KURENAI

Kyoto University Research Information Repository

KYOTO UNIVERSITY

| Title | Reduced representational momentum for subtle dynamic facial expressions in individuals with autism spectrum disorders |
|---|---|
| Author(s) | Uono, Shota; Sato, Wataru; Toichi, Motomi |
| Citation | Research in Autism Spectrum Disorders (2014), 8(9): 1090-1099 |
| Issue Date | 2014-09 |
| URL | http://hdl.handle.net/2433/189087 |
| Right | © 2014 Elsevier Ltd. |
| Type | Journal Article |
| Textversion | author |

Kyoto University

1     **Running Head**: Representational momentum in ASD

2

3     **Reduced representational momentum for subtle dynamic facial express**

4     **ions in individuals with autism spectrum disorders**

5     Shota Uono[1], Wataru Sato[2], Motomi Toichi[1,3]

6

7     1 Graduate School of Medicine, Faculty of Human Health Science, Kyoto University,

8     53 Shogoin Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan.

9     2 The Hakubi Project, Primate Research Institute, Kyoto University, Inuyama, Aichi

10     484-8506, Japan.

11     3 The Organization of Promoting Developmental Disorder Research, 40 Shogoin

12     Sannou-cho, Sakyo-ku, Kyoto 606-8392, Japan.

13

14     Correspondence concerning this article should be addressed to Shota Uono, Graduate

15     School of Medicine, Faculty of Human Health Science, Kyoto University, 53 Shogoin

16     Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan.

17     Tel: +81- 75-751-3965; Fax: +81-75-751-3965;

18     E-mail: uonoshota1982@gmail.com

19

20   **Abstract**

21   The cognitive mechanisms underlying social communication via emotional facial

22   expressions are crucial for understanding the social impairments experienced by people

23   with autism spectrum disorders (ASD). A recent study (Yoshikawa & Sato, 2008) found

24   that typically developing individuals perceived the last image from a dynamic facial

25   expression to be more emotionally exaggerated than a static facial expression; this

26   perceptual difference is termed representational momentum (RM) for dynamic facial

27   expressions. RM for dynamic facial expressions might be useful for detecting emotion

28   in another's face and for predicting behavior changes. We examined RM for dynamic

29   facial expressions using facial expression stimuli at three levels of emotional intensity

30   (subtle, medium, and extreme) in people with ASD. We predicted that individuals with

31   ASD would show reduced RM for dynamic facial expressions. Eleven individuals with

32   ASD (three with Asperger's disorder and eight with pervasive developmental disorder

33   not otherwise specified) and 11 IQ-, age- and gender-matched typically developing

34   controls participated in this study. Participants were asked to select an image that

35   matched the final image from dynamic and static facial expressions. Our results

36   revealed that subjectively perceived images were more exaggerated for the dynamic

37   than for the static presentation under all levels of intensity and in both groups. The ASD

38  group, however, perceived a reduced degree of exaggeration for dynamic facial

39  expressions under the subtle intensity condition. As facial expressions are often

40  displayed subtly in daily communications, reduced RM for subtle dynamic facial

41  expressions may prevent individuals with ASD from appropriately interacting with

42  other people as a consequence of their difficulty detecting others' emotions.

43  Keywords: Autism spectrum disorders; Dynamic facial expression; Representational

44         momentum; Social impairment

45

46 **Reduced representational momentum for subtle dynamic facial expressions in**

47 **individuals with autism spectrum disorders**

48 **1. Introduction**

49 Individuals with autism spectrum disorders (ASD) have difficulty with social

50 interaction, including communication via emotional facial expressions (American

51 Psychiatric Association [APA], 2000). Clinical observation studies have consistently

52 confirmed that individuals with ASD are impaired in many types of social interactions

53 involving facial expressions. For example, previous studies examining children's

54 behavior under structured conditions have demonstrated that individuals with ASD

55 exhibit reduced attention (Sigman, Kasari, Kwon, & Yirmiya, 1992), emotional

56 behaviors (Corona, Dissanayake, Arbelle, Wellington, & Sigman, 1998), and facial

57 reactions (Yirmiya, Kasari, Sigman, & Mundy, 1989) in response to the facial

58 expressions of other individuals.

59 Extensive work has also been done to investigate the processing of emotional

60 facial expressions in individuals with ASD, though findings still remain rather

61 inconsistent. Almost all of these studies have used static facial expressions as stimuli. In

62 some of these studies, individuals with ASD have shown more perturbation in the

63 ability to recognize facial expressions than typically developing individuals (Ashwin,

64    Chapman, Colle, & Baron-Cohen, 2006; Braverman, Fein, Lucci, & Waterhouse, 1989;

65    Celani, Battacchi, & Arcidiacono, 1999). However, other studies have failed to show

66    such impaired recognition (Adolphs, Sears, & Piven, 2001; Castelli, 2005; Grossman,

67    Klin, Carter, & Volkmar, 2000).

68        Everyday communication of emotions is largely based on dynamic facial cues.

69    Real-life facial expressions reflect dynamic, moment-to-moment changes in emotional

70    state (Ekman & Friesen, 1975). A growing body of studies has consistently shown that

