Title: Decline or improvement?

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Decline or improvement?: Age-related differences in facial expression recognition
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Abstract
We examined age-related differences in facial expression recognition in association with potentially interfering variables such as general cognitive ability (verbal and visuospatial abilities), face recognition ability, and the experiences of positive and negative emotions. Participants comprised 34 older (aged 62?81 years) and 34 younger (aged 18?25 years) healthy Japanese adults. The results showed not only age-related decline in sadness recognition but also age-related improvement in disgust recognition. Among other variables,

visuospatial ability was moderately related to facial expression recognition in general, and the experience of negative emotions was related to sadness recognition. Consequently, age-related decline in sadness recognition was statistically explained by age-related decrease in the experience of negative emotions. On the other hand, age-related improvement in disgust recognition was not explained by the interfering variables, and it reflected a higher tendency in the younger participants to mistake disgust for anger. Possible mechanisms are discussed in terms of neurobiological and socio-environmental factors.
 * Previous article in issue
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Keywords
Aging
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Affective aging has attracted attention among researchers because of its unique life-span trajectory that is contrasted with cognitive aging. Despite a predominant view of age-related declines in cognitive functions (Hedden and Gabrieli, 2004), the socio-emotional selectivity theory proposed by Carstensen et al. (1999) argues that at least some aspects of emotional functions _improve_ with advancing age. Specifically, the theory asserts that emotional experiences in older adults are optimally regulated in terms of the relative increase in positive emotions against negative emotions (Mather and Carstensen, 2005). Consistently with the theory, earlier studies examined age-related differences in daily emotional experiences using self-report questionnaires and found a decrease in negative emotions as well as maintenance of or increase in positive emotions (Carstensen and Charles, 1998, Mroczek, 2001). In addition, older adults reported better emotional control than their younger counterparts (Gross et al., 1997). Recent experimental studies also support this view: they show that older adults? attentional (Mather and Carstensen, 2003, Rosler et al., 2005) and memory (Charles et al., 2003) biases mask negative emotion elicitors (but see also Comblain et al., 2004, Kensinger et al., 2002 for contradictory findings on the memory bias).
However, the optimistic view on affective aging has recently been challenged by the research focusing on the other fundamental aspect of emotional functions, that is, emotion recognition. Human competency to infer and recognize others? emotional states ? mostly from non-verbal cues ? underlies success in interpersonal communication, and it is suggested that this competency involves age-related decline. Among others, facial expression recognition is the most thoroughly studied area in emotion recognition, of which neural and cognitive mechanisms are well documented (Adolphs, 2002, Calder et al., 2001); therefore, age-related differences in facial expression recognition have been of great interest.
In particular, the recognition of facial expressions of _basic emotions_ (happiness, surprise, fear, anger, disgust, and sadness; Ekman, 1994, Russell, 1994) has been examined in detail (Calder et al., 2003, MacPherson et al., 2002, McDowell et al., 1994, Moreno et al., 1993, Phillips and Allen, 2004, Phillips et al., 2002, Sullivan and Ruffman, 2004). There are cross-nationally standardized photograph sets for such facial expressions (e.g., Ekman and Friesen, 1976, Matsumoto and Ekman, 1988), ensuring the comparability of different experiments by different researchers. Overall, the earlier studies indicated age-related declines in recognizing facial expressions of specific basic emotions; age-related declines in anger and/or sadness recognition are

the most prevailing observations (Calder et al., 2003, MacPherson et al., 2002, McDowell et al., 1994, Moreno et al., 1993, Phillips and Allen, 2004, Phillips et al., 2002, Sullivan and Ruffman, 2004). This is followed by age-related decline in fear recognition (Calder et al., 2003, McDowell et al., 1994, Sullivan and Ruffman, 2004). Interestingly, not only age-related decline (Sullivan and Ruffman, 2004) but also age-related improvement (Calder et al., 2003) was observed in the recognition of facial expressions of disgust, although the authors interpreted the results as preservation instead of improvement.

The above-mentioned emotion-specific effects of aging have often been attributed to age-related structural and functional changes in the neural substrates that are hypothesized to play an important role in the recognition of specific basic emotions. At present, the involvement of dissociable neural substrates in the recognition of facial expressions of fear and disgust is particularly emphasized (Calder et al., 2001). Since Adolphs et al. (1994) demonstrated a disproportionate impairment of the recognition of fear in a patient with selective amygdala damage, a number of neurological (Broks et al., 1998, Calder et al., 1996, Sato et al., 2002) and functional imaging studies (Morris et al., 1996, Whalen et al., 1998, Yoshimura et al., 2005) have replicated the link between the amygdala and fear recognition. Damage to the amygdala also compromises the recognition of other emotions such as anger and sadness to a certain extent (Adolphs and Tranel, 2004, Fine and Blair, 2000); however, impairment of fear recognition is the most consistent and disproportionately severe one (Adolphs et al., 1999).

