreya & Burton, 2006, 2008). In Experiment 2, we therefore sought to replicate our findings with such a 1-to-1 pairwise matching task. Our aim here was to determine whether the developmental disadvantage and the age-related decline in face matching persists when task difficulty is reduced in this way.

In an additional step, we also compared matching for upright faces with inverted faces that are turned upside down. Such inversion impairs face perception across a wide

range of tasks. This is held to reflect a disruption of normal face processes, whereby inverted faces are processed in a manner that is more similar to general object processing (see, e.g., de Gelder & Rouw, 2000; Farah, Wilson, Drain, & Tanaka, 1995; Moscovitch, Winocur, & Behrmann, 1997). The absence of an inversion effect is also taken as evidence that the face-processing system is damaged or underdeveloped (see, e.g., Behrmann & Avidan, 2005; de Gelder & Rouw, 2000; Duchaine, Yovel, Butterworth, & Nakayama, 2006). If the developmental disadvantage and the age-related decline that were observed in Experiment 1 reflect an impairment of face-specific processes then performance should be more comparable in the affected groups (e.g., the 7- and 65-year-olds) for upright and inverted faces. If, on the other hand, these face processes are intact but simply not functioning at the level of adolescents and young- and middle-aged adults, then we would expect to find a decrease in accuracy in the youngest and oldest observers but also an inversion effect. The inverted face condition therefore allows us to explore whether the developmental disadvantage and the age-related decline reflect a qualitative shift in the manner that faces are processed or a quantitative effect.

Method

Participants

A total of 200 Egyptian participants volunteered for this experiment. As in Experiment 1, these participants consisted of children, adolescents and young, middle-aged and older adults, which were recruited from primary and secondary schools and Menoufia University. However, none of these participants had taken part in Experiment 1. These participants were assigned to five groups, with ages from 7 to 65 years (see

Table 4). All participants had normal or corrected to normal vision and self-reported to be in good health. As in Experiment 1, parental consent for participation for child and adolescent participants was obtained prior to the experiment.

Stimuli

The stimuli consisted of 160 face pairs, which depicted unfamiliar faces. As in Experiment 1, all face stimuli were taken from Megreya and Burton's (2008) Egyptian face-matching database. Half of these face pairs depicted identity matches, in which two different photographs of the same person were shown. The other half consisted of identity mismatches, in which two different people were depicted. In each match and mismatch display, one face image was taken with a high-quality digital camera whereas the other consisted of a still frame from high-quality video footage. In all of these pictures, the faces were shown in a frontal view, with a neutral expression, and any extraneous background was removed. To produce the inverted face conditions, each of these stimulus pairs was turned upside-down. This resulted in a total of 320 experimental displays, comprising 80 match and 80 mismatch pairs in the upright and the inverted face condition. Example stimuli are shown in Figure 3.

Procedure

In the experiment, these stimuli were presented in a booklet at a rate of one face pair per page. Observers were asked to decide whether the two faces in a pair showed one person or two different people and recorded their responses on an answer sheet. Each participant was shown 80 stimuli consisting of 20 match and 20 mismatch pairs for the

upright and the inverted condition. The stimulus set was rotated around conditions, so that each target identity was only shown once to each observer in any of the conditions. However, over the course of the experiment, the presentation of face pairs was counterbalanced across participants (in four separate booklets), so that each stimulus appeared in each condition an equal number of times.

Results

The mean percentage responses for match trials (correct identifications) and for mismatch trials (false positives) are shown in Table 5 as a function of face orientation and age. A series of independent-samples t-tests did not find sex differences in any of the age groups for the upright and inverted face conditions in both correct identifications and false positives (all $t_s \leq 1$, all $p_s > 0.05$). In addition, a series of one-sample Kolmogorov-Smirnov tests revealed that these data were distributed normally around the group means (Z_s ranged from 0.46 to 0.98, all $p_s > 0.05$). Finally, a series of one-sample t-tests showed that correct identifications and correct rejections (the complement of FPs) were higher in all age groups than a chance level of 50%, all $t_s > 2.23$, all $p_s < 0.05$.