71    various psychological activities including subjective perception (Yoshikawa & Sato,

72    2008), recognition (Ambadar, Schooler, & Cohn, 2005; Bould & Morris, 2008; Bould,

73    Morris, & Wink, 2008), and emotional responses (Sato & Yoshikawa, 2007a, 2007b)

74    are enhanced in response to dynamic expressions as compared with static facial

75    expressions. Neuroimaging studies have also demonstrated that some brain regions

76    show increased activity in response to dynamic, rather than static, facial expressions

77    (LaBar, Crupain, Voyvodic, & McCarthy 2003; Sato, Kochiyama, Yoshikawa, Naito, &

78    Matsumura, 2004). Taken together, these findings indicate that dynamic facial

79    expressions are more effective for emotional communication than are static facial

80    stimuli. These findings also suggest the possibility that individuals with ASD may have

81    more difficulty processing dynamic facial expressions than static facial expressions.

82        To investigate the processing of dynamic facial expressions in individuals with

83    ASD, pioneering studies have examined their recognition of these stimuli (Gepner,

84    Deruelle, & Grynfeltt, 2001; Tardif, Lainé, Rodriguez, & Gepner, 2007). Gepner et al.

85    (2001) showed that a strobe presentation (i.e., presentation of a few frames of a clip

86    revealing changes in dynamic facial expressions, to produce the illusion of motion)

87    improved facial expression recognition as measured by a matching-to-sample task,

88    compared to static presentation, in typically developing controls but not in individuals

89    with ASD. However, individuals with ASD were able to recognize both dynamic and

90    static facial expressions. Using a similar matching-to-sample method, Tardif et al.

91    (2007) demonstrated that individuals with ASD were less able than typically developing

92    individuals to recognize dynamic and static facial expressions, but slowing down the

93    presentation of dynamic facial expressions improved their recognition. These studies

94    suggest differences in performance between individuals with ASD and typically

95    developing individuals in the recognition of dynamic facial expression. However,

96    dynamic presentation did not improve the recognition of facial expressions by typically

97    developing individuals in these studies. Recently, Kessels, Spee, and Hendriks (2010)

98    found that labeling of dynamic facial expressions, specifically those of fearful and

99    disgusted emotions, was defective in individuals with ASD. However, recognition

100    involved several processing stages; these included perceptual processing, interpretation

101    of emotional meaning, and selection of an appropriate verbal label. Consequently, it is

102    difficult to reach definite conclusions about which of the stages involved in processing

103    dynamic facial expressions are impaired in individuals with ASD. To elucidate

104    impairments specific to ASD, it is necessary to use an experimental paradigm in which

105    dynamic presentation enhances the processing of facial expressions in typically

106    developing individuals and to examine each component of this dynamic facial

107    expression processing, such as the perception and interpretation of emotional meaning.

108          Functional magnetic resonance imaging (fMRI) studies have shown that

109    dynamic facial expressions elicit atypical neural activation in several brain regions of

110    ASD individuals (Pelphrey, Morris, McCarthy, & Labar, 2009; Sato, Toichi, Uono, &

111    Kochiyama, 2012). Pelphrey et al. (2007) presented dynamic and static facial

112    expressions depicting anger, fear, or neutral emotions, and found that observation of

113    dynamic facial expressions elicited less activation in the superior temporal

114    sulcus/middle temporal gyrus (STS/MTG), fusiform gyrus (FG), amygdala (AMY), and

115    medial prefrontal cortex (MPFC) in individuals with ASD compared to typically

116    developing individuals. Sato et al. (2012) extended these findings using happy and

117    fearful emotional stimuli. The results showed that, compared to the typically developing

118    group, the ASD group exhibited less activation in the brain regions described above,

119    and also in the inferior frontal gyrus (IFG), in response to dynamic facial expressions.

120    These regions are involved in various aspects of processing of social stimuli, including

121    visual analysis of the dynamic aspects of faces (STS/MTG; Allison, Puce, & McCarthy,

122    2000); visual analysis of the invariant aspects of faces; the subjective perception of

123    faces (FG; Haxby, Hoffman, & Gobbini, 2000); emotional processing (AMY; Calder,

124    Lawrence, & Young, 2001); attribution of mental states (MPFC; Frith & Frith, 2003);

125    and motor mimicry (IFG; Iacoboni, 2005). It is tempting to speculate that deficits in

126    such psychological functions influence the processing of dynamic facial expressions in

127    individuals with ASD. However, as fMRI has inherent technical limitations in terms of

128    temporal resolution, and as the abovementioned brain regions are functionally and

129    structurally connected, it remains unclear which level or levels of processing are

130    impaired in the processing of dynamic facial expressions in individuals with ASD.

