AGING & FACIAL EXPRESSION IDENTIFICATION

PROCESSING OF FACIAL EXPRESSIONS BY OLDER AND YOUNGER ADULTS

By

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Abstract

Processing of Facial Expressions by Older and Younger Adults

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Older adults tend to show overall recognition deficits and qualitatively different patterns in the particular expressions that are most difficult to identify (Ruffman et al., 2008). In the current study, 23 younger (18-33 years old) and 23 older (60-80 years old) adults performed a 4AFC (angry, fearful, happy, sad) facial expression categorization task varying orientation (upright/inverted) and stimulus duration (100, 500, 1000 ms). For both groups, happiness was the easiest expression to identify and fear and sadness were the most difficult. Compared to younger adults, older adults were more affected by stimulus orientation, and generally benefit less from increased stimulus duration. For upright faces, there was no age difference in response accuracy but response latency was longer in older subjects. For inverted faces, older adults showed lower accuracy and longer latencies for expressions of anger, fear, and sadness. Recognition of inverted happy faces was spared in older adults for accuracy, but not response latency. These findings could not be explained by impaired detection sensitivity, as no systematic age differences were found for perceived intensity ratings. Finally, the expressions that were most to least difficult to identify was the same in each age group at both orientations. Overall, these results suggest that older individuals process expressive faces in a qualitatively similar way to their younger counterparts, but are less efficient at extracting the diagnostic information.

Preface

This thesis comprises four chapters. All chapters were written collaboratively with my supervisors, Patrick J. Bennett, and Allison B. Sekuler. The content of this thesis has not yet been submitted for publication. Some of these data were presented as a poster at the 12th Annual Meeting of the Vision Sciences Society (May, 2012). The abstract can be accessed at the following web site:

`http://www.journalofvision.org/content/12/9/964.abstract?sid=7b1c9013-67e5-4460-be33-0de3e151a7b4`

I oversaw all aspects of the research presented in this thesis. Conceptualization and design of the experiment was a collaborative effort between myself and my supervisors. I was solely responsible for programming the experiment. Data collection was performed by our research assistant, Donna Waxman, and several undergraduate research assistants. I was primarily responsible for analyzing the data. My supervisors, Eugenie Roudaia, Yaroslav Konar, Matthew Pachai, Mark Vida, and Jordan Lass provided advice on appropriate analyses and subsequent interpretation of the results. I was solely responsible for the initial draft of the thesis.

Acknowledgements

First and foremost, I would like to thank my supervisors, Drs. Patrick Bennett and Allison Sekuler, for their continued support and guidance, and for helping me develop as a researcher and scientist. Thank you to my third committee member, Dr. Mel Rutherford, for his helpful feedback, comments, and discussions. I also want to sincerely thank Donna Waxman for her friendship, laughter, and constant encouragement. I am grateful for all of my friends and colleagues in the department of Psychology, Neuroscience, & Behaviour, and would especially like to thank: Rayna Friendly, Tiffany Deschamps, Laura Gibson, Maria Giammarco, and Juliana Loureiro-Kent. Thank you to the past and present members of the Vision and Cognitive Neuroscience Lab: Ryan Kealey, Alexa Roggeveen, Chris Taylor, Karin Pilz, Yaro Konar, Eugenie Roudaia, Emilie Harvey, Nidhi Trivedi, Lindsay Farber, Justine Spencer, Matt Pachai, Jordan Lass, Amanda Beers, and Ali Hashemi. Finally, my love and heartfelt thanks go out to my family, Stephen Connell, Jill Belrose, and Alison Schure – without your love and support none of this would have been possible. Thank you for always believing in me.

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Chapter 1

Introduction

The ability to detect, discriminate, and identify emotional expressions is important for social communication (Blair, 2003). It is interesting to note, therefore, that older adults are less able to identify expressions (Brosgole and Weisman, 1995; Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; MacPherson et al., 2002; Malatesta et al., 1987; McDowell et al., 1994; Mill et al., 2009; Moreno et al., 1993; Murphy and Isaacowitz, 2010; Phillips et al., 2002; Ruffman et al., 2008; Sullivan and Ruffman, 2004; Suzuki et al., 2007; Wong et al., 2005), although the effect of age appears to depend on the type of facial expression (Isaacowitz et al., 2007).

Why is expression identification accuracy worse in older adults? Many studies of aging and facial expression identification have used all six basic emotions: angry, fearful, happy, sad, disgust, and surprise. Given that older adults have deficits in working memory (Salthouse, 1991), a possible explanation for the age difference in identification accuracy is that six response options taxes working memory in older adults (OA) but not younger adults (YA), and therefore that using fewer options would reduce or eliminate the age difference. Indeed, this hypothesis has some support: Orgeta (2010) looked at how age differences vary as a function of the number (i.e., 2, 4, or 6) of expressive stimuli that have to be held in memory. Older adults were impaired relative to younger adults when identifying fearful and sad expressions in both the 4- and 6-AFC conditions, and surprise in the 4-AFC condition. However, in the 2-AFC condition there were no age differences for any pair of emotions. Thus, age differences in identification accuracy for facial expressions may be sensitive to age differences in working memory. Another possible explanation for the observed age difference in expression identification is that older adults fail to detect expressions: In other words, faces that look expressive to younger adults are perceived by older adults as neutral faces. Age differences in expression identification also might reflect a general slowing of perceptual processing (Salthouse, 1991), which would increase the time needed by older adults to extract the information necessary to identify expressions. Finally, older and younger adults may rely on different sources of information to identify facial expressions. In the face perception literature, a major distinction has been placed on holistic and feature-based processing. Some evidence suggests that holistic processing plays a greater role in face identification by older adults than younger adults (Adduri and Marotta, 2009; Konar et al., 2012; Murray et al., 2010; Slessor et al., 2012), and it is possible that this age difference contributes to differences in expression identification.

The current experiment was designed to explore whether these factors contribute to age differences in expression identification. To reduce the effect of age differences in working memory, the number of expressions was reduced from six to four by not including disgust and surprise. These two expressions were dropped because previous studies indicate that they result in the most confusions (i.e., are most difficult to discriminate from other expressions; Adolphs, 2002), and because the remaining expressions – angry, fearful, happy, and sad – have been used in nearly all previous studies of expression identification. To determine whether age differences in detection sensitivity contribute to differences in identification accuracy, subjects were asked to rate the intensity of expressive faces. To examine the effect of perceptual slowing, expression identification accuracy was measured for faces presented over a wide range of stimulus durations. Finally, we measured expression identification with upright and inverted faces to examine whether holistic processing has different influences on the performance of older and younger subjects.

Chapter 2

Methods

2.1 Subjects

Twenty-three younger Caucasian adults between the ages of 19 and 33 ($M = 24.34$, $SD = 3.14$; 11 males, 12 females) and 23 older Caucasian adults between the ages of 60 and 80 ($M = 67.96$, $SD = 6.12$; 11 males, 12 females) participated in this experiment for \$10/hr. Older participants were screened for visual pathologies via a vision and general health questionnaire, and for cognitive impairments via the Mini Mental State Examination (Folstein et al., 1975) and The Montreal Cognitive Assessment (Nasreddine et al., 2005), with all scores falling in the normal range. All participants were naïve to the purpose of the experiment and all had normal or corrected-to-normal Snellen visual acuity.

2.2 Apparatus & Stimuli

Stimuli were generated on an Apple Macintosh G5 PowerPC (OS 10.5.8) using MATLAB (v 7.4.0) and the Psychophysics and Video toolboxes (Brainard, 1997; Pelli, 1997). Stimuli were presented on a 17-in. NEC monitor (36.3 cm × 27.2 cm) with a resolution of 1280 × 1024 and frame rate of 75 Hz. The average luminance of the display was 101.70 cd/m^2. Participants viewed the stimuli binocularly at a distance of 60 cm while seated in an adjustable chair in a dark room. A chin rest was used to stabilize head position throughout the experiment.

Four Caucasian male and four Caucasian female faces – each displaying angry, fearful, happy, and sad expressions – were selected from the NimStim Face Stimulus Set (Tottenham et al., 2009), which has been used in many studies of facial expression with younger adults. All faces were free of facial hair, visible piercings, and eye glasses. Averaged across identity, percent agreement for each expression was as follows: angry (93.2 %), fearful (61.5 %), happy (100.0 %), and sad (81.8 %) (Palermo and Coltheart, 2004).

Images were converted to grey scale and had a light grey background matching the average luminance of the display. External contours (e.g. hair, ears, chin, neck) were left visible. Stimuli were 650×650 pixels, which subtended a visual angle of $16° \times 16°$. RMS contrast was 0.30.

All 32 faces in the stimulus set (8 identities $\times$ 4 expressions) were presented in the experiment. The first response screen consisted of the words labelling four emotions – angry, fearful, happy, sad – and the second response screen consisted of the numbers 1 through 7. Text was written in uppercase, black letters (24 pt., Courier font), and each response option was outlined with a white box. See Figure 2.1.