To compare matching performance across age groups, these data were subjected to two 2 (upright vs. inverted) x 5 (7-, 10-, 13-, 19- and 65-year olds) mixed-subjects ANOVAs. For correct identifications, main effects of age, $F(4,195) = 7.42, p < 0.001, \eta_p^2 = 0.45$, and orientation, $F(1,195) = 176.89, p < 0.001, \eta_p^2 = 0.48$, and an interaction between these factors were found, $F(4,195) = 5.49, p < 0.001, \eta_p^2 = 0.10$. Table 6 reports Tukey HSD tests between adjacent age groups. For upright face pairs, these comparisons show that correct identifications increased between the ages of 10 and 13 and then

declined between 19 and 65. The percentage of false positives showed a decline between 7 and 13 years of age and an increase between 19 and 65 years. By contrast, performance for inverted face pairs appeared to be consistent across age groups. Tukey HSD revealed only a decrease of false positives between the ages of 7 and 10. No other comparisons were significant (see Table 6). In addition, a consistent inversion effect was found. This was present in both correct identifications and false positives across all age groups.

Discussion

This experiment aimed to replicate the findings of Experiment 1 with a less difficult task, by reducing the 1-in-10 displays to a 1-to-1 comparison. This manipulation was clearly successful. Correct identifications, for example, improved for 7-year-olds from 41% in Experiment 1 to 75% in Experiment 2, and for 19-year-olds from 79% to 85%. Despite these differences between experiments, we again observed a developmental improvement and an age-related decline. This improvement continued into adolescence in both correct identifications and false positives, but then deteriorated again by the age of 65. These findings are remarkable because the current paradigm provides a highly optimized test for the perceptual identification of unfamiliar faces (see, e.g., Burton et al., 2010; Megreya & Burton, 2006, 2007, 2008). These results therefore rule out that the pattern of Experiment 1 arises simply from the difficulty of the 1-in-10 task.

We also compared face matching for upright with inverted faces to explore whether these age effects reflect a qualitative shift in the manner that faces are processed or a quantitative effect (see, e.g., Behrmann & Avidan, 2005; de Gelder & Rouw, 2000; Duchaine, Yovel, Butterworth, & Nakayama, 2006). This manipulation revealed a

consistent inversion effect for match and mismatch face pairs across all age groups. This indicates that the drop in accuracy that is found with the youngest and oldest participants here does not reflect an impaired reliance on face-specific processes. Instead, these findings suggest that these typical face processes are intact in the younger and oldest observers here, but are simply not functioning at the level of adolescents and young- and middle-aged adults.

General Discussion

This study examined age-related changes in the perceptual processing of faces with two matching tasks. In Experiment 1, participants from seven age groups, ranging from 7 to 65 years, were asked to match unfamiliar face targets to lineups of 10 faces. In this task, a continuous developmental improvement in face matching was found between the ages of 7 and 16 years in the ability to identify the targets from lineups (i.e., correct identifications). By the age of 16, adolescent observers appeared to have reached performance levels that are comparable to 19- and 35-year old adults. However, this ability then declined again by the age of 65. A slightly different pattern was observed for the correct rejection of lineups that did not include the target. In these cases, performance also improved from 7 to 10 years of age, but then remained constant throughout adolescence and early and middle adulthood. However, similar to correct identifications, the ability to notice the absence of a target from a lineup also deteriorated by the age of 65. Both measures therefore show a developmental improvement, albeit along different trajectories, and an age-related decline in face matching ability.

In Experiment 2, participants from five age groups, ranging also from 7 to 65 years, were then presented with pairs of faces that required simple identity match or mismatch decisions. For both types of decisions, this task showed a developmental improvement between 7- and 13 years of age and an age-related decline for 65-year-old observers. In addition, Experiment 2 also compared performance for pairs of upright and inverted faces to explore whether the impairment in children and old adults arises from a qualitative shift in the manner that faces are processed or a quantitative effect (see, e.g., Behrmann & Avidan, 2005; de Gelder & Rouw, 2000; Duchaine et al., 2006). A consistent inversion effect was found across all age groups. This indicates that the youngest and the oldest participants, despite their impaired performance, also rely on face-specific processes to complete the matching tasks. However, the level at which these processes are generally functioning appears to be impaired compared with adolescents and young- and middle-aged adults.