131         To investigate the more rapid components of dynamic facial expression

132    processing, Uono, Sato, and Toichi (2010) recently studied the subjective perception of

133    facial expressions in individuals with ASD. This study measured the representational

134    momentum (RM) of dynamic facial expressions. RM refers to a phenomenon in which

135    the perceived final position of a moving object shifts in the direction of the actually

136  observed movement (Freyd & Finke 1984; Hubbard, 1990). This effect has also been

137  reported in the perception of biological stimuli, including dynamic facial expressions

138  (Hudson, Liu, & Jellema, 2009; Yoshikawa & Sato, 2008). Uono et al. presented

139  dynamic or static facial expressions and asked participants to choose from a display of

140  variable emotional expressions the image that matched the final image from the

141  presented expression. In this task, dynamic presentation clearly enhanced processing of

142  facial expressions in typically developing individuals (Yoshikawa & Sato, 2008).

143  Further, the task allowed the perceptual processing of dynamic facial expressions to be

144  investigated, because neither interpretation of emotional meaning nor selection of a

145  verbal label was required. Contrary to expectations, both those with and without ASD

146  perceived the final images from the dynamic facial expressions to be more emotionally

147  exaggerated than the static facial expressions. This finding suggests that individuals

148  with ASD have an intact ability to process dynamic information from facial cues, at

149  least on a perceptual level.

150      However, one limitation of that study was that only a single intensity level of

151  facial expression stimuli was used. The stimuli were at a facial expression intensity of

152  80% based on a standard set (Ekman & Friesen, 1976) and showed clear to moderately

153  clear emotions.

154        One important area for exploration involves studying subtle facial expressions.

155    In everyday communication, many facial expressions are displayed with subtle intensity

156    (Ekman, 2003; Motley & Camden, 1988). Behavioral studies suggest that the detection

157    of subtle expressions provides an advantage in social interactions (e.g., Warren,

158    Schertler, & Bull, 2009; Yoon, Joormann, & Gotlib, 2009) because it allows us to notice

159    others' subtle emotional changes and to regulate our own behaviors appropriately.

160    Consistent with these notions, it has been suggested that dynamic information is more

161    important when processing subtle than when processing intense emotional expressions

162    (cf. Ambadar et al., 2005; Bould & Morris, 2008; Bould et al., 2008). If RM for

163    dynamic facial expressions is an adaptive mechanism for detecting emotion, it is

164    assumed to play a particularly crucial role in processing subtle expressions. Thus, one

165    contributor to the social interaction difficulties of individuals with ASD may be

166    compromised processing of subtle dynamic facial expressions. We hypothesize that

167    individuals with ASD may perceive subtle dynamic facial expressions in a less

168    exaggerated form than typically developing individuals do.

169        Another possible avenue of exploration would be to use more extreme facial

170    expressions. In the previous study that tested RM in typically developing individuals

171    (Yoshikawa & Sato, 2008), the researchers suggested that the effects of dynamic facial

172    expressions tend to be weaker at 100% intensity compared with at 80% intensity.

173    Yoshikawa and Sato speculated that the RM for 100% expressions might be suppressed

174    because participants evaluate such expressions as extreme during realistic social

175    interactions. A recent behavioral study (Rutherford & McIntosh, 2007) investigated the

176    perception of facial expressions varying in intensity in ASD. Rutherford and McIntosh

177    (2007) presented two emotional faces with different intensities and asked participants to

178    select the more realistic image. The results showed that individuals with ASD were

179    more likely to judge extremely exaggerated facial expressions as the most realistic.

180    Based on these findings, dynamic facial expressions of extremely high intensity might

181    trigger further changes in individuals with ASD, but not controls, whereas those of

182    medium intensity did so in both groups. Thus, we hypothesized that individuals with

183    ASD might perceive dynamic facial expressions as more exaggerated than normal

184    controls do under the highest intensity condition.

185         This study investigated RM for dynamic facial expressions at various intensities

186    among individuals with high-functioning ASD and IQ-, age-, and gender-matched

187    typically developing controls. We presented dynamic and static facial expressions at

188    subtle, medium, and extreme intensities and asked participants to change an emotional

189    face display to match the perceived final image from dynamic and static facial

190    expression stimuli. Based on a previous study (Uono et al., 2010) and the

191    aforementioned evidence, we predicted that (1) both the ASD and control groups would

192    perceive the final images from the dynamic facial expressions to be more emotionally

193    exaggerated than the static facial expressions; (2) the ASD group would perceive subtle

194    dynamic facial expressions as less exaggerated than would the control group; and (3)

195    the ASD group, compared with the control group, would perceive dynamic facial

196    expression as more exaggerated under the extremely intense emotion condition.