2.3 Procedure

After consent was given, the procedure was verbally explained to participants. At the start of the experimental session, task instructions were presented on the screen, and a 60 s adaptation period followed. To familiarize participants with the task, several practice trials were performed using faces that did not appear in the actual experiment. On each practice trial, participants identified the expression and then rated its intensity. For the intensity ratings, participants were shown a sample display consisting of 3 expressive faces and 3 neutral faces to illustrate how to use the scale. Participants were instructed to make use of the entire rating scale, and explicitly instructed: "You are *not* judging whether the face is a good representation of that particular emotion. Your task is simply to respond how intense that face looked." All research was conducted in accordance with the guidelines set out by the Tri-Council Policy Statement, and approved by the McMaster University Research Ethics Board.

Each trial began with a central fixation dot ($0.15° \times 0.15°$) that was displayed for 500 ms, followed by a face stimulus of variable duration, a blank screen for 200 ms, and then two response screens (see Figure 2.1). Participants performed a four alternative forced-choice (AFC) (angry, fearful, happy, sad) expression categorization task asking them to "Click on the word that best describes the facial expression you just saw." Participants responded by clicking on one word with a computer mouse. Unlimited response time was given and participants were instructed to respond as accurately as possible. The expression labels remained on screen until one of the boxes was clicked. Response accuracy and latency, measured from stimulus offset to subject response, were collected. No feedback was provided. The second response screen required participants to "Rate the intensity of the facial expression you just saw (1 = not very intense, 7 = very intense)." Again, unlimited response time was given. After the intensity rating was recorded, the central fixation dot appeared, indicating the beginning of the next trial.

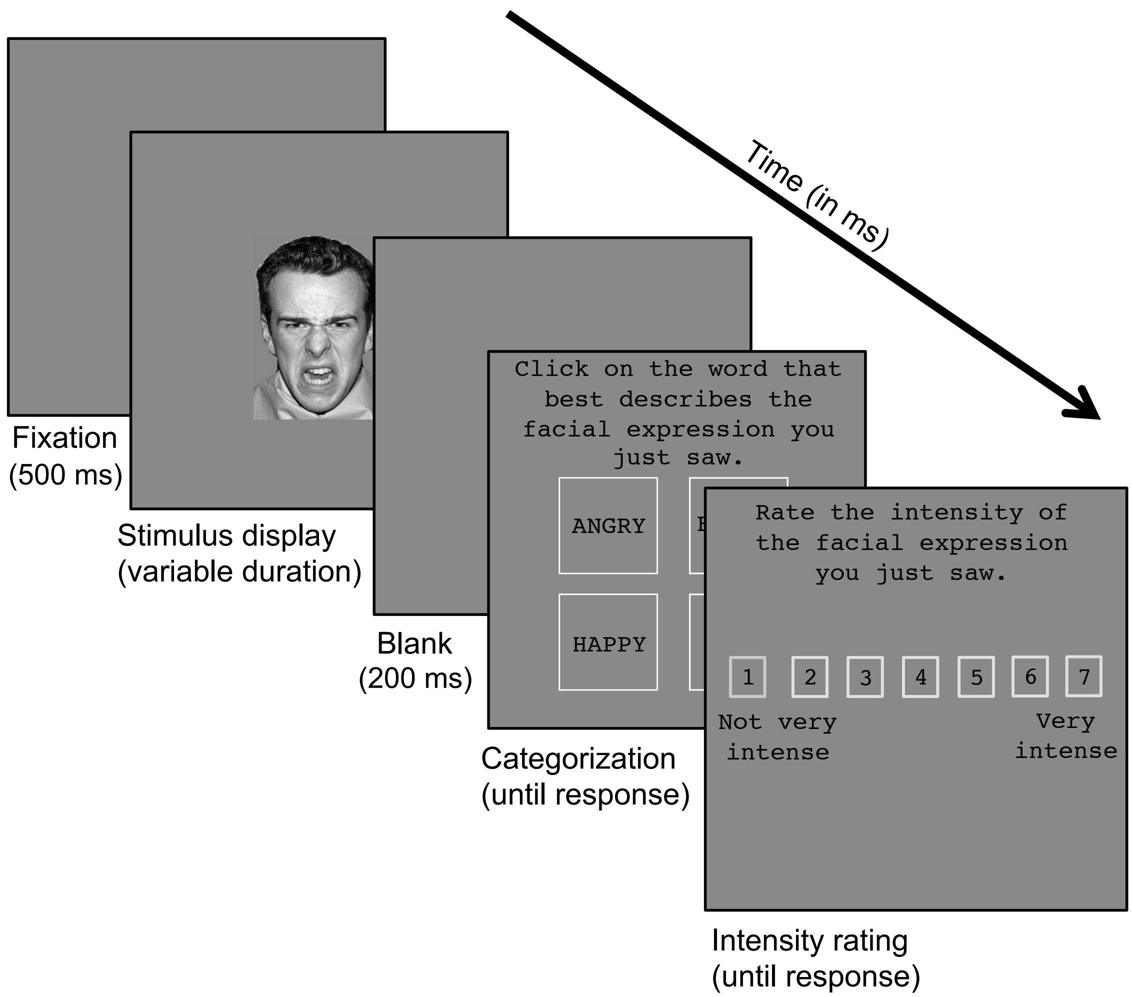

Figure 2.1: Procedure used in the experiment.

2.4 Design

Every face in the stimulus set was presented once at each orientation (upright and inverted) and each duration (100, 500, and 1000 ms), yielding a total of 192 experimental trials (2 orientations $\times$ 3 stimulus durations $\times$ 8 identities $\times$ 4 expressions). Stimuli were blocked by orientation, and randomized within each block, and blocked by stimulus duration. The order of these 6 blocks was counterbalanced, with face, gender and expression randomized within each block.

2.5 Data Analysis

All statistical analyses were performed in R (R Development Core Team, 2012). Where appropriate, the Huynh-Feldt correction for departure from sphericity, $\tilde{\epsilon}$, was used to correct p values of F tests conducted on within-subjects factors (Maxwell and Delaney, 2004). Effect size is reported as partial eta-squared (η_p^2). Degrees-of-freedom for two-sample t tests were adjusted by the Welch-Satterthwaite correction for unequal variances (Welch, 1947).

Chapter 3

Results

3.1 Response Accuracy

Response accuracy was analyzed with a 2 (group) $\times$ 2 (orientation) $\times$ 3 (duration) $\times$ 4 (expression) ANOVA. Analyses on the raw data (i.e., proportion correct) and on the arcsin-transformed data yielded very similar results, and therefore only the results of the ANOVA on proportion correct measures are reported (Table 3.1).

The ANOVA revealed significant main effects of age group ($F(1,44) = 36.12$, $p < .001$, $\eta_p^2 = .451$), orientation ($F(1,44) = 142.19$, $p < .001$, $\eta_p^2 = .764$), duration ($F(2,88) = 35.15$, $\tilde{\epsilon} = .930$, $p < .001$, $\eta_p^2 = .444$), and expression ($F(3,132) = 71.46$, $\tilde{\epsilon} = .836$, $p < .001$, $\eta_p^2 = .619$).

The ANOVA found a significant three-way interaction between age group, expression, and duration ($F(6,264) = 3.56$, $\tilde{\epsilon} = .778$, $p = .005$, $\eta_p^2 = .075$). To analyze this interaction, we first averaged response accuracy across face orientation for each subject. Inspection of the average scores (Figure 3.1) suggests that the difference between age groups depended on facial expression – averaged across stimulus duration, the group difference with happy faces was much smaller than the difference obtained with the other three expressions. Furthermore, Figure 3.1 suggests that the group difference measured with fearful faces, and perhaps sad faces, depended on stimulus duration. To test this idea, the data in each panel in Figure 3.1 were analyzed with a 2 (group) $\times$ 3 (duration) ANOVA. The results of each ANOVA are shown in Table 3.2. The main effect of duration was significant with all four expressions, and the main effect of age group was significant

Effect	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
G	1.72	1	2.10	44	36.12	-	$< .001$
O	4.71	1	1.46	44	142.19	-	$< .001$
G × O	1.30	1	1.46	44	39.21	-	$< .001$
D	0.66	2	0.82	88	35.15	.930	$< .001$
G × D	0.00	2	0.82	88	0.21	.930	.795
O × D	0.16	2	1.24	88	5.54	.934	.007
G × O × D	0.00	2	1.24	88	0.04	.934	.954
E	5.07	3	3.12	132	71.46	.836	$< .001$
G × E	0.52	3	3.12	132	7.37	.836	$< .001$
O × E	2.05	3	2.47	132	36.38	.770	$< .001$
G × O × E	0.40	3	2.47	132	7.09	.770	.001
D × E	0.06	6	2.70	264	0.90	.778	.475
G × D × E	0.22	6	2.70	264	3.56	.778	.005
O × D × E	0.02	6	2.57	264	0.36	.890	.884
G × O × D × E	0.03	6	2.57	264	0.47	.890	.810

Table 3.1: Accuracy ANOVA: Group (G) × Orientation (O) × Duration (D) × Expression (E).