A disproportionate impairment of disgust recognition was first reported in patients with Huntington's disease (Sprengelmeyer et al., 1996, Sprengelmeyer et al., 1997), a hereditary neurodegenerative disorder associated with pathological changes in the basal ganglia and possibly in the insula (Hennenlotter et al., 2004, Thieben et al., 2002). The proposed contributions of the two neural substrates to disgust recognition are also confirmed in functional imaging research (Phillips et al., 1997, Sprengelmeyer et al., 1998) and in a single-case report (Calder et al., 2000).

Currently, less evidence is available with respect to the recognition of the other emotions, but a meta-analysis of functional imaging research (Murphy et al., 2003) highlights the activation of the orbitofrontal cortex in response to facial expressions of anger.

Considering the involvement of the amygdala in fear recognition, and to a certain extent in anger and sadness recognition, the aging of the amygdala can explain age-related decline in recognizing facial expressions of fear (Calder et al., 2003), anger (Sullivan and Ruffman, 2004), and sadness (MacPherson et al., 2002). Indeed, a part of the medial temporal lobe structures, including the amygdala, is suspected to be mildly affected with advancing age (for a review, Raz, 2000). In line with the structural changes, age-related decrease in the amygdala activation in response to emotional stimuli (Gunning-Dixon et al., 2003, Iidaka et al., 2002), particularly to negative ones (Mather et al., 2004), is demonstrated.

A limitation of the amygdala aging hypothesis is that it may predict the most severe age-related decline in fear recognition (Adolphs et al., 1999, Calder et al., 2003), which does not appear to be the case; the age-related decline is reported most consistently in the recognition of anger and sadness. Thus, Sullivan and Ruffman (2004) suggest that the aging of the orbitofrontal cortex may underlie age-related decline in the recognition of anger. The effects of aging on the orbitofrontal cortex are indeed demonstrated by both structural (Convit et al., 2001, Raz et al., 1997, Tisserand et al., 2002) and functional

(Lamar et al., 2004) examination. On the other hand, for sadness recognition, no dedicated neural substrates are currently indicated (Murphy et al., 2003) except the amygdala (Fine and Blair, 2000).

With regard to the preserved recognition of facial expressions of disgust, Calder et al. (2003) speculates that it may reflect the relative insensitivity of the globus pallidus to aging. Among other nuclei constituting the basal ganglia, it is suggested that the globus pallidus is activated most consistently in response to facial expressions of disgust (Murphy et al., 2003). However, a recent longitudinal study by Raz et al. (2003) showed that age-related shrinkage was indeed evident in the whole basal ganglia, although the shrinkage was milder in the globus pallidus than in the other nuclei (caudate and putamen). In addition, Good et al. (2001) reported age-related reduction in the gray matter volume of the insula. Thus, it appears that the neural substrates involved in disgust recognition may not be very insensitive to aging and that some other factors may underlie the preserved recognition of disgust in older adults.

As such, it has been explained that age-related differences in recognizing facial expressions of specific emotions may reflect some specific neurobiological factors. However, before identifying the emotion-specific factors, it is necessary to carefully examine the possibility that the observed emotion-specificity may stem in part from non-emotional factors. It is well known that the difficulty levels involved in recognizing facial expressions substantially differ across emotions. For example, fear is the most difficult emotion to recognize, and negative emotions as a whole are more difficult to recognize as compared with happiness and surprise (Biehl et al., 1997, Russell, 1994). Owing to the differential difficulty levels across emotions, general cognitive and visual disturbances can disproportionately impair the recognition of facial expressions of fear (Rapcsak et al., 2000) and negative emotions (Johnston et al., 2003). Since age-related decline in facial expression recognition is reported mainly in negative emotions, it is likely that the decline may be underlain at least in part by age-related cognitive and visual disturbances.