197

198    **2. Materials and methods**

199    2.1 Participants

200         The participants were 11 individuals with ASD and 11 typically developing

201    controls. The two groups (ASD and control) were matched for chronological age (ASD

202    group: mean $\pm$ $SD$ = 22.1 $\pm$ 4.8; control: mean $\pm$ $SD$ = 22.8 $\pm$ 2.5; independent $t$-test,

203    $t(20) = 0.46$ , $p > 0.10$), gender (ASD group: eight males, three females; control: seven

204    males, four females; Fisher's exact test, $p > 0.10$) and IQ (mean $\pm$ $SD$ verbal IQ, control:

205    117.1 $\pm$ 10.9, ASD: 113.1 $\pm$ 10.2, $t(20) = 0.86$, $p > 0.10$; mean $\pm$ $SD$ performance IQ,

206    control: 111.5 $\pm$ 10.7, ASD: 108.5 $\pm$ 13.9, $t(20) = 0.57$, $p > 0.10$; mean $\pm$ $SD$ full-scale

207    IQ, control: 116.1 $\pm$ 10.3, ASD: 111.6 $\pm$ 9.9, $t(20) = 1.03$, $p > 0.10$) . Verbal and

208   performance IQ was measured using the Japanese version of the WAIS-R (Shinagawa,

209   Kobayashi, Fujita, & Maekawa, 1990), WAIS-III (Fujita, Maekawa, Dairoku, &

210   Yamanaka, 2006), WISC-R (Kodama, Shinagawa, & Motegi, 1982), and WISC-III

211   (Azuma et al., 1998). Handedness was assessed in individuals with and without ASD

212   using the Edinburgh Handedness Inventory (Oldfield, 1971). The scores did not differ

213   between groups (control: mean $\pm$ $SD$ = 80.0 $\pm$ 53.7; ASD: mean $\pm$ $SD$ = 80.0 $\pm$ 41.0;

214   independent $t$-test, $t(20) < 0.01$, $p > 0.10$). Both groups included 10 right-handed and

215   one left-handed participants. All the participants had normal or corrected-to-normal

216   visual acuity.

217        The participants in the ASD group were diagnosed with either Asperger's

218   disorder (three males) or pervasive developmental disorder not otherwise specified

219   (PDD-NOS; five males and three females) at the time of the present study according to

220   the DSM-IV-TR criteria (APA, 2000). PDD-NOS includes heterogeneous subgroups of

221   PDD with varying degrees of qualitative social impairment. The participants with

222   PDD-NOS included in the present study did not satisfy criteria for Asperger's disorder

223   because 1) they had similar impairments in qualitative social interaction without

224   apparently restricted interests or stereotyped behaviors, or (2) their impairment in

225   qualitative social interaction was milder than that observed in Asperger's disorder. Thus,

226     our participants with PDD-NOS had milder pathologies than did those with Asperger's

227     disorder. The final diagnoses were made by a child psychiatrist (MT) based on the

228     reports of clinical psychologists, interviews with each participant, information from

229     each participant's parents or teachers, and childhood clinical records when available.

230     The participants in the ASD group were outpatients who had been referred to Kyoto

231     University Hospital or to the Division of Human Health Science of Kyoto University

232     Graduate School of Medicine due to social maladaptation. They were all free of

233     neurological or psychiatric problems other than those derived from ASD, and none was

234     receiving any medication. The members of the typically developing control group were

235     students at several universities who were recruited using paper- and web-based

236     advertisements. After acquiring the data from the ASD group, we collected IQ data

237     from typically developing participants. Eleven typically developing participants who

238     matched the ASD group in terms of age and IQ were selected for participation. The

239     participants aged younger than 18 years received written informed consent from their

240     parents to participate in the study. The study was conducted in accord with institutional

241     ethical provisions and the Declaration of Helsinki.

242        The severity of symptoms was assessed using the Childhood Autism Rating

243     Scale (CARS; Schopler, Reichler, & Renner, 1986), which was completed based on

244     interviews with participants and their parents and direct observations of participants

245     during these interviews. The evaluations were performed by psychiatrists. The CARS

246     has been shown to be an effective tool for diagnosing autism in adolescents, adults, and

247     children (Mesibov, Schopler, Schaffer, & Michal, 1989). The CARS scores of the ASD

248     group (mean ± $SD$ = 21.04 ± 2.67) were comparable to those of Japanese individuals

249     with Asperger's disorder in a previous study (mean ± $SD$ = 22.22 ± 3.57; $t(45) = 1.01$, $p$

250     > 0.10) (Koyama, Tachimori, Osada, Takeda, & Kurita, 2007). These data indicate that

251     the symptoms of individuals in the ASD group were severe enough to allow for the

252     diagnosis of ASD.

253

254     2.2 Design

255          The experiment was constructed as a three-factorial mixed randomized–repeated

256     design, with group (ASD or control) as the randomized factor and presentation

257     condition (dynamic or static) and intensity (52%, 80%, or 108%) as the repeated factors.

258

259     2.3 Stimuli

260          From a set of facial images (Ekman & Friesen, 1976), we selected one neutral

261     expression slide and two emotional expression (fearful and happy) slides for each of

262    four actors (two men and two women). We used computer-morphing techniques

263    (Mukaida et al., 2000) to produce images that were intermediate between the neutral

264    expression and each of the two emotional expressions in 4% steps. We produced

265    dynamic facial expression stimuli that changed from 4% emotional expression to a

266    maximum of 52%, 80%, or 108% of the original emotional expression in 4% steps. To

267    create the images of 108% emotional expression, we changed the facial features of the

268    100% emotional expression in the direction opposite from that depicted in the neutral

269    face. We presented a total of 13, 20, and 27 image frames in succession for the 52%,

270    80%, and 108% conditions, respectively (e.g., under the 52% condition, the first image

271    was followed by 11 intermediate images changing from 8% to 48% in 4% steps, ending

272    with the final image). Under the dynamic condition, each frame was presented for 10 ms.