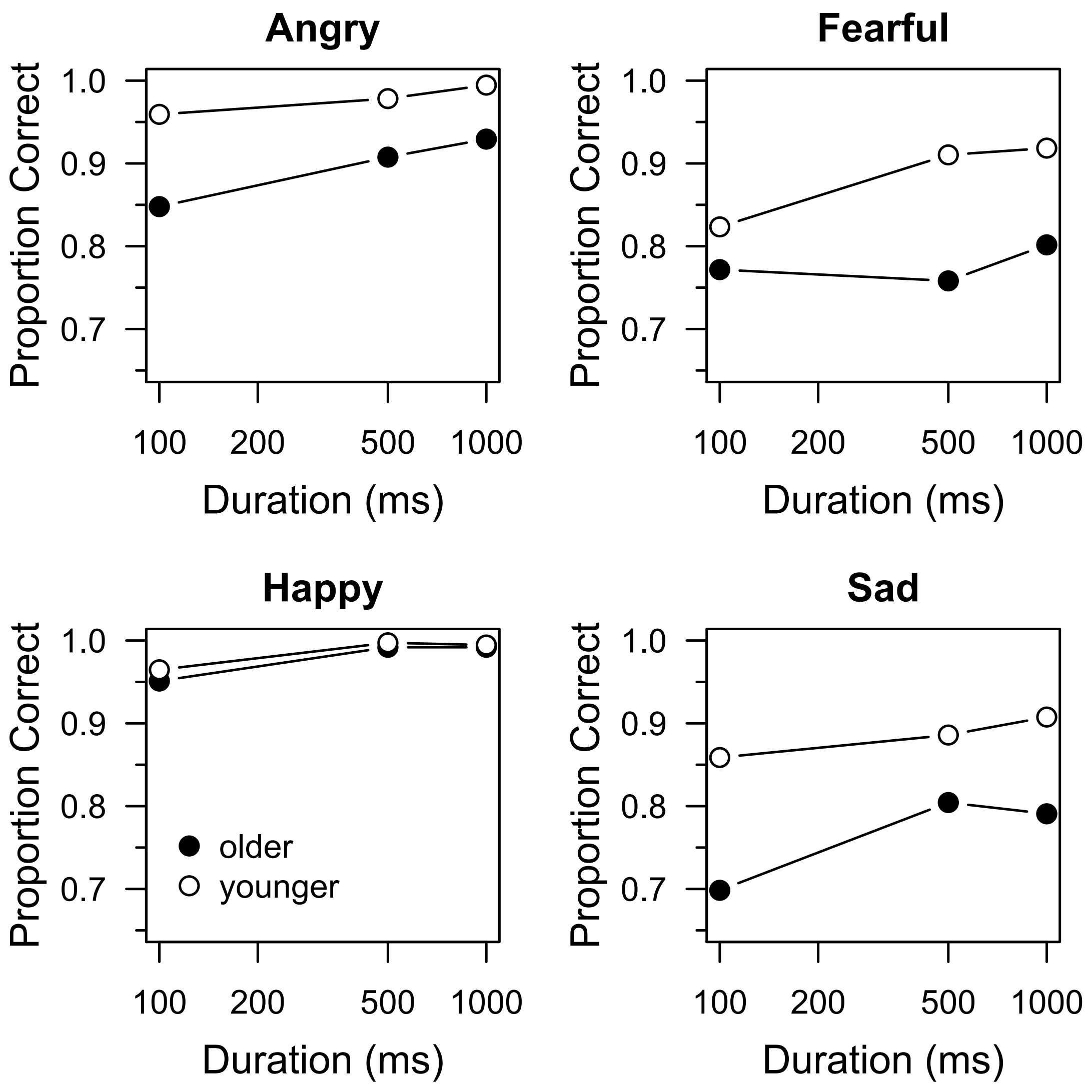

Figure 3.1: An illustration of the Group × Expression × Duration interaction obtained with response accuracy. For each facial expression at each stimulus duration, response accuracy for each subject was averaged across face orientation. These scores were then averaged across subjects in each age group. Each panel shows mean accuracy for older and younger adults plotted as function of stimulus duration for a single facial expression.

with all expressions except happy. The Group × Duration interaction was significant with fearful faces, and marginally significant with sad faces. With fearful faces, two-tailed t tests found that the group difference was significant at the two longest stimulus durations (500 ms: $t(35.58) = -4.30$, $p < .001$; 1000 ms: $t(37.44) = -4.08$, $p < .001$) but not at the shortest duration ($t(42.91) = -1.27$, $p = .209$). With sad faces, the group difference was significant at each stimulus duration ($t \leq -3.06$, $p \leq .004$ in each case). Hence, these results suggest that, when the effects of stimulus orientation are ignored, older adults are less accurate when identifying angry, fearful, and sad expressions, and that accuracy for fearful expressions improves less with increasing stimulus duration in older adults than younger adults.

Angry Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.234	1	0.340	44	30.37	-	< .001
Duration	0.082	2	0.404	88	8.90	.904	< .001
Group × Duration	0.015	2	0.404	88	1.60	.904	.210

Fearful Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.394	1	1.180	44	14.69	-	< .001
Duration	0.091	2	0.698	88	5.72	.973	.005
Group × Duration	0.060	2	0.698	88	3.77	.973	.028

Happy Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.002	1	0.088	44	0.90	-	.347
Duration	0.040	2	0.137	88	12.82	.591	< .001
Group × Duration	0.001	2	0.137	88	0.24	.591	.668

Sad Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.493	1	1.003	44	21.63	-	< .001
Duration	0.145	2	0.523	88	12.19	.794	< .001
Group × Duration	0.036	2	0.523	88	3.02	.794	.067

Table 3.2: Results of ANOVAs performed on data in each panel of Figure 3.1.

The original ANOVA on the accuracy data also found a significant Group × Expression × Orientation interaction ($F(3, 132) = 7.09$, $\tilde{\epsilon} = .778$, $p = .001$, $\eta_p^2 = .139$). To analyze this interaction, accuracy for each facial expression and each orientation was

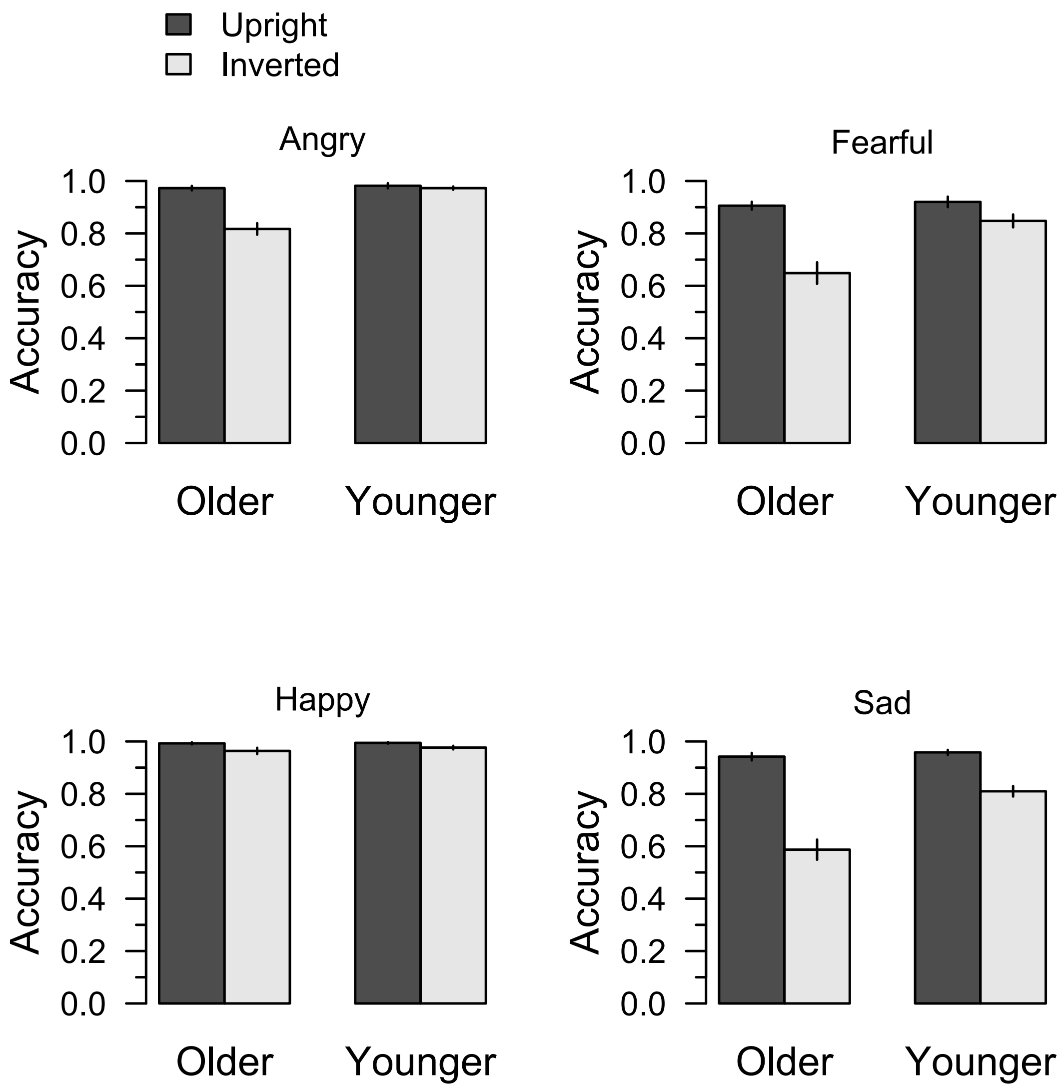

Figure 3.2: An illustration of the Group × Expression × Orientation interaction obtained with response accuracy. For each facial expression at each orientation, response accuracy for each subject was averaged across all three stimulus durations. These scores were then averaged across subjects in each age group. Each panel shows mean accuracy for older and younger adults plotted as function of stimulus orientation for a single facial expression. Error bars represent ±1 SEM.