First, the effects of aging on general cognitive ability are well documented, and specifically, age-related decline in visuospatial or fluid ability rather than in verbal or crystallized ability is highlighted (Howieson et al., 1993, Kaufman et al., 1989). Some aging studies (Phillips and Allen, 2004, Phillips et al., 2002) actually reported significant relationships between general cognitive ability and facial expression recognition, although the covariation alone may not fully account for the age-related differences in facial expression recognition (McDowell et al., 1994, Sullivan and Ruffman, 2004). Second, all types of face recognition, including facial expression recognition, primarily entail visuospatial processing, which was termed as _structural encoding_ by Bruce and Young (1986). Because aging is known to affect both the visuospatial processing of faces (Benton and Van Allen, 1968, Owsley et al., 1981) and neural responses to faces (Grady et al., 1994, Grady et al., 2000; for a review, Grady, 2000), it is possible that age-related decline in facial expression recognition may be a part of age-related decline in face recognition in general. To date, only one study (Sullivan and Ruffman, 2004) examined this issue carefully and found that age-related decline in facial expression recognition was at least partially independent from the age-related decline in another type of face recognition (i.e., facial gender recognition). Given that in clinical research, general deficits in face recognition (typically, facial identity recognition) contribute to the impaired recognition of facial expressions (Beatty et al., 1989, Milders et al., 2003), replication concerning this matter will be beneficial.

In addition to these non-emotional confounders, a theoretically interesting issue is concerned with a link between emotional experiences and emotion recognition. Currently, there is a growing emphasis on the inseparability between emotional experiences and emotion recognition, particularly facial expression recognition (Adolphs, 2002, Goldman and Sripada, 2005). The emphasized view referred to as the _simulation theory_ proposes that a person recognizes the emotional state of another person by attempting to generate and experience (i.e., simulate) the analogous emotional state in himself/herself.

It then follows that a decline in the recognition of certain emotions is accompanied by a decrease in the experience of those emotions, which is indeed observed in some neuropathological cases (for reviews, Goldman and Sripada, 2005, Lawrence and Calder, 2003). Similarly, it is possible that age-related decrease in experiencing negative emotions in general may lead to age-related decline in recognizing facial expressions of negative emotions. Indeed, Phillips and Allen (2004) reported that most of the age-related differences in facial expression recognition could be explained by lower negative emotions (depression and anxiety) in the older adults.

Thus, aging is associated with a range of general factors that can affect facial expression recognition, and due to the differential difficulty levels across emotions, these factors can be responsible for at least part of the age-related differences in the recognition of specific emotions. To the best of our knowledge, there have been rare attempts to individually examine the joint effects of the general factors, and this fact substantially limits our inference with regard to which age-related differences in facial expression recognition may truly involve emotion-specific factors. Therefore, the current study was designed to examine age-related differences in facial expression recognition in association with general cognitive ability, face recognition ability in general, and emotional experiences.

1\. Methods

1.1. Participants

A total of 68 participants were paid to participate in this study. Of these, 34 were older adults (17 men; aged 62?81 years, _M_ = 69.7, S.D. = 4.8) and 34 were younger adults (17 men; aged 18?25 years, _M_ = 20.6, S.D. = 1.8). The two groups were matched in terms of years of education (older, _M_ = 13.2, S.D. = 2.6; younger, _M_ = 13.6, S.D. = 1.7; _t_(66) = ?0.836, _p_ = 0.406). The older participants were recruited from a public human resource center for the elderly in a special ward of Tokyo. The younger participants were graduate or postgraduate students from several universities in Tokyo; they were recruited by means of posted and aural announcements and word of mouth. None of the participants reported any history of neurological or psychiatric disorders. For the older participants, the scores of the Mini-Mental State Examination (MMSE; Folstein et al., 1975) ranged from 26 to 30 (_M_ = 29.0, S.D. = 1.1), indicating no signs of clinical dementia.

1.2. Procedure and tasks

The participants were tested individually in a quiet room and were engaged in the following five tasks: Facial Expression Identification, two WAIS-R subtests of Information and Picture Completion, Facial Identity Matching, and General Affect Scales.1 At the beginning of the experiment, the nature of the current study was explained to each participant, and written informed consent was obtained.

1.2.1. Facial Expression Identification

As a test of facial expression recognition, we used a forced-choice identification (labeling) task that was commonly used in earlier studies

(Calder et al., 2003, MacPherson et al., 2002, McDowell et al., 1994, Moreno et al., 1993, Phillips et al., 2002). The participants viewed the photographs of prototypical facial expressions enacting the six basic emotions, and they were asked to identify (label) each photograph as one basic emotion that best described it.

The photographs used in this task were selected from the Japanese and Caucasian Facial Expressions of Emotion (JACFEE; Matsumoto and Ekman, 1988). For each of the six basic emotions, there were eight facial expression photographs enacted by different persons, of which gender (female or male) and race (Caucasian or Japanese) were counterbalanced, yielding a total of 48 photographs.

Each photograph was printed in gray scale on a letter size gloss photo paper. The photographs were presented to the participants in either of two quasi-random orders, and the orders assigned were counterbalanced within each age group.

1.2.2. WAIS-R subtests

We used the WAIS-R subtests of Information and Picture Completion as the tests of verbal (crystallized) ability and visuospatial (fluid) ability, respectively.