273    Thus, the total presentation time was 130 ms, 200 ms, and 270 ms for the 52%, 80%,

274    and 108% conditions, respectively. Fig. 1 shows the first image, some intermediate

275    images, and the final image of a dynamic stimulus. Under the static condition, only the

276    last frame of each dynamic facial expression stimulus was presented. The total

277    presentation time was the same as that for the dynamic facial expression with the

278    corresponding intensity.

279                                    *********************

280          Place Fig. 1 around here

281          ********************

282

283    2.4 Apparatus

284          Stimulus presentation and data acquisition were controlled using a program

285    written in Visual C++ 5.0 (Microsoft) on a Windows computer (HP xw4300

286    Workstation). Stimuli were presented on a 17-in CRT monitor (Iiyama; screen

287    resolution $1024 \times 768$ pixels; refresh rate 100 Hz). The distance between the monitor

288    and participants was fixed at approximately 57 cm using a headrest.

289

290    2.5 Procedure

291          The procedure in this study was the same as that used in previous studies (Uono

292    et al., 2010; Yoshikawa & Sato, 2008). On the monitor, two windows were presented.

293    The left window was used for stimulus presentation, and the right window was used for

294    responses. The vertical and horizontal visual angles of the stimulus and response

295    windows were 11.1° and 7.8°, respectively. In each trial, a cross hair was first presented

296    at the center of the stimulus window. The participants were instructed to fixate on this.

297    Then, a dynamic or static stimulus was presented in the stimulus window, and 250 ms

298    later, an initial face image was presented in the response window. Participants were

299    instructed to match the image in the response window exactly with the last image shown

300    in the dynamic or static stimulus, by using the mouse to drag a slider to the left or right.

301    The face shown in the initial image in the response window had an emotional

302    expression with -10%, 0%, or +10% intensity of the presented stimuli (e.g., under the

303    52% condition, 42%, 52%, or 62%). The upper or lower limit of the slide had one of

304    three predefined ranges, each of which covered an 80% range of intensity (e.g., under

305    the 52% condition, 2–82%, 12–92%, or 22–102%). The ranges of the scale varied

306    randomly across trials and were not visible to the participants. After a participant

307    selected an image, he or she clicked a button, and the image in the response window

308    disappeared. Then, the stimulus was presented again in the left window, and 250 ms

309    later, the image chosen by the participant appeared in the response window. If the

310    participant thought the images matched, he or she clicked the button on the display and

311    went on to the next trial; if not, the participant could modify the image until he or she

312    thought it matched. No time limits were set for the first or second judgment. Before

313    starting the experiment, each participant was given several practice trials and allowed to

314    practice image manipulation using the mouse to move the slider. A total of 48 trials

315    (eight trials per condition) were performed in blocks, and the order of trials was

316    counterbalanced across participants.

317

318    2.6 Data analysis

319        Data were analyzed using SPSS10.0J (SPSS Japan). For each participant, the

320    mean intensity of response images was calculated for each condition. Then, the ratio

321    between the intensity of responses and of presented images was calculated for each

322    condition. The ratios were analyzed with a 2 (group) $\times$ 2 (presentation) $\times$ 3 (intensity)

323    repeated-measures analysis of variance (ANOVA). To test our predictions, follow-up

324    simple interaction analyses and simple–simple main-effect analyses were conducted (cf.

325    Kirk, 1995).

326        The CARS (Schopler et al., 1986) was used to assess the level of social

327    dysfunction in individuals with ASD. As in our previous studies (Uono, Sato, & Toichi,

328    2011; 2013), we used the following CARS items, which were classified as elements of

329    the social functioning construct: ''imitation,'' ''nonverbal communication,''

330    ''relationship to people,'' ''verbal communication,'' and ''visual response.'' We

331    averaged the scores on these items to obtain the social dysfunction scale. To analyze the

332    relationships between degree of RM and CARS scores, the ratio between the mean

333    intensity of the responses to images under dynamic and static conditions was calculated

334    for each intensity condition. Pearson's product–moment correlations between

335    combinations of these variables were calculated. The significance of correlation

336    coefficients was evaluated using $t$-tests (two-tailed). We excluded multivariate outliers

337    by calculating the Mahalanobis distance for each case ($p < 0.10$).

338

339    **3. Results**

340        The mean response under each condition (with *SE*) is shown in Table 1. The

341    ratios between the intensity of response images and presented images were calculated

342    (Fig. 2) and subjected to a group × presentation × intensity ANOVA. Most importantly,

343    the results revealed a significant three-way interaction ($F(2, 40) = 3.52$, $p = 0.04$).