Angry Faces	SS	df	Error SS	Error df	F	p
Group	0.156	1	0.226	44	30.37	< .001
Orientation	0.156	1	0.124	44	55.65	< .001
Group × Orientation	0.124	1	0.124	44	44.09	< .001

Fearful Faces	SS	df	Error SS	Error df	F	p
Group	0.263	1	0.787	44	14.69	< .001
Orientation	0.625	1	0.701	44	39.23	< .001
Group × Orientation	0.196	1	0.701	44	12.32	.001

Happy Faces	SS	df	Error SS	Error df	F	p
Group	0.001	1	0.059	44	0.90	.347
Orientation	0.013	1	0.053	44	10.68	.002
Group × Orientation	0.001	1	0.053	44	0.57	.455

Sad Faces	SS	df	Error SS	Error df	F	p
Group	0.329	1	0.669	44	21.63	< .001
Orientation	1.458	1	0.434	44	148.03	< .001
Group × Orientation	0.245	1	0.434	44	24.89	< .001

Table 3.3: Results of ANOVAs performed on data in each panel of Figure 3.2.

averaged across durations. Inspection of the average scores (see Figure 3.2) suggest that the effect of stimulus orientation was smaller with happy faces than with the other three expressions, and generally was larger in older adults than younger adults. The data in each panel in Figure 3.2 were analyzed with a 2 (group) × 2 (orientation) ANOVA; the results are shown in Table 3.3. With happy faces, only the main effect of orientation was significant, indicating that accuracy was lower with inverted faces. However, with angry, fearful, and sad expressions, the Group × Orientation interaction was significant. Inspection of Figure 3.2 suggests that the significant interactions between group and orientation reflect the fact that age differences with angry, fearful, and sad expressions were greater with inverted faces. Consistent with this idea, two-tailed t tests found that the group difference was significant with inverted angry, fearful, and sad faces ($t \leq -4.14$, $p \leq .0002$ in each case) but not with upright faces ($t \geq -0.58$, $p \geq .568$ in each case). These analyses suggest that, averaging across stimulus durations, older subjects were less accurate identifying inverted angry, fearful, and sad faces, but that the age groups did not differ in terms of accuracy for upright faces or for happy faces at either orientation.

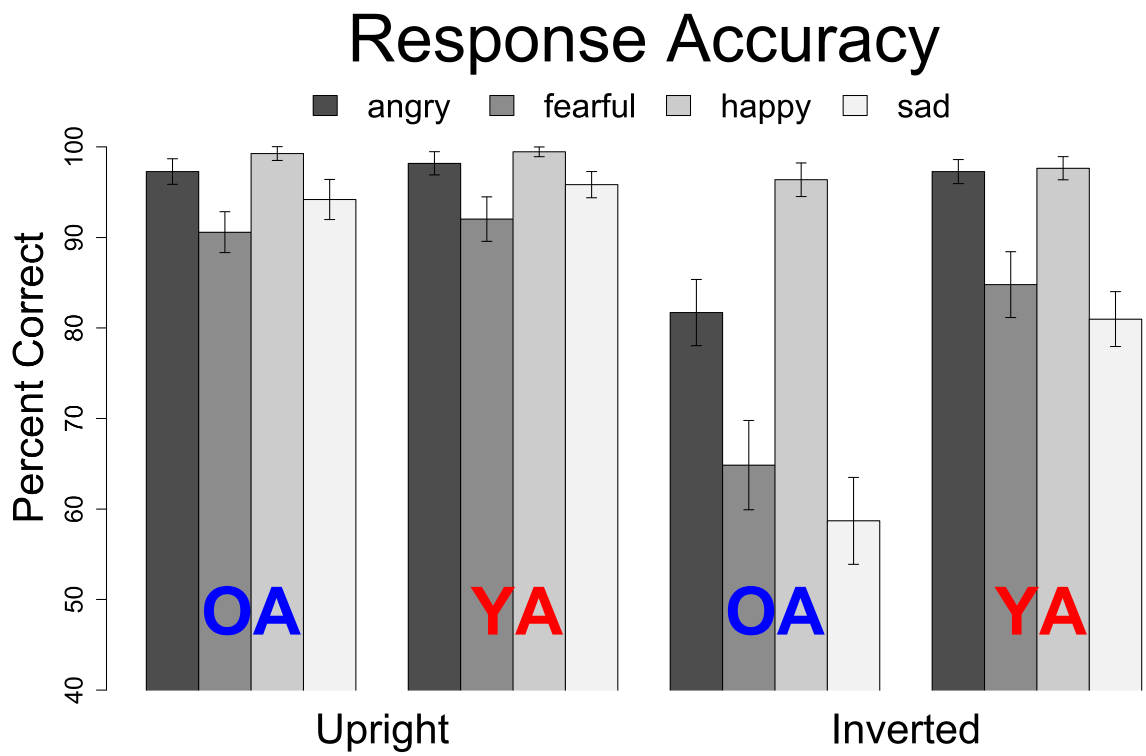

Figure 3.3: Pattern of rank order difficulty in older and younger adults' identification of upright and inverted facial expressions for the response accuracy measure. Error bars represent ± 1 SEM.

Both groups demonstrated a qualitatively similar pattern in the rank order of expressions they found most and least difficult to identify, and this pattern was consistent across orientations (Figure 3.3). Identification accuracy for upright faces was highest for happy (YA: 99.5%; OA: 99.3%), followed by angry (YA: 98.2%; OA: 97.3%), sad (YA: 95.8%; OA: 94.2%), and fearful (YA: 92.0%; OA: 90.5%). Paired t tests were used to evaluate pairwise differences between expressions for each age group. To maintain a family-wise error rate of .05, the observed p values were compared to the critical value $\alpha = .0083$. Unadjusted p values are reported here. In both age groups, accuracy for happy faces was significantly greater than accuracy for fearful faces (both $p's < .001$) and sad faces (YA: $p = .002$; OA: $p = .004$) faces, and accuracy for angry faces was significantly greater than for fearful faces (YA: $p = .007$; OA: $p = .001$). No other pairwise comparisons were significant ($p \geq .047$).

Similarly, for inverted faces, accuracy in both groups was higher for angry and happy expressions than for either fearful or sad (all $p's < .001$) expressions. A group difference was found only for the inverted angry-happy comparison: Older adults were more accurate with inverted happy than inverted angry faces ($p < .001$), whereas younger adults showed no difference in response accuracy ($p = .665$). This failure to find a difference between accuracy for inverted happy and angry faces in younger adults may have been due to a ceiling effect because accuracy was nearly 100% for both expressions. No other pairwise differences were significant ($p \geq .136$).

3.2 Response Latency

Three older participants failed to produce any correct responses (i.e., 0% accuracy) with at least one expression for inverted faces presented for 100 ms. Because the analyses of response latencies used only correct responses, these three subjects were not included in the analyses of response latency.

Analyses of the response latency data were performed on log-transformed reaction times for correct trials; the results are presented in Table 3.4. Significant main effects were obtained for age group ($F(1, 41) = 45.45$, $p < .001$, $\eta_p^2 = .527$), orientation ($F(1, 41) = 16.12$, $p < .001$, $\eta_p^2 = .290$), stimulus duration ($F(2, 82) = 32.87$, $\tilde{\epsilon} = .925$, $p < .001$, $\eta_p^2 = .441$), and expression ($F(3, 123) = 52.56$, $\tilde{\epsilon} = .978$, $p < .001$, $\eta_p^2 = .557$).