1.2.3. Facial Identity Matching

In order to test face recognition ability in general, we developed a task named Facial Identity Matching, which is designed as a Japanese version of the Benton test of face recognition (Benton and Van Allen, 1968). In each trial, the participants were asked to match a facial photograph (target) with a set of six facial photographs (references) of different persons of the same gender.

The photographs used in this task were selected from the Facial Information Norm Database (FIND; Yoshida et al., 2004) distributed by Nihon University. The selected photographs were of 60 Japanese people, half of whom were female, yielding 10 sets of six facial photographs (neutral faces) of different men or women. There were photographs of the front-view, side-view, and upward face of each male and female. The Facial Identity Matching task included three conditions: front-view target with front-view references, front-view target with side-view references, and upward target with front-view references. Thus, the task consisted of 30 trials (10 sets × 3 conditions).

Each photograph was printed in gray scale either on a letter size (target) or an A4-size (references) gloss photo paper. The photographs were presented to the participants in either of two quasi-random orders, and the orders assigned were counterbalanced within each age group.

1.2.4. General Affect Scales

A self-report questionnaire of General Affect Scales (Ogawa et al., 2000) was used as a measure of emotional experiences. The questionnaire included subscales of Positive Affect and Negative Affect, each of which contained eight descriptors (adjectives) related to positive and negative emotions, respectively (e.g., ?Excited? for Positive Affect and ?Afraid? for Negative Affect). The participants were asked to rate the extent to which they had experienced each described emotion in the previous month on a 4-point scale, and summed scores (max score = 32) were calculated for the respective subscales. The questionnaire was developed on the basis of the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) and other existing instruments, and their reliability and validity were confirmed in a Japanese population (Ogawa et al., 2000).

2\. Results

Fig. 1 provides the mean number of correct identifications by age and emotion in the task of Facial Expression Identification. An analysis of variance was conducted on the number of correct identifications of the six basic emotions with two factors of age and emotion. The results showed a marginally significant main effect of age (_F_(1, 66) = 11.669, _p_ = 0.078) and a significant main effect of emotion (_F_(5, 330) = 66.802, _p_ < 0.001). Importantly, the main effects were qualified by a significant interaction between age and emotion (_F_(5, 330) = 5.000, _p_ < 0.001). Therefore, the simple main effects of age were examined for respective emotions, indicating a significant age-related improvement for disgust (_F_(1, 396) = 8.768, _p_ = 0.003) and a significant age-related decline for sadness (_F_(1, 396) = 10.207, _p_ = 0.002). Age-related declines for surprise and anger (for both, _F_(1, 396) = 2.939, _p_ = 0.087) were only marginal, and age-related differences were insignificant for happiness and fear (_p_ > 0.1).

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Fig. 1. Mean number (±S.E.) of correct identifications in the task of Facial Expression Identification by age and emotion. HA: happiness, SU: surprise, FE: fear, AN: anger, DI: disgust, SA: sadness.

The performances of the older and younger participants in the other four tasks are summarized in Table 1. The scores the two WAIS-R subtests were consistently lower in the older participants than in the younger participants, and statistically, the age-related decline was marginal in Information (_t_(66) = ?1.764, _p_ = 0.082) and was highly significant in Picture Completion (_t_(66) = ?4.563, _p_ < 0.001). The results probably reflect steeper age-related decline in visuospatial ability than in verbal ability (Howieson et al., 1993, Kaufman et al., 1989). The age-related difference was also significant in Facial Identity Matching (_t_(66) = ?3.245, _p_ = 0.002), indicating age-related decline in face recognition ability in general. With regard to General Affect Scales, age-related decrease in Negative Affect (_t_(66) = ?2.713, _p_ = 0.008) as well as the maintenance of Positive Affect (_t_(66) = 0.264, _p_ = 0.793) was observed, which is consistent with the earlier literature (Carstensen and Charles, 1998, Mroczek, 2001).

Table 1. Means (±S.E.) for the scores of two WAIS-R subtests, Facial Identity Matching, and General Affect Scales

Empty Cell	Older	Younger
WAIS-R subtests		
Informationa	17.85 ± 0.75	19.65 ± 0.69
Picture Completiona	11.53 ± 0.56	14.53 ± 0.34
Facial Identity Matching	23.35 ± 0.60	25.76 ± 0.44
General Affect Scales		
Positive Affect	26.03 ± 0.71	25.76 ± 0.70
Negative Affect	16.00 ± 0.77	19.12 ± 0.85

a

Raw scores.