These findings converge with previous research that has employed the BFRT to study developmental improvements in face perception (Carey et al., 1980; de Heering et al., 2012). However, the exact age at which adult-like levels of performance emerge appears to vary somewhat across studies. de Heering et al. (2012) found, for example, that accuracy on the BFRT increased between childhood, adolescence and early adulthood. By contrast, Carey et al. (1980) already observed adult-like performance in 16-year-old adolescents. We also found some variation in our study, whereby adult-like levels of performance in correct identifications were reached at an earlier age in Experiment 2, at 13 years, than in Experiment 1. In the current study, it is possible that this reflects the difficulty of the different tasks. For example, whereas 7-year-olds

recorded correct identifications on only 41% of trials in Experiment 1 compared to 75% in Experiment 2, this difference had narrowed to 62% and 81% by the age of 13, and performance was much more comparable, at 79% and 85%, in 19-year-olds. Thus, this suggests that children and adolescents might reach adult-like levels in face matching performance later during development under more difficult task conditions.

Interestingly, these developmental changes in correct identifications in Experiment 1 and 2 do not seem to support the encoding overload hypothesis (Pozzulo & Lindsay, 1998). According to this theory, the delayed onset of adult-like identification rates in face recognition experiments, as compared to eyewitness identification studies, can be attributed to the larger numbers of faces that need to be encoded in this type of study. Seemingly in line with this reasoning, it has already been shown that memory load (the number of targets shown in the initial learning phase) rather than recognition load (the total number of targets and distractors faces shown in the subsequent recognition phase) accounts for the decline in recognition memory for unfamiliar faces (Metzger, 2002; Podd, 1990). However, these memory load effects seem to occur independent of the age of participants (Metzger, 2002). Moreover, the current study revealed developmental improvements in correct identifications with a task in which only one target had to be encoded at a time and memory loads were minimized. This indicates that the delayed onset of adult-like identification rates in face recognition experiments cannot be attributed to the memory load of these tasks. Further research is clearly required to examine why correct identifications reach maturation later in face recognition tasks than eyewitness paradigms.

In contrast to previous matching studies that have explored age effects in face perception (Carey et al., 1980; de Heering et al., 2012), our paradigms also measured correct rejections and false positives. There is a general consensus that correct identifications increase dramatically, and false positives decrease, prior to or during adolescence in face recognition (see, e.g., Chung & Thomson, 1995; Shapiro & Penrod, 1986) and eyewitness identification (e.g., Bartlett & Memon, 2006; Havard, 2014; Pozzulo & Lindsay, 1998). The present study provides a further replication of this finding but with perceptual tasks in which memory factors are minimized. This indicates that a difficulty in encoding unfamiliar faces in the first place, independent of any memory-related problems, contributes to problems in eyewitness identification in children. This is interesting as researchers have already attempted to improve the reliability of eyewitness identifications in children by implementing procedural changes such as elimination lineups (Pozzulo & Lindsay, 1999) or the inclusion of a “not sure” response option (Brewer, Keast, & Sauer, 2010). The current findings suggest that attempts to improve the accuracy of eyewitness identification in children also need to focus on assessing their ability to encode unfamiliar faces in the first place (for similar approaches with adult observers, see, e.g., Bindemann, Avetisyan, & Rakow, 2012; Bindemann, Brown, et al., 2012; Geiselman et al., 2001; Hosch, 1994).

In addition to the developmental improvements in face matching, Experiment 1 and 2 also recorded a decline in matching accuracy in later adulthood, in 65-year-old observers. These detrimental aging effects converge with previous studies on face recognition memory (Bäckman, 1991; Bartlett et al., 1991; 2009; Boutet & Faubert, 2006; Germine et al., Lamont, et al., 2005) and eyewitness identification (Memon et al.,

2003; Searcy et al., 1999; 2001). A similar decline is also observed in face matching with the BFRT (Benton et al., 1981; Searcy et al., 1999). Our experiments reaffirm these findings and extend previous results with the BFRT to correct rejections for target-absent lineups (Experiment 1) and identity-mismatch face pairs (Experiment 2). Similar to the developmental improvements in childhood and early adolescence, our findings therefore indicate that the age-related decline in face recognition memory and eyewitness identification is not only a memory problem but also reflects a visual problem in the perceptual encoding of unfamiliar faces.