344    Additionally, the results revealed a main effect of presentation ($F(1, 20) = 52.20$, $p <$

345    0.01), indicating that participants perceived more exaggerated images under dynamic

346    than under static conditions. A main effect of intensity was also found ($F(2, 40) = 26.75$,

347    $p < 0.01$). Other main effects and interactions were not significant ($F < 2.37$, $p$s $> 0.10$).

348                    ********************

349                    Place Table 1 and Fig. 2 about here

350                    ********************

351    As follow-up analyses for the three-way interaction, a simple interaction analysis

352    was conducted for each intensity condition. The results revealed that the simple

353    interactions between group and presentation condition were significant under the 52%

354    intensity condition ($F(1, 60) = 6.93$, $p = 0.01$) but not under the 80% ($F(1, 60) = 0.46$, $p$

355    $> 0.10$) and 108% intensity conditions ($F (1, 60) = 1.52$, $p > 0.10$). A follow-up

356    simple–simple main-effect analysis of group under the 52% intensity condition revealed

357    that typically developing controls perceived more exaggerated images than did

358    individuals with ASD under the dynamic condition ($F(1, 120) = 6.76$, $p = 0.01$) but not

359    under the static condition ($F(1, 120) = 0.08$, $p > 0.10$).

360    To confirm the main effect of presentation which would replicate our previous

361    findings (Uono et al., 2010; Yoshikawa & Sato, 2008), a follow-up analysis was

362    conducted for each group and intensity. For the control group, the simple–simple main

363    effects of presentation were significant under all intensity conditions (52%: $F(1, 60) =$

364    $34.03$, $p < 0.01$; 80%: $F(1, 60) = 5.21$, $p = 0.03$; 108%: $F(1, 60) = 22.29$,   $p < 0.01$).

365    For the ASD group, the simple–simple main effects of presentation were significant

366    under all intensity conditions (52%: $F(1, 60) = 4.46$, $p = 0.04$; 80%: $F(1, 60) = 10.50$, $p$

367    $< 0.01$; 108%: $F(1, 60) = 8.88$, $p < 0.01$). In sum, the results indicated that both control

368     and ASD groups perceived the final dynamic facial expression images to be more

369     exaggerated than the static expressions under all intensity conditions.

370          The correlation between the degree of RM and the CARS score was significant

371     under the 52% ($r(10) = -0.71, p < 0.05$) but not the 80% ($r(11) = 0.33 , p > 0.10$) or

372     108% ($r(11) = 0.14 , p > 0.10$) condition, indicating that the greater the reduction in RM

373     for subtle dynamic facial expressions, the more severe the extent of social dysfunction

374     in that ASD individual (see Fig. 3).

375                              ********************

376                              Place Fig. 3 about here

377                              ********************

378

379     **4. Discussion**

380          Our results indicated that both control and ASD groups perceived the final

381     images in dynamic facial expressions to be more exaggerated than static facial

382     expressions. These results support our first prediction and replicate previous findings

383     showing the existence of RM for dynamic facial expressions in individuals without

384     (Yoshikawa & Sato, 2008) and with ASD (Uono et al., 2010).

385    More importantly, our results reveal that when dynamic, but not static, facial

386    expressions with subtle emotion are presented, typically developing controls perceive

387    more exaggerated images than do individuals with ASD. This group difference is in line

388    with previous studies suggesting that dynamic information is more important for the

389    processing of subtle emotional expressions than for intense emotional expressions

390    (Ambadar et al., 2005; Bould & Morris, 2008; Bould et al., 2008). The results of the

391    present study are also consistent with the impaired recognition of dynamic facial

392    expression in individuals with ASD found in previous studies (Kessels et al., 2010;

393    Tardif et al., 2007). However, as no work has yet investigated subtle emotions in this

394    paradigm, using RM, this is the first study to show the compromised processing of

395    dynamic facial expressions with subtle emotions at a perceptual level. The results

396    suggest that individuals with ASD and typically developing individuals may see their

397    social world differently, though dynamic presentation enhances the subjective

398    perception of facial expression in both groups. Yoshikawa and Sato (2008) suggested

399    that exaggerated perceptions of dynamic facial expressions are useful for detecting the

400    emotions of others. It follows that we can predict another person's behavior based on

401    his or her emotional changes. Consistent with this notion, the results revealed that the

402    extent of reduction in RM for subtle dynamic facial expressions was closely related to

403    the degree of social dysfunction in ASD individuals. As it is difficult to detect emotion

404    in subtle emotional facial expressions, the more exaggerated perceptions of subtle

405    dynamic facial expressions, shown by typically developing individuals in comparison

406    with individuals with ASD, may play a crucial role in difficulties experienced by the

407    latter group with regard to efficiently extracting emotional meaning from faces.

408    Consequently, the reduced RM for dynamic facial expressions reflecting subtle

409    emotions may prevent individuals with ASD from noticing the subtle emotional changes

410    of others and regulating their own behaviors appropriately.