Table 2 shows correlations between the number of correct identifications of respective emotions in Facial Expression Identification on one hand and the remaining five measures on the other hand for each age group. Happiness and surprise were excluded from the correlation analyses because ceiling effects and poor variances are indicated in Fig. 1. The score of Picture Completion had the most consistent relationship with the performances in Facial Expression Identification across age and emotion. Specifically, in the younger participants, the positive correlations between the two tasks were significant or marginally significant for any emotion, whereas in the older participants, all the correlations were positive but reached the significance level only for disgust. As compared with Picture Completion, Information appeared to have a less marked relationship with Facial Expression Identification. Likewise, the correlations between the score of Facial Identity Matching and performances in Facial Expression Identification were not significant for any emotion. With respect to emotional experiences, the positive correlation between Negative Affect and Facial Expression Identification was noted only for sadness, and it reached the significance level in the younger participants.

Table 2. Correlations between performances in Facial Expression Identification and the other five measures

Empty Cell	FE	AN	DI	SA
Older				
Information	0.160	?0.217	0.284	0.223
Picture Completion	0.137	0.212	0.378*	0.050
Facial Identity Matching	0.226	0.134	0.095	0.167
Positive Affect	?0.129	0.186	0.119	?0.165
Negative Affect	?0.050	0.004	?0.081	0.242
Younger				
Information	0.199	?0.087	0.159	0.047
Picture Completion	0.411*	0.289?	0.381*	0.543**
Facial Identity Matching	?0.168	?0.009	0\. 141	0.101
Positive Affect	0.069	0\. 058	?0.124	?0.003
Negative Affect	?0.009	0\. 150	?0.018	0.340*

Note : FE: fear, AN: anger, DI: disgust, SA: sadness.
? $p < 0.10$. *$p < 0.05$. **$p < 0.01$.

In order to clarify the unique contribution of age to disgust and sadness identification, regression analyses were conducted on the number of correct identifications of disgust or sadness as the dependent variable; the scores of Information, Picture Completion, Facial Identity Matching, Positive Affect, Negative Affect, and age (dummy variable; older = 1, younger = 0) were entered as the independent variables. Table 3 summarizes the results for the regression analyses. With regard to disgust, the addition of age resulted in a significant increment in R^2 (? R^2 = 0.144, F(1, 61) = 11.110, p = 0.001), indicating the unique contribution of age. In line with Table 2, the score of Picture Completion was another significant predictor of disgust identification. On the other hand, the addition of age did not result in a significant increment in R^2 for sadness (? R^2 = 0.004, F(1, 61) = 0.361, p = 0.550). Table 3 indicated that the score of Negative Affect was a significant predictor of sadness identification, as was expected from Table 2.

Table 3. Summary of regression analyses on the number of correct identifications of disgust or sadness

Empty Cell	Disgust			Sadness		
Empty Cell	*B*	S.E. *B*	*?*	*B*	S.E. *B*	*?*
Information	0.080	0.064	0.154	0.029	0.052	0.068
Picture Completion	0.242	0.098	0.337*	0.119	0.079	0.199
Facial Identity Matching	0.089	0.085	0.131	0.055	0.069	0.098
Positive Affect	0.004	0.064	0.008	?0.065	0.052	?0.144
Negative Affect	?0.038	0.056	?0.085	0.111	0.046	0.298*
Age	2.081	0.624	0.473**	?0.302	0.503	?0.083
	R^2 = 0.210 (p = 0.021)			R^2 = 0.254 (p = 0.005)		

Note : All the independent variables were forcibly entered into the regression model.
*$p < 0.05$. **$p < 0.01$.

We then analyzed whether some age-related differences in erroneous identification underlay age-related improvement in disgust identification. A trivial possibility was that the older participants? preferential use of the disgust label might lead to an apparent improvement in disgust identification (Calder et al., 2003). Indeed, the number of older participants misusing the disgust label was marginally significantly larger than that of the younger participants (older, M = 3.88, S.E. = 0.38; younger, M = 2.91, S.E. = 0.38; $t(66)$ = 1.811, p = 0.075). However, the correlation between the number of correct identifications of disgust and the number of such misuse was neither significant nor positive (r = ?0.139, $t(66)$ = ?1.140, p = 0.259).

Another possibility was that the younger participants might tend to make some specific errors in identifying facial expressions of disgust. Table 4 summarizes the frequencies of erroneous identifications mistaking facial expressions of disgust to be other emotions.2 Table 4 reveals that the younger participants misused the anger label almost twice as often as the older participants did, and statistically, the mean of such errors was significantly larger in the younger participants (older, M = 1.53, S.E. = 0.25; younger, M = 2.79, S.E. = 0.42; $t(66)$ = ?2.568, p = 0.012). As a natural consequence, the number of correct identifications of disgust and the number of erroneous identifications as anger were negatively correlated almost perfectly (r = ?0.980, $t(66)$ = ?40.008, p < 0.001).