The Group × Duration interaction also was significant ($F(2, 82) = 4.54$, $\tilde{\epsilon} = .925$, $p = .016$, $\eta_p^2 = .125$). Inspection of Figure 3.4 indicates longer response latencies at all stimulus durations for older adults than younger adults. Two-tailed t tests confirmed this notion ($t \leq 5.58$, $p \leq .001$ in each case). Figure 3.4 suggests the interaction reflects the fact that response latencies in younger adults seem to improve at each duration, but not in older adults. Composite scores were calculated for each subject, and a two-sample t test was conducted on these scores to evaluate the linear trend of response latency across log-duration. The trend was significantly more negative in younger adults ($t(35.00) = 3.23$, $p = .001$). Overall, these results suggest that older adults benefit less from increased stimulus duration.

The ANOVA also found a significant three-way interaction between age group, orientation, and expression ($F(3, 123) = 3.05$, $\tilde{\epsilon} = 1.00$, $p = .031$, $\eta_p^2 = .079$). Figure 3.5 indicates the effect of stimulus orientation was largest for sad faces, and was much larger

Effect	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
G	10.80	1	9.70	41	45.45	-	$< .001$
O	0.60	1	1.47	41	16.12	-	$< .001$
G × O	0.60	1	1.47	41	17.06	-	$< .001$
D	1.10	2	1.39	82	32.87	.925	$< .001$
G × D	0.20	2	1.39	82	4.54	.925	.016
O × D	0.10	2	1.37	82	1.52	.969	.225
G × O × D	0.00	2	1.37	82	0.10	1.00	.905
E	2.70	3	2.15	123	52.56	.978	$< .001$
G × E	0.20	3	2.15	123	3.16	.978	.028
O × E	0.40	3	1.17	123	13.71	1.00	$< .001$
G × O × E	0.10	3	1.17	123	3.05	1.00	.031
D × E	0.20	6	2.43	246	2.70	.967	.016
G × D × E	0.10	6	2.43	246	1.11	.967	.358
O × D × E	0.00	6	1.98	246	0.77	.969	.594
G × O × D × E	0.00	6	1.98	246	0.55	.969	.740

Table 3.4: Response latency ANOVA: Group (G) × Orientation (O) × Duration (D) × Expression (E).

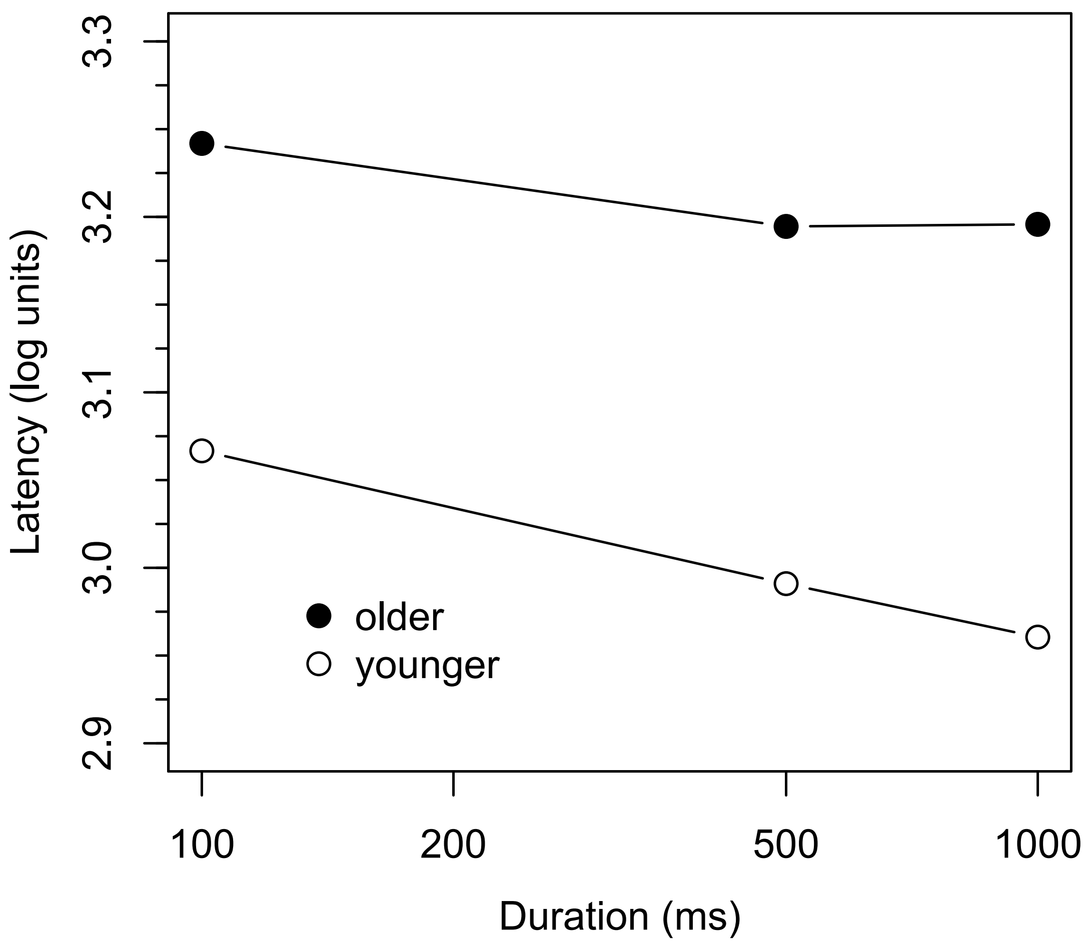

Figure 3.4: An illustration of the Group × Duration interaction obtained with response latency. For each duration, response latency for each subject was averaged across all expressions and orientations. These scores were then averaged across subjects in each age group. Mean response latency (in log units) for older and younger adults plotted as function of stimulus duration.

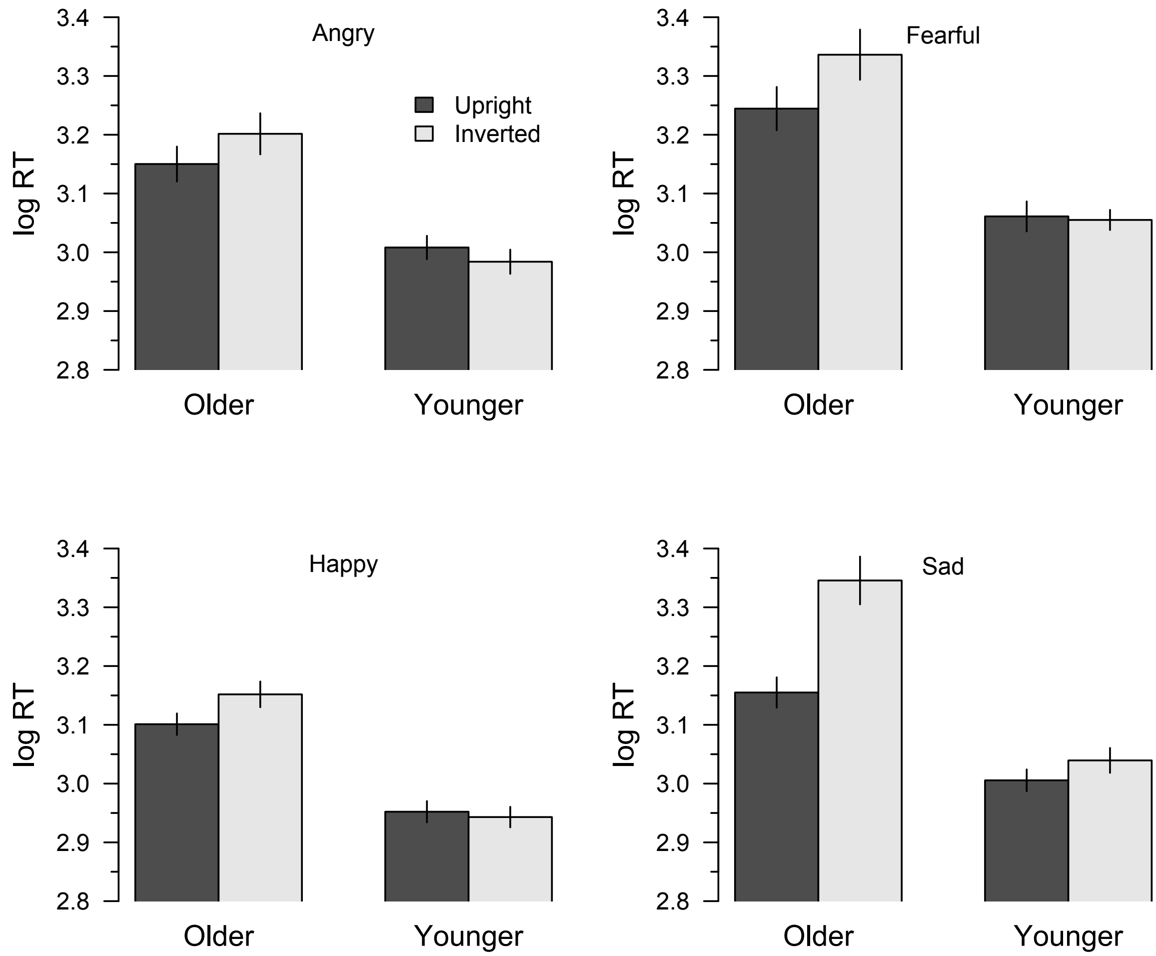

Figure 3.5: An illustration of the Group × Expression × Orientation interaction obtained with response latency. For each facial expression at each orientation, response latency for each subject was averaged across all three stimulus durations. These scores were then averaged across subjects in each age group. Each panel shows mean response latency (in log units) for older and younger adults plotted as a function of orientation for a single facial expression. Error bars represent ±1 SEM.