411        One might argue that the short presentation time under the 52% condition

412    contaminated the processing of the stimuli by individuals with ASD. However,

413    participants were asked to exactly match the image in the response window with the last

414    image of the stimulus. The presentation time for the last image (10 ms) was identical

415    across dynamic conditions. The performance of the ASD group was comparable to that

416    of the control group under the 80% and 108% dynamic conditions. Furthermore, no

417    difference in the performance of the groups was found under the 52% static condition,

418    which used the same presentation time as under the dynamic condition. Based on these

419    results, the short presentation time under the 52% condition cannot explain the reduced

420    RM for subtle dynamic facial expressions in individuals with ASD.

421        The finding that individuals with ASD have a less exaggerated perception of

422    subtle dynamic facial expressions is important for understanding the nature of impaired

423    social interactions and emotional expression processing in ASD. Difficulty with facial

424    communication is one of the diagnostic criteria for ASD (APA, 2000). Observational

425    studies under structured conditions have demonstrated that individuals with ASD

426    exhibit reduced attention and emotion in response to others' dynamic facial expressions

427    (Corona et al., 1998; Sigman et al., 1992; Yirmiya et al., 1989). However, experimental

428    studies investigating the processing of dynamic (Gepner et al., 2001; Kessels et al.,

429    2010; Tardif et al., 2007) and static (Adolphs et al., 2001; Ashwin et al., 2006;

430    Braverman et al., 1989; Castelli, 2005; Celani et al., 1999; Grossman et al., 2000) facial

431    expressions with relatively intense emotions have reported conflicting findings.

432    Emotional communication in daily life is mainly based on dynamic facial cues. Facial

433    expressions are often displayed with subtle intensity (Ekman, 2003; Motley & Camden,

434    1988). Based on the results of the present study, the use of dynamic facial expressions

435    depicting subtle emotion reveals impairments in the emotional communication of

436    people with ASD, even in experimental settings. The less exaggerated perception of

437    subtle dynamic facial expressions may explain the discrepancy between experimental

438    settings and real-life in individuals with ASD as experimental settings have generally

439    used dynamic facial expressions depicting intense emotion. The use of subtle dynamic

440    facial expressions may be useful for revealing deficits in other components of the

441    processing of dynamic facial expressions among those with ASD (e.g., recognition,

442    physiological responses, and subjective feelings).

443         Impairment of low-level and biological motion processing might explain

444    reduced RM to subtle dynamic facial expressions in ASD, as individuals who are at risk

445    for the impairment of motion processing show reduced RM (Taylor & Jacobson, 2010).

446    There is evidence that individuals with ASD have impairments in the perception of

447    biological motion depicting human actions (Blake, Turner, Smoski, Pozdol, & Stone,

448    2003), particularly emotional actions (Hubert et al., 2007; Moore, Hobson, & Lee 1997).

449    Moore et al. (1997) found that few children with ASD could correctly recognize

450    biological motion when stimuli were presented briefly, although their performance did

451    not significantly differ from that of children with mental retardation. Furthermore,

452    Atkinson (2009) demonstrated that impaired recognition of biological motion depicting

453    emotional actions was associated with a deficit in low-level motion processing in ASD,

454    and recently, individual differences have been reported in the degree of this impairment

455    (Milne et al., 2002; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). Based on

456    these findings, the reduced RM in dynamic facial expressions with subtle, but not

457    intense, emotion might reflect variability in the impairment of low-level and biological

458    motion processing. Subtle expressions are more likely to reveal varying levels of

459    impairment in dynamic facial expression processing.

460        Our current findings provide insights into the neural mechanisms involved in

461    processing of dynamic facial expressions. Previous studies reported reductions in brain

462    activation of ASD individuals in response to dynamic facial expressions (Pelphrey et al.,

463    2007; Sato et al., 2012). The brain regions affected were the STS/MTG and IFG, which

464    are associated with processing of the dynamic aspects of social stimuli (Allison et al.,

465    2000; Iacoboni, 2005). Moreover, it has been suggested that these two regions are

466    directly connected (Catani, Howard, Pajevic, & Jones, 2002; Rilling et al., 2008;

467    Thiebaut de Schotten et al., 2011). Sato et al. (2012) showed that effective bidirectional

468    connectivity in the primary visual cortex–STS/MTG–IFG circuit is enhanced during

469    observation of dynamic versus static facial expressions in typically developing

470    individuals but not in those with ASD. In agreement with previous neuroimaging results,

471    the current findings indicating diminished perception of emotional intensity in ASD

472    individuals suggest that bidirectional information flow may play an important role in the

473    enhancement of the perception of emotional intensity in dynamic facial expressions.

474    The work of a previous behavioral study showing that facial imitation is associated with

475    IFG function (Iacoboni, 2005), and facilitates the recognition of dynamic facial

476    expressions (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001), encourages us to

477    speculate that feedback input from the IFG and the STS to the visual cortex modulates

478    the subjective perception of dynamic facial expressions.