Table 4. Frequencies of erroneous identification of facial expressions of disgust as other emotions

Empty Cell	HA	SU	FE	AN	SA
Older	0	1	5	52	2
Younger	0	0	1	95	2

Note : HA: happiness, SU: surprise, FE: fear, AN: anger, SA: sadness.

3. Discussion

In the current study, we found not only age-related decline in the recognition of facial expressions of sadness but also age-related improvement in the recognition of facial expressions of disgust. The results of the current study are consistent with those of earlier studies (Calder et al., 2003, MacPherson et al., 2002, McDowell et al., 1994, Moreno et al., 1993, Phillips and Allen, 2004, Phillips et al., 2002, Sullivan and Ruffman, 2004). Although age-related decline in anger recognition has been reported as frequently as that in sadness recognition, it was only marginally significant in the current study. However, we believe that age-related improvement in disgust recognition and age-related decline in anger recognition may be closely related; which will be discussed in detail later. We also failed to replicate age-related decline in fear recognition (Calder et al., 2003, McDowell et al., 1994, Sullivan and Ruffman, 2004), which may reflect less robust effects of aging on fear than on anger and sadness (Sullivan and Ruffman, 2004). As seen in earlier studies, performances in the recognition of happiness and surprise indicated ceiling effects, and thus it may be inappropriate to discuss age-related differences in them based on the present data.

We then explored whether facial expression recognition had any relationship with other mental functions that were sensitive to aging, such as general cognitive ability, the visuospatial processing of faces, and emotional experiences. First, we found that visuospatial ability, and not verbal ability, was consistently related to facial expression recognition. The results are plausible considering that facial expression recognition is visuospatial in nature (Buitelaar et al., 1999, Haxby et al., 2000) and may preferentially involve the right hemisphere (Damasio et al., 2000), although the differential involvements of visuospatial and verbal abilities have not been documented in the aging research (Phillips and Allen, 2004, Phillips et al., 2002). Intriguingly, the results also indicated that the relationship between facial expression recognition and visuospatial ability was consistently reliable in the younger participants, but not in the older participants. Such age-related difference is not readily explicable, and thus replication is necessary in order to determine its robustness. Despite the reservations, we can safely recommend that an investigation into the effects of aging on facial expression recognition should include a measure of visuospatial ability, given its marked age-related decline (Howieson et al., 1993, Kaufman et al., 1989).

Second, we found no evidence for the relationship between facial expression recognition and the visuospatial processing of faces measured by Facial Identity Matching. The findings are consistent with the work of Sullivan and Ruffman (2004), demonstrating that age-related decline in facial expression discrimination was independent from that in facial gender discrimination. Cumulatively, facial expression recognition may be related more to high-level visuospatial cognition, which requires manipulation of and reasoning about visual stimuli (e.g., Picture Completion; Cummings and Huber, 1992), than to elementary visuospatial perception that is tapped by unfamiliar face matching such as in the Benton test and in this study (see also Gagliardi et al., 2003).

Third, from the simulation theory, we expected that the less experiences of negative emotions might lower the recognition of facial expressions of negative emotions, but the expectation was only partially supported. In other words, we found that the score of Negative Affect was positively correlated only with the performance in sadness recognition. The findings indicate that reduction in negative emotions in general may not have remarkable effects on the recognition of facial expressions of negative emotions, which supports the view that the relationship between emotion recognition and emotion experience is more emotion-specific: the relationship based on a discrete emotion (e.g., fear, anger, sadness) as a unit (Goldman and Sripada, 2005, Lawrence and Calder, 2003).

We further analyzed whether or not the observed age-related differences in disgust and sadness recognition were statistically accounted for by these other age-sensitive functions. The results showed that age-related improvement in disgust recognition was not explained by the other functions; rather, a positive association between disgust recognition and visuospatial ability suggests that age-related decline in the latter might have obscured age-related improvement in the former in earlier studies with the exception of the study by Calder et al. (2003). In contrast, age-related decline in sadness recognition was statistically explained by age-related decrease in the score of Negative Affect. Phillips and Allen (2004) reported similar results in that age-related decline in emotional intensity rating for facial expressions of sadness was attributable to age-related decrease in anxiety and depression. Moreover, MacPherson et al. (2002) demonstrated that age-related decline in the recognition of sadness disappeared when memory performance was partialed out. These findings suggest that age-related decline in sadness recognition may not reflect specific factors intimately linked with the emotion of sadness but may reflect general factors influencing a range of mental functions. A definitive conclusion on this matter should await further research. At present, we can safely say that age-related improvement in disgust recognition is far more likely to require some specific factors.