in older than younger subjects. The data in each panel of Figure 3.5 were analyzed with a 2 (group) × 2 (orientation) ANOVA (see Table 3.5 for the results). For all expressions, a significant Group × Orientation interaction was present. Closer inspection of Figure 3.5 suggests that the significant interactions between group and orientation reflect the fact that response latencies generally were slower for inverted faces for older, but not younger, participants. Consistent with this idea, paired t tests found that younger adults' response times for angry, fearful, happy, and sad faces did not depend on stimulus orientation ($t \geq -1.65$, $p \geq .114$ in each case). In contrast, older participants had longer response latencies for inverted faces for all facial expressions ($t \leq -3.24$, $p \leq .004$ in each case). In summary, a consistent, significant effect of stimulus orientation was found in older, but not younger, participants.

Angry Faces	SS	df	Error SS	Error df	F	p
Group	0.690	1	1.007	41	28.17	< .001
Orientation	0.000	1	0.211	41	0.77	.386
Group × Orientation	0.030	1	0.211	41	5.95	.019

Fearful Faces	SS	df	Error SS	Error df	F	p
Group	1.150	1	1.420	41	33.31	< .001
Orientation	0.040	1	0.270	41	5.96	.019
Group × Orientation	0.050	1	0.270	41	7.75	.008

Happy Faces	SS	df	Error SS	Error df	F	p
Group	0.680	1	0.508	41	55.28	< .001
Orientation	0.010	1	0.125	41	3.05	.088
Group × Orientation	0.125	1	0.053	41	6.28	.016

Sad Faces	SS	df	Error SS	Error df	F	p
Group	1.110	1	1.014	41	44.88	< .001
Orientation	0.270	1	0.271	41	40.79	< .001
Group × Orientation	0.130	1	0.271	41	19.89	< .001

Table 3.5: Results of ANOVAs performed on data in each panel of Figure 3.5.

Consistent with the accuracy findings, both groups demonstrated a qualitatively similar pattern in the rank ordering of the expressions they found most and least difficult to

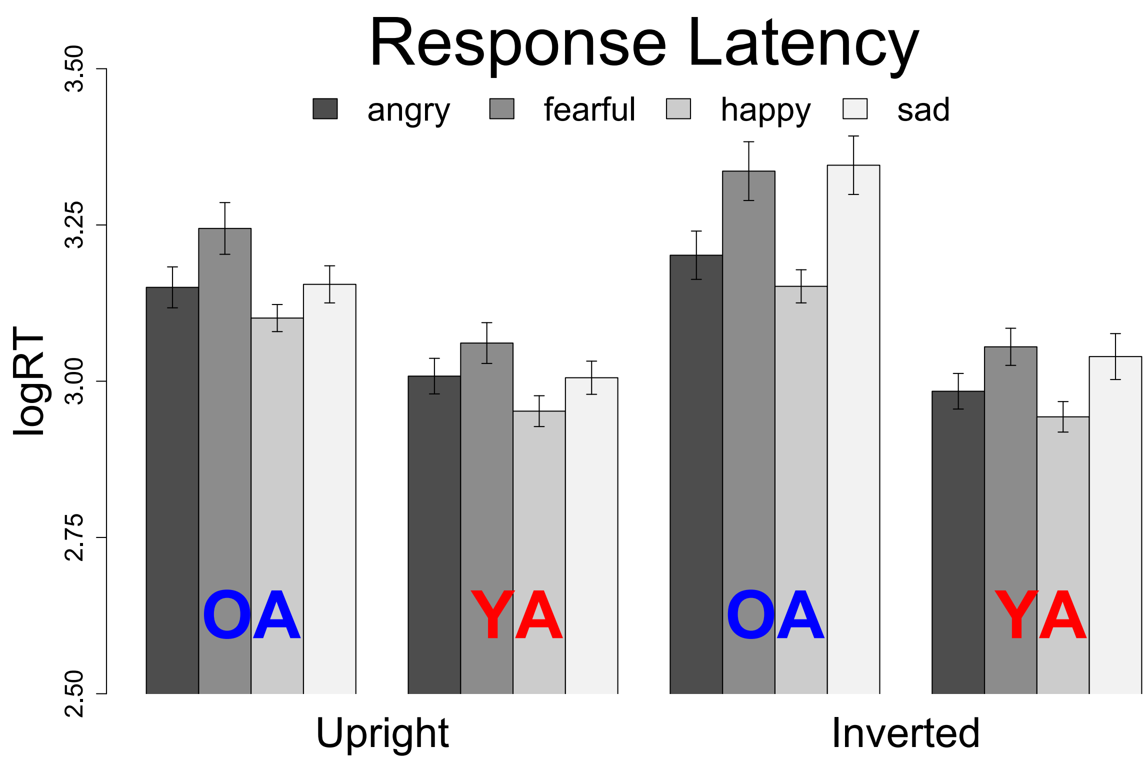

Figure 3.6: Pattern of rank order difficulty in older and younger adults' identification of upright and inverted facial expressions for the response latency measure. Error bars represent ± 1 SEM.

identify (see Figure 3.6). Paired t tests were used to evaluate pairwise differences between expressions for each age group. To maintain a family-wise error rate of .05, the observed p values were compared to the critical value $\alpha = .0083$. Unadjusted p values are reported here. For upright faces, responses in both age groups were fastest for happy faces, slowest for fearful faces, and intermediate for angry and sad expressions. Two age group differences were found: Younger adults were faster for upright happy faces than angry faces (YA: $p = .003$; OA: $p = .025$), and older adults were faster for upright angry faces than fearful faces (OA: $p = .002$; YA: $p = .009$). For inverted faces, responses in both age groups were fastest for happy faces, slowest for fearful and sad faces, and intermediate for angry faces. An age group difference was found for the angry-sad comparison: Older adults were faster for inverted angry faces than sad faces (OA: $p < .001$; YA: $p = .015$).

3.3 Intensity Ratings

Mean intensity ratings on correct trials were analyzed with a 2 (age) × 2 (orientation) × 3 (duration) × 4 (expression) ANOVA (see Table 3.6 for the results). The main effects of orientation ($F(1, 41) = 57.50$, $p < .001$, $\eta_p^2 = .581$), and expression ($F(3, 123) = 48.50$, $\tilde{\epsilon} = .936$, $p < .001$, $\eta_p^2 = .543$) were significant.

The ANOVA found a significant three-way interaction between age group, expression, and duration ($F(6, 246) = 2.26$, $\tilde{\epsilon} = .941$, $p = .042$, $\eta_p^2 = .056$). To analyze this interaction, for each subject we averaged the intensity rating scores for each expression across stimulus orientation. The means for each expression and age group are shown in Figure 3.7. The figure shows that angry expressions were rated as more intense than the other expressions and that the effect of stimulus duration was small. Group differences in intensity ratings also were small, but the direction and magnitude of the age difference in intensity ratings varied across expressions and durations. For example, happy expressions were given higher intensity ratings by older participants than younger participants, fearful expressions were given higher ratings by younger participants than older participants, and the direction of the group difference for sad expressions changed with stimulus duration. To assess these observations, the averaged scores in each panel of Figure 3.7 were analyzed with a 2 (group) × 3 (duration) ANOVA. The results of each ANOVA are listed in Table 3.7. None of the expressions showed a main effect of age group. The main effect of duration was significant, but only for fearful and sad faces. Finally, with sad faces the Group × Duration interaction was significant, however none of the group

Effect	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
G	0.20	1	357.88	41	0.02	-	.880
O	54.20	1	38.62	41	57.50	-	$< .001$
G × O	22.30	1	38.62	41	23.65	-	$< .001$
D	1.10	2	30.34	82	1.50	.977	.229
G × D	0.90	2	30.34	82	1.15	.977	.321
O × D	0.70	2	22.61	82	1.24	.938	.295
G × O × D	0.10	2	22.61	82	0.23	.938	.781
E	158.80	3	134.20	123	48.50	.936	$< .001$
G × E	8.30	3	134.20	123	2.54	.936	.064
O × E	28.70	3	33.42	123	35.25	.963	$< .001$
G × O × E	5.60	3	33.42	123	6.89	.963	$< .001$
D × E	3.20	6	34.05	246	3.80	.941	.002
G × D × E	1.90	6	34.05	246	2.26	.941	.042
O × D × E	1.80	6	31.69	246	2.38	.844	.040
G × O × D × E	1.30	6	31.69	246	1.63	.844	.152

Table 3.6: Intensity rating ANOVA: Group (G) × Orientation (O) × Duration (D) × Expression (E).