It is noteworthy that some researchers have previously argued against this suggestion on the basis that false positives in eyewitness identification remain high in older adults who also perform well on the BFRT (Searcy et al., 1999). However, it has emerged subsequently that correct identifications and false positives reflect dissociable processes, whereby the ability to make a person identification is unrelated to the ability to reject an identity lineup (Burton et al., 2010; Bruce et al., 1999; Megreya & Burton, 2006b, 2007). This indicates that it is inappropriate to use a measure of correct identifications, such as performance on the BFRT, to support inferences about an observer's tendency to record false positives.

In summary, the current study provides direct evidence from identity matching paradigms that the widely documented age-related changes in face recognition occur during the perceptual encoding of faces. These effects were accompanied in all age groups by a consistent inversion effect. This indicates that even the youngest and oldest participants, despite their impaired performance, rely on face-specific processes to complete the matching tasks. However, the level at which these processes are generally

functioning appears to be impaired in observers below the ages of 16 (Experiment 1) or 13 (Experiment 2) and in 65-year-old adults (Experiment 1 and 2). We attribute the difference in the age at which this disadvantage disappeared in children to the difficulty of our different tasks. However, the precise age at which face recognition generally reaches maturation does, in fact, remain controversial. It has been argued that all qualitative (for a review, see, e.g., McKone, Crookes, & Kanwisher, 2009) and quantitative aspects (Crookes & McKone, 2009) of adult-like face recognition are present in young children at 5-7 years of age at the latest. According to this view, any developmental increases in face recognition reflect improvements in general cognitive mechanisms such as concentration, visual attention, and explicit memory ability (see, e.g., Crookes & McKone, 2009). However, it has also been suggested that recognition memory for names and inverted faces reaches maturation in the early 20s, whereas the ability to learn and recognize unfamiliar faces peaks later, in the early 30s (Germine et al., 2011). This difference could indicate that improvements in face recognition cannot be accounted for by general cognitive factors. The present study adds to this debate by demonstrating that face matching reaches adult-like levels of performance at an earlier age than face memory, between 13 and 16 years of age (c.f., e.g., Germine et al., 2011). These results appear to converge with neuroimaging studies, which have revealed significant expansions of face-selective brain areas between childhood and adolescence (Aylward et al., 2005) whereas adolescents then show more adult-like patterns of face-selective brain activation (Scherf, Behrmann, Humphreys, & Luna, 2007).

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TABLE 1. Summary statistics for the seven age groups of the participant sample in Experiment 1.

Age group	N	Sex	Age (SD)
7-year-olds	40	20 M / 20 F	7.3 (0.5)
10-year-olds	50	25 M / 25 F	10.0 (0.7)
13-year-olds	40	20 M / 20 F	13.4 (0.5)
16-year-olds	50	25 M / 25 F	16.1 (0.2)
19-year-olds	50	17 M / 33 F	19.5 (1.5)
35-year-olds	50	20 M / 30 F	34.9 (2.8)
65-year-olds	50	32 M / 18 F	65.0 (4.7)

TABLE 2. Descriptive statistics for face matching performance across age groups in Experiment 1.

Age Groups	Correct identifications		False positives	
	Mean	SD	Mean	SD
7-year olds	41.3	11.5	54.6	15.4
10-year olds	51.8	14.4	38.4	20.1
13-year olds	61.7	14.3	37.2	21.9
16-year olds	74.7	12.9	31.5	21.5
19-year olds	79	14.7	28.6	20.5
35-year olds	74.8	16.0	31.8	23.3
65-year olds	62.7	13.3	55.4	30.5

TABLE 3. Tukey HSD comparisons for face matching performance across adjacent age groups in Experiment 1. Note: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

	Correct identifications		False positives	
	Tukey's q	Cohen's d	Tukey's q	Cohen's d
7 vs. 10	5.14**	0.81	4.92*	0.91
10 vs. 13	4.81*	0.69	0.36	0.06
13 vs. 16	6.35**	0.96	1.73	0.26
16 vs. 19	2.11	0.31	0.90	0.14
19 vs. 35	2.07	0.27	0.97	0.15
35 vs. 65	5.89**	0.82	7.17**	0.87

TABLE 4. Summary statistics for the seven age groups of the participant sample in Experiment 2.