Calder et al. (2003) also observed the improved levels of disgust recognition in older adults (but see also Sullivan and Ruffman, 2004), which are consistent with our findings, but they interpreted their results as the evidence of preservation of disgust recognition rather than as the evidence of improvement. However, with our clear replication for the Japanese population, it may be more plausible to believe that older adults are able to better recognize facial expressions of disgust, at least in a forced-choice identification task. Then, what types of mechanisms underlie the observed age-related improvement in disgust recognition? It may appear slightly difficult to speculate that some factors directly enhance the sensitivity to the emotion of disgust in older adults. An ongoing study using an intensity rating task (Suzuki et al., 2006, Suzuki et al., 2005) indicates that in reality, older adults are not more sensitive to disgust than younger adults, by showing that the intensity rating of disgust for facial expressions containing disgust is not higher in older adults. In this regard, we believe that another aspect of our current findings may serve as a clue: the higher tendency in younger participants to mistake facial expressions of disgust to be anger.

It has thus far been argued that younger adults are better able to recognize facial expressions of anger (Calder et al., 2003, McDowell et al., 1994, Phillips et al., 2002, Sullivan and Ruffman, 2004). However, at the same time, we can speculate that the younger adults? high sensitivity to the emotion of anger may lead to frequent false alarms. Phillips and Allen (2004) empirically support this view by showing that younger adults rated ?neutral? faces as those expressing a higher intensity of anger than the older adults did.

As mentioned in the introduction, age-related decline in anger recognition has been linked with the effects of aging on specific neural substrates such as the amygdala and the orbitofrontal cortex (Calder et al., 2003, Sullivan and Ruffman, 2004). Because the aging of the amygdala will primarily affect the recognition of fear (Adolphs et al., 1999, Calder et al., 2003), the aging of the orbitofrontal cortex appears to be more attractive in explaining age-related decline in anger recognition (Sullivan and Ruffman, 2004), given its specific contribution to the recognition of anger (Murphy et al., 2003). It is well-documented that, among other brain regions, the prefrontal cortex is the most sensitive to the effects of aging (Raz, 2000). A number of studies investigating the sub-regions of the prefrontal cortex further reveal a significant negative correlation between age and the volumes of the orbitofrontal cortex (Convit et al., 2001, Raz et al., 1997, Tisserand et al., 2002; but see also Salat et al., 2001). The structural changes are supported by a functional imaging study (Lamar et al., 2004) demonstrating that the older adults failed to activate the orbitofrontal cortex during delayed match and non-match to sample tasks, which were previously shown to engage the orbitofrontal cortex in the younger adults (Elliott and Dolan, 1999). Thus, it is likely that age-related decline in anger recognition may be underlain by such structural and functional changes in the orbitofrontal cortex with advancing age.

In addition to the neurobiological factors, socio-environmental factors may also contribute to age-related decline in the recognition of anger. Carstensen and Charles (1998) and Carstensen et al. (1999) argue that advancing age or an appraisal process in which people perceive their lifetime to be limited, is associated with motivational shifts that prioritize present-oriented emotional comfort over future-oriented knowledge acquisition. The motives are accomplished by a proactive pruning process of social networks that selectively emphasizes familiar social partners (Carstensen et al., 1999), which results in decreasing experiences of negative emotions. In particular, there are surveys indicating a negative association between age and anger experiences (Birditt and Fingerman, 2003, Mirowsky and Ross, 1995, Schieman, 1999). Schieman (1999) showed that the less frequent experiences of anger among older adults were attributable to age-related differences in the psychosocial and structural environment such as freedom from work and family roles. In addition, it is argued that older adults are motivated to control anger experiences specifically because anger is the only negative emotion that involves blaming others, which is potentially harmful for social relationships (Birditt and Fingerman, 2003).

The simulation theory will explain that age-related decline in anger recognition may be partly due to the negative association between age and anger experiences. We examined the effects of age-related differences in emotional experiences on facial expression recognition by using broad measures of Positive Affect and Negative Affect. However, the descriptors constituting the Negative Affect subscale were primarily related to anxiety and tension, and thus possibly failed to capture anger experiences. Earlier studies suggest that the experiences of negative emotions such as fear, anger, and disgust can be impaired separately after focal brain damage (Calder et al., 2000, Calder et al., 2004, Sprengelmeyer et al., 1999). Therefore, the use of a measure specific to anger experiences will be beneficial in future research.