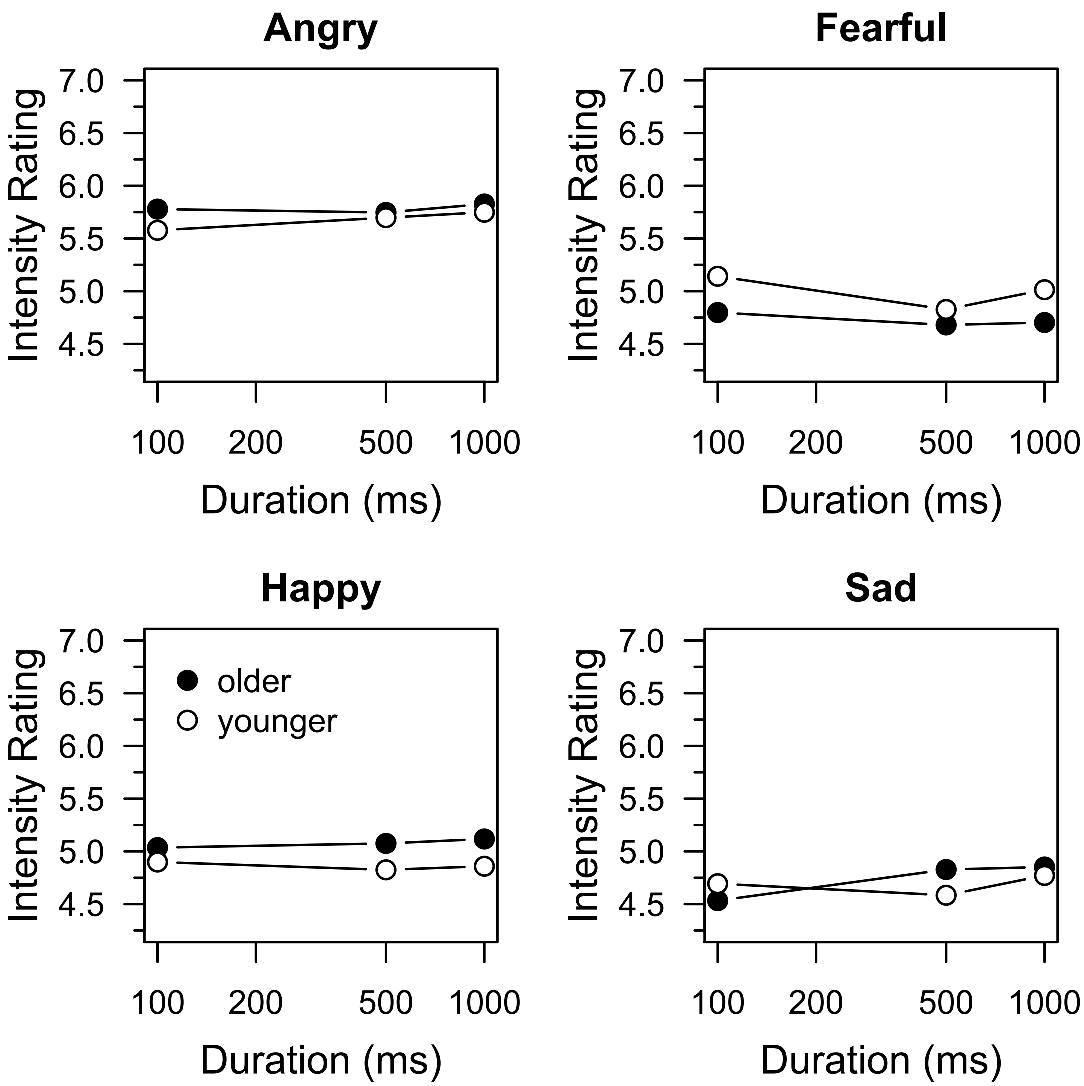

Figure 3.7: An illustration of the Group × Expression × Duration interaction obtained with intensity ratings. For each facial expression at each duration, intensity rating for each subject was averaged across orientations. These scores were then averaged across subjects in each age group. Each panel shows mean intensity rating for older and younger adults plotted as a function of duration for a single facial expression. Error bars represent ±1 SEM.

comparisons were significant ($t \geq -0.650$, $p \geq .304$ in each case). These analyses suggest that age differences in the perceived intensity of emotion expressions were small for each type of expression and all stimulus durations.

Angry Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.40	1	39.56	41	0.40	-	.531
Duration	0.30	2	6.39	82	1.67	1.00	.194
Group × Duration	0.01	2	6.39	82	0.89	1.00	.414

Fearful Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	2.29	1	62.87	41	1.50	-	.228
Duration	1.00	2	10.32	82	3.97	.872	.028
Group × Duration	0.24	2	10.32	82	0.95	.872	.381

Happy Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	1.50	1	74.62	41	0.82	-	.371
Duration	0.00	2	5.20	82	0.25	1.00	.783
Group × Duration	0.10	2	5.20	82	0.78	1.00	.462

Sad Faces	SS	df	Error SS	Error df	F	$\tilde{\epsilon}$	p
Group	0.09	1	68.99	41	0.06	-	.814
Duration	0.84	2	10.28	82	3.37	.924	.043
Group × Duration	0.89	2	10.28	82	3.54	.924	.037

Table 3.7: Results of ANOVAs performed on data in each panel of Figure 3.7.

The original ANOVA also found a significant interaction of group, expression, and orientation ($F(3, 123) = 6.89$, $\tilde{\epsilon} = .963$, $p < .001$, $\eta_p^2 = .146$). Intensity ratings for each facial expression and each orientation were averaged across durations. Examination of Figure 3.8 suggests that the effect of stimulus orientation was largest for fearful and sad faces, and generally was larger in older than younger subjects. Furthermore, it appears that the group difference measured with fearful, sad, and perhaps angry faces depended on stimulus orientation. To test these hypotheses, the averaged scores for each expression (i.e., each panel of Figure 3.8) were submitted to a 2 (group) × 2 (orientation) ANOVA; the results are shown in Table 3.8. The Group × Orientation interaction was significant with angry, fearful, and sad faces. Two-tailed t tests found that older subjects assigned

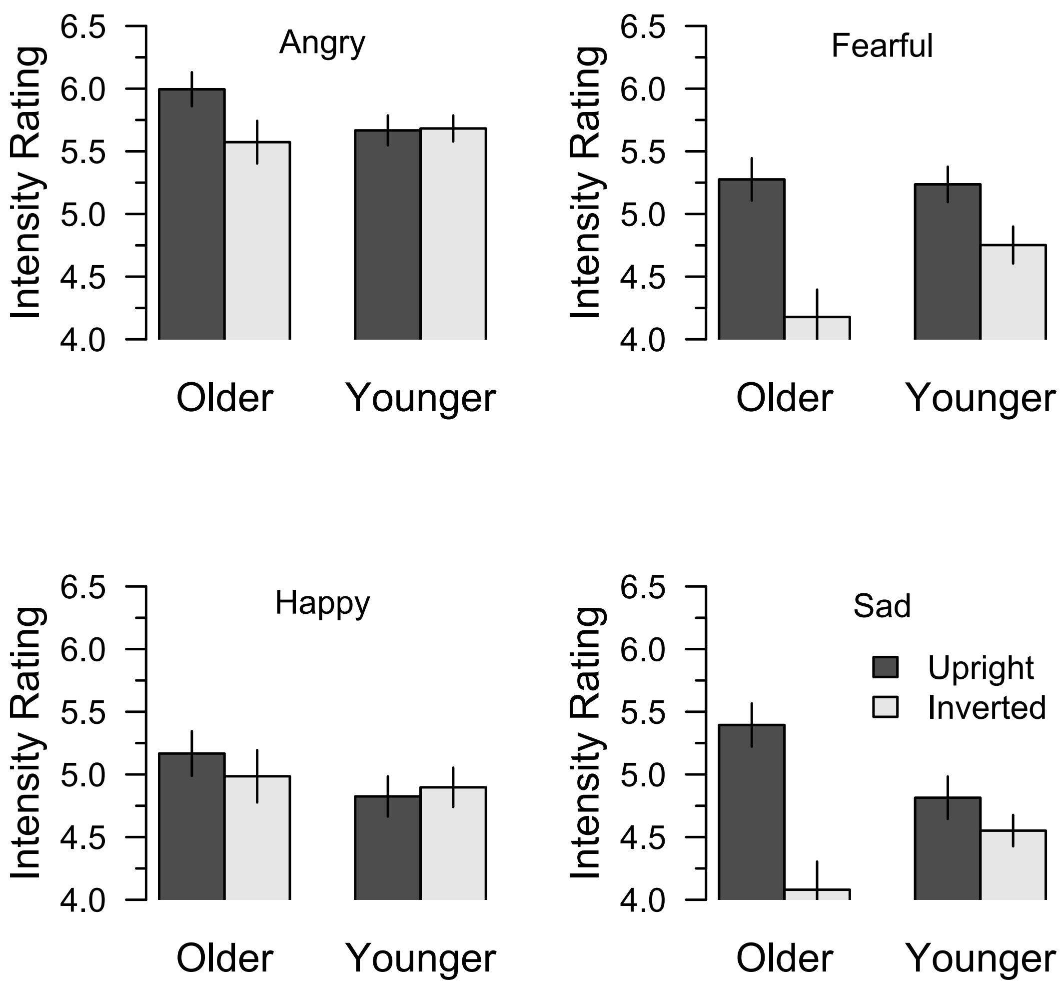

Figure 3.8: An illustration of the Group × Expression × Orientation interaction obtained with intensity ratings. For each facial expression at each orientation, intensity rating for each subject was averaged over all three stimulus durations. These scores were then averaged across subjects in each age group. Each panel shows mean intensity rating for older and younger adults plotted as a function of orientation for a single facial expression. Error bars represent ±1 SEM.