479         Our results did not support our third prediction, namely that individuals with

480    ASD would show stronger RM than would controls in response to extreme dynamic

481    facial expressions. There might be several reasons for this result. First, the clear RM in

482    typically developing individuals might mask any group difference. Yoshikawa and Sato

483    (2008) noted that RM for dynamic facial expressions among typically developing

484    individuals is suppressed at 100% intensity. In the present study, it is possible that facial

485    expressions with intense emotion (108%) might seem equally natural to individuals with

486    and without ASD. Using even more exaggerated facial expressions as stimuli may still

487    induce a group difference in RM. Second, the speed of movement (10 ms per frame)

488    might affect RM under the 108% condition. In research conducted by Yoshikawa and

489    Sato, slowing down the presentation of dynamic facial expressions to 40 ms per frame

490    induced a reduction in RM, particularly when facial expressions with intense emotion

491    were used (Experiment 1). Tardif et al. (2007) found that slowing down presentation

492    improved recognition of dynamic facial expression in individuals with ASD but not in

493    typically developing individuals. Thus, slowing down the presentation of dynamic facial

494    expressions with intense emotions might reveal a difference in RM between individuals

495    with and without ASD.

496        It should be acknowledged that this study had several limitations. First, the

497    dynamic facial expressions used in the present study represented a linear transition

498    developed using a computer morphing technique because this approach is advantageous

499    for controlling the amount of change and reducing the noise. However, actual facial

500    expressions would differ from the present stimuli in terms of the pattern of kinematics

501    in each facial feature. It may be helpful to use real dynamic facial expressions to further

502    elucidate the deficits in RM for dynamic facial expressions. Second, the present study

503    did not address the possibility that clinical symptoms other than ASD also affected

504    perceptions of subtle dynamic facial expressions. Although the participants with ASD in

505    the present study did not meet the criteria for neurological or other psychiatric disorders,

506    previous studies have found that individuals with ASD have high rates of associated

507    psychiatric problems, including anxiety and depression (e.g., de Bruin, Ferdinand,

508    Meester, de Nijs, & Verheij, 2007). Interestingly, recent behavioral studies also suggest

509    that the extent of co-morbid alexithymia contributes to emotional recognition

510    impairments in ASD individuals (see Bird and Cook (2013) for a review). Promising

511    directions for further research include analysis of the effects of psychological states and

512    traits on individuals with and without ASD.

513

514    **5. Conclusions**

515        In summary, the present study showed that individuals with ASD perceived the

516    final images in dynamic facial expressions to be more exaggerated than static facial

517    expressions. However, when they observed facial expressions with subtle emotion,

518    typically developing controls perceived them as more exaggerated than did individuals

519    with ASD under dynamic but not under static conditions. Emotional communication in

520    daily life is based principally on dynamic facial cues, and facial expressions are often

521    subtle. It is possible that individuals with ASD, with their reduced perception of

522    emotional intensity, have a reduced ability to detect subtle changes in other people's

523    facial expressions for use as information for adaptive behavioral responses.

524

528

538

539        **References**

540     Adolphs, R., Sears, L., & Piven, J. (2001). Abnormal processing of social information

541         from faces in autism. *Journal of Cognitive Neuroscience, 13*, 232–240.

542     Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role

543         of the STS region. *Trends in Cognitive Sciences, 4*, 267–278.

544     Ambadar, Z., Schooler, J.W., & Cohn, J.F. (2005). Deciphering the enigmatic face: The

545         importance of facial dynamics in interpreting subtle facial expressions.

546         *Psychological Science, 16*, 403–410.

547     American Psychiatric Association (2000). *Diagnostic and statistical manual for mental*

548         *disorders (DSM-IV-TR).* Washington, DC: Author.

549     Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of

550         negative basic emotions in autism: A test of the amygdala theory. *Social*

551         *Neuroscience, 1*, 349–363.

552     Atkinson, A. P. (2009). Impaired recognition of emotions from body movements is

553         associated with elevated motion coherence thresholds in autism spectrum disorders.

554         *Neuropsychologia, 47,* 3023–3029.

555     Azuma, H., Ueno, K., Fujita, K., Maekawa, H., Ishikuma, T., & Sano, H. (1998).

556         *Japanese Wechsler intelligence scale for children—III.* Tokyo:

557    Nihon-Bunka-Kagaku-sha.

558    Bird, G., & Cook, R. (2013). Mixed emotions: The contribution of alexithymia to the

559    emotional symptoms of autism. *Translational Psychiatry*, *3*, e285.

560    Blake, R., Turner, L.M., Smoski, M.J., Pozdol, S.L., & Stone, W.L. (2003). Visual

561    recognition of biological motion is impaired in children with autism. *Psychological*

562    *Science, 14*, 151–157.

563    Bould, E., & Morris, N. (2008). Role of motion signals in recognizing subtle facial

564    expressions of emotion. *British Journal of Psychology, 99*, 167–189.

565    Bould, E., Morris, N., & Wink, B. (2008). Recognising subtle emotional expressions:

566    The role of facial movements. *Cognition