Thus far, the explanation based on the neurobiological factors has been dominant, and age-related decline in anger recognition is regarded as a type of ?deficit? caused by the aging brain. However, it is also likely that the older adults? lower performance in anger recognition may result from some adaptive processes in response to their ?anger-less? environment, rather than from passive, deteriorative processes. Thus, older adults may be more cautious about the recognition of anger than younger adults as suggested by Phillips and Allen (2004) and the current study. Eventually, the neurobiological and socio-environmental factors are not mutually exclusive. Further, the most challenging topic will be to capture age-related changes in anger recognition in the realm of brain?environment interactions.

Finally, we would like to note some limitations of this study. First, due to its nature as an extreme group design, the current findings are not free from cohort effects and are insensitive to the non-linear effects of aging (Salthouse, 2000). The latter aspect is particularly important because Calder et al. (2003) contrasted the non-linearity of age-related improvement in disgust recognition with the linearity of age-related decline in fear recognition. Second, the universality/culture specificity of the current findings may merit further investigation giving the well-known differences in facial expression recognition between the Japanese and Caucasian populations (Matsumoto, 1992, Russell, 1994, Shioiri et al., 1999). We believe that our findings on the link between age-related differences in disgust and anger recognition may be rather universal phenomena because Calder et al. (2003) also observed age-related improvement in disgust recognition and because the confusion between facial expressions of disgust and anger is also very common in the Caucasians (Ekman and Friesen, 1976). Third, the relationships between age-related differences in facial expression recognition and those in other emotional functions such as the recognition of emotional prosody (Brosgole and Weisman, 1995) and lexical stimuli (Grunwald et al., 1999, Phillips and Allen, 2004), expressive behaviors (Borod et al., 2004, Nakamura and Masutani, 2001), and emotional control (Gross et al., 1997) are unclear. Both the neurobiological and socio-environmental factors will predict coupled changes in affective processing as a whole (Calder et al., 2001, Carstensen et al., 1999), which will be worth empirical examination in the future.

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Appendix A. Frequencies of erroneous identification of facial expressions of a given emotion as other emotions

Group	Stimulus	Response					
Empty Cell	Empty Cell	HA	SU	FE	AN	DI	SA
Older	HA	?	1	0	0	0	1
	SU	12	?	18	3	0	1
	FE	0	119	?	15	7	10
	AN	0	0	5	?	73	21
	DI	0	1	5	52	?	2
	SA	0	1	8	21	52	?
Younger	HA	?	0	0	0	0	0
	SU	4	?	6	1	0	1
	FE	0	103	?	9	8	11
	AN	0	0	1	?	61	15
	DI	0	0	1	95	?	2
	SA	0	1	2	8	30	?

Note : HA: happiness, SU: surprise, FE: fear, AN: anger, DI: disgust, SA: sadness.

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understanding of others? beliefs and intentions. The course and specificity of age changes in belief reasoning across the adult lifespan is unclear, as is the cause of the age effects. Cognitive and neuropsychological models predict that two types of processing might influence age differences in belief reasoning: executive functioning and social cue detection. In the current study we assessed 129 adults aged between 18 and 86 on novel measures of ToM (video clips and verbal vignettes), which manipulated whether true or false belief reasoning was required. On both video and verbal tasks, older adults (aged 65?88) had specific impairments in false belief reasoning, but showed no such problem in performing true belief tasks. Middle-aged adults (aged 40?64) generally performed as well as the younger adults (aged 18?39). Difficulties in updating information in working memory (but not inhibitory problems) partially mediated the age differences in false belief reasoning. Also, the ability to decode biological motion, indexing social cue detection, partially mediated age-related variance in the ability to interpret false beliefs. These results indicate that age differences in decoding social cues and updating information in memory may be important influences on the specific problems encountered when reasoning about false beliefs in old age.

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This meta-analysis of 28 data sets (_N_ =705 older adults, _N_ =962 younger adults) examined age differences in emotion recognition across four modalities: faces, voices, bodies/contexts, and matching of faces to voices. The results indicate that older adults have increased difficulty recognising at least some of the basic emotions (anger, sadness, fear, disgust, surprise, happiness) in each modality, with some emotions (anger and sadness) and some modalities (face?voice matching) creating particular difficulties. The predominant pattern across all emotions and modalities was of age-related decline with the exception that there was a trend for older adults to be better than young adults at recognising disgusted facial expressions. These age-related changes are examined in the context of three theoretical perspectives?positivity effects, general cognitive decline, and more specific neuropsychological change in the social brain. We argue that the pattern of age-related change observed is most consistent with a neuropsychological model of adult aging stemming from changes in frontal and temporal volume, and/or changes in neurotransmitters.

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1

The five tasks were carried out in either of two fixed orders.

2

For reference, the entire pattern of erroneous identification is provided in Appendix A.

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