Age group	N	Sex	Age (SD)
7-year-olds	40	18 M / 22 F	7.0 (0.4)
10-year-olds	40	20 M / 20 F	9.8 (0.5)
13-year-olds	40	20 M / 20 F	13.2 (0.3)
19-year-olds	40	14 M / 26 F	19.2 (0.4)
65-year-olds	40	26 M / 14 F	65.6 (0.3)

TABLE 5. Descriptive statistics for face matching performance as a function of participant age and face orientation in Experiment 2.

	Correct identifications				False positives			
	Upright		Inverted		Upright		Inverted	
	M	SD	M	SD	M	SD	M	SD
7-year-olds	74.6	12.5	68.7	11.7	40.8	13	46.1	11
10-year-olds	68.2	12.4	61	10.9	27.5	12.7	33.5	11.8
13-year-olds	80.7	12.3	69.6	13.6	15.4	9.7	30	15
19-year-olds	85	13	69.6	11.8	22.6	12.7	33.9	12.3
65-year-olds	72.7	14.2	64.5	15.4	34.4	12.9	39.4	15.9

TABLE 6. Tukey HSD comparisons for face matching performance across adjacent age groups in Experiment 2. Note: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

Comparisons	Correct identifications		False positives	
	q	Cohen's d	q	Cohen's d
<i>Upright Faces</i>				
7 vs. 10	2.42	0.51	5.14**	1.03
10 vs. 13	4.74**	1.01	4.70**	1.07
13 vs. 19	1.61	0.34	2.81	0.64
19 vs. 65	4.65*	0.90	4.55*	0.92
<i>Inverted Faces</i>				
7 vs. 10	2.94	0.68	4.89**	1.10
10 vs. 13	3.27	0.70	1.36	0.24
13 vs. 19	0.00	0.00	1.50	0.28
19 vs. 65	1.95	0.37	2.13	0.39
<i>Upright vs. Inverted Faces</i>				
7-year-olds	5.16**	0.49	4.31**	0.44
10-year-olds	6.37**	0.62	4.81**	0.49
13-year-olds	9.77**	0.86	11.73**	1.15
19-year-olds	13.51**	1.24	9.03**	0.90
65-year-olds	7.25**	0.55	4.01**	0.34

FIGURE 1. Examples of Bruce et al.'s (1999) 1-in-10 face matching arrays. The person shown at the top may or may not be one of the ten below. Observers have to decide whether this target is present, and if so, which lineup face he is.