Angry Faces	SS	df	Error SS	Error df	F	p
Group	0.26	1	26.38	41	0.40	.531
Orientation	0.88	1	4.35	41	8.33	.006
Group × Orientation	1.02	1	4.35	41	9.65	.003

Fearful Faces	SS	df	Error SS	Error df	F	p
Group	1.53	1	41.91	41	1.50	.228
Orientation	13.39	1	8.19	41	67.02	$< .001$
Group × Orientation	2.01	1	8.19	41	10.07	.003

Happy Faces	SS	df	Error SS	Error df	F	p
Group	0.99	1	49.75	41	0.82	.371
Orientation	0.06	1	4.59	41	0.57	.454
Group × Orientation	0.35	1	4.59	41	3.09	.086

Sad Faces	SS	df	Error SS	Error df	F	p
Group	0.06	1	45.99	41	0.06	.814
Orientation	13.30	1	6.89	41	79.18	$< .001$
Group × Orientation	5.92	1	6.89	41	35.23	$< .001$

Table 3.8: Results of ANOVAs performed on data in each panel of Figure 3.8.

lower ratings to inverted fearful faces ($t(34.13) = -2.18$, $p = .037$), and higher ratings to upright sad faces ($t(40.66) = 2.40$, $p = .021$) compared to younger subjects. No other comparisons were significant ($t \geq -1.83$, $p \geq .077$, in all cases). These results suggest that older adults perceive inverted fearful faces as less intense, but upright sad faces as more intense, than younger adults, while the two groups perceive the intensity of angry and happy faces similarly, regardless of stimulus orientation.

Chapter 4

Discussion

4.1 Synthesis of Results

The current study examined the ability of older and younger adults to identify facial expressions of emotion by varying stimulus orientation and duration, and by obtaining ratings of perceived intensity. In general, older adults were slower and less accurate at identifying emotional faces. Age group differences in accuracy and response latency tended to be smallest for happy faces, and largest for fearful and sad faces. In addition, older adults were more affected by stimulus orientation, and benefit less from increased stimulus duration, compared to younger adults. When ignoring the effect of stimulus orientation, the age groups did not differ in their intensity ratings of angry, fearful, happy, or sad faces. Finally, the two age groups generally did not differ on the emotions they found most to least difficult to identify.

4.2 Assessment of Hypotheses

Consistent with previous studies, older adults were impaired at identifying facial expressions of emotion – older adults generally were slower and less accurate at identifying angry, fearful, happy, and sad faces. These results are typically interpreted as evidence of an age-related deficit in processing emotional content. The current experiment examined if these deficits might instead reflect age differences in working memory, detection sensitivity, general perceptual slowing, and/or inefficient information processing strategies.

Given that working memory declines as we age (Salthouse, 1991), we hypothesized that reducing the number of response options might decrease or eliminate age differences in expression identification, yet older adults still were impaired at recognizing all emotions. It is possible, however, that we would not have observed age differences had we used only two response options (Orgeta, 2010). Thus, while we cannot conclusively rule out the working memory hypothesis, we can surmise that the deficits we observed cannot solely be due to age differences in working memory. Indeed, covarying this measure cannot fully account for the decrease in older adults' performance accuracy on facial expression recognition tasks (Sullivan and Ruffman, 2004; Suzuki et al., 2007; Murphy and Isaacowitz, 2010; MacPherson et al., 2002; Phillips et al., 2002).

The detection sensitivity hypothesis – that older adults are impaired at emotion identification because they fail to detect its presence – was assessed by measuring perceived intensity. Previous findings on perceived emotional intensity have demonstrated inconsistent results: Orgeta and Phillips (2008) found older adults gave lower ratings to angry, fearful, and sad facial expressions, while Phillips and Allen (2004) observed an age-related decrease in the perceived intensity of happy and sad expressions. Furthermore, although the older adults in McDowell et al. (1994)'s study were less accurate at identifying sad faces, their perception of sad faces was more intense than younger adults. Note that this last result is opposite to what the detection sensitivity hypothesis would predict, and consistent with our finding that older adults perceived upright sad faces as more intense than did younger adults. One caveat, however, is that the current study used only maximum intensity expressions – age differences may be evident for more subtle portrayals of emotion (i.e., older adults may have higher intensity thresholds for correct identification of facial expressions) (Orgeta and Phillips, 2008).

To address the effect of perceptual slowing on older adults' ability to accurately identify facial expressions, we tested a range of stimulus durations. If older adults simply need more time to process the task-relevant information, identification accuracy should improve as stimulus duration increases. Furthermore, we would expect any age differences to be attenuated as a function of increasing duration, that is, older adults' performance should draw nearer to younger adults. For the accuracy data, the two groups did not differ on any expressions except for fearful faces, where age differences actually *increased* at longer durations. Similarly, for the response latency data, we found that, while both younger and older adults improved as stimulus duration increased, older adults received *less* benefit from the increased time. These results are, in fact, counter to what would be predicted by the perceptual slowing hypothesis.

In the current study, stimulus duration was always limited, whereas many previous studies of aging and emotion recognition allow participants unlimited viewing time. Perhaps the older adults in our study would perform similarly to younger adults had we also included an unlimited duration condition. This, however, seems an unlikely explanation, given that our older adults where equally fast at correctly identifying faces presented for 500 or 1000 ms. When one considers that social interactions take place in real-time, where displays of facial emotions are likely to be very brief, the stimulus durations used in the current study more closely represent what younger and older adults experience in their daily lives.

Finally, we suggested that age differences in expression identification may reflect older adults adopting a suboptimal (i.e., less efficient) information processing strategy. To that end, we tested whether younger and older adults process upright and inverted expressive faces similarly. Several studies have suggested that older adults may show a larger inversion effect when mentally rotating complex objects (Dror et al., 2005), such as faces (Adduri and Marotta, 2009). Importantly, Konar et al. (2012) demonstrated that performance on a task purported to tap holistic face processing was correlated with older adults' poorer performance on a later face identification task. Thus, it seems plausible that the disproportionate impairment following stimulus inversion demonstrated in our study by older adults is directly related to older adults' slower, and poorer, performance on the expression identification task.

The current experiment examined whether the observed age-related differences in expression identification reflect qualitative or quantitative changes in face processing of emotions. In our view, a change in the rank order of difficulty with which expressions are identified is best explained by a qualitative change in the way expressions are processed, whereas an overall decrease in accuracy, with no change in the rank order of difficulty, is best explained by a quantitative change in processing. Our data support this second view – for both groups, happy expressions were easiest, and fearful and sad expressions the hardest. Furthermore, these results were consistent across orientation – those expressions that were easiest to identify upright also were easiest to identify when inverted.

4.3 Remaining Questions

To our knowledge, this is the first study of emotion identification in aging that has explored the possibility that holistic face processing differs between younger and older adults. However, we do not yet know exactly what information younger and older adults are using to perform the task, how they use this information to perform the task, and whether this differs based on expression. When judging the identity of upright and inverted faces, younger adults make use of information around the eye region (Sekuler et al., 2004). Recently, it has been suggested that older adults are less able than younger adults to make use of this information in upright faces (Slessor et al., 2012). A similar suggestion has been put forward to explain the age-related deficits in recognizing upright facial expressions. Specifically, it has been suggested that older adults spend proportionately less time looking toward the upper- than lower-halves of upright angry, fearful, and sad faces compared to younger adults, and that this difference in gaze pattern is correlated with identification accuracy (Wong et al., 2005; Sullivan et al., 2007), although not all studies find this result (Murphy and Isaacowitz, 2010). Future research will be required to ascertain whether this also applies to the identification of inverted expressive faces.

4.4 Conclusions

Our results suggest that, in general, older individuals process expressive faces in a qualitatively similar way to their younger counterparts, but are less efficient at extracting the diagnostic information. Thus, age-related deficits observed in previous studies may reflect a general decrease in processing efficiency, rather than facial expression identification per se.

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