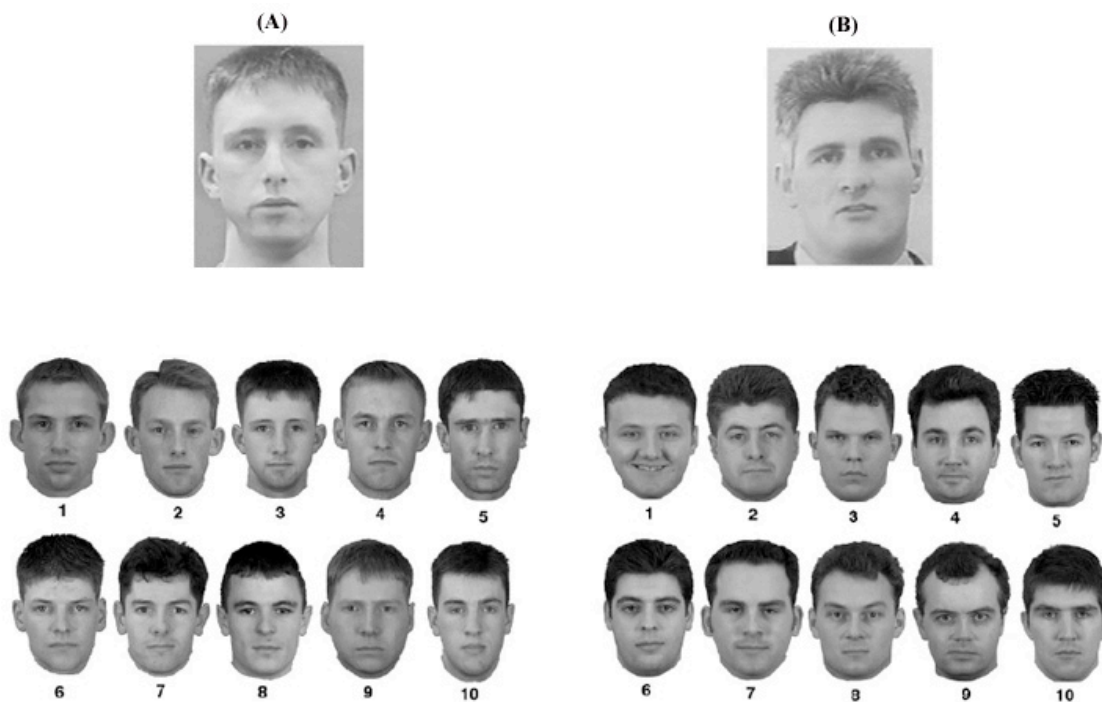


FIGURE 2. Examples of the 1-in-10 face matching arrays that were used in this study.

The person shown at the top may or may not be one of the ten below.

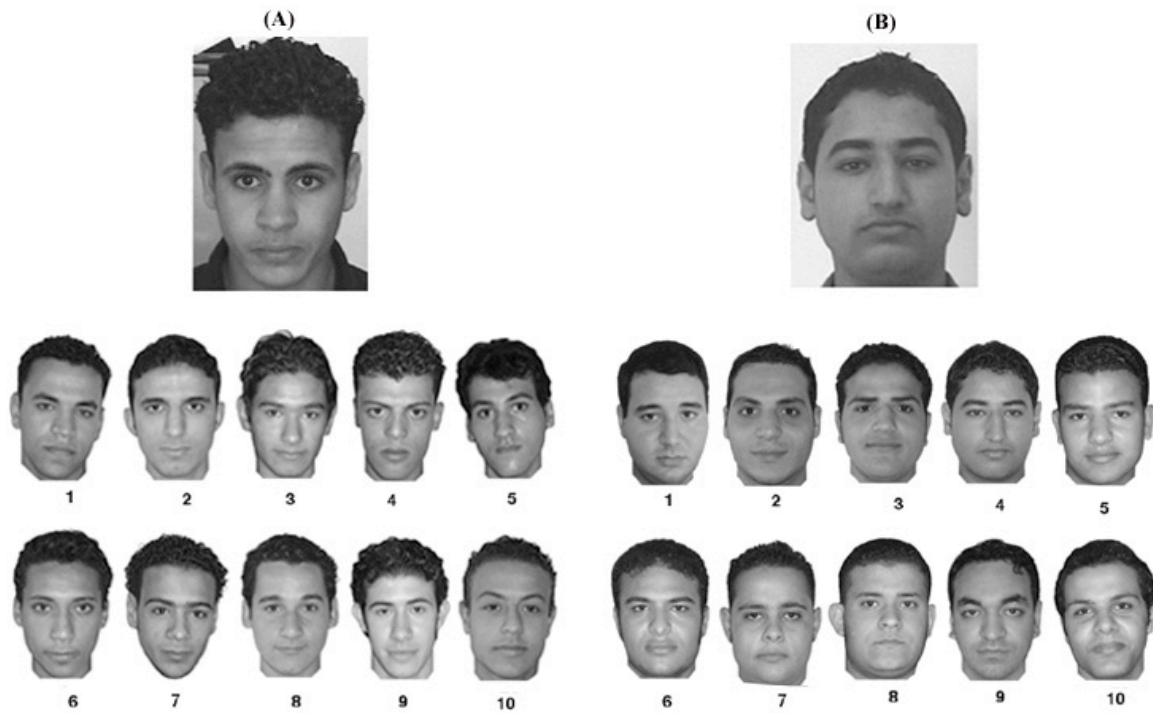


FIGURE 3. Examples of the face pairs used in Experiment 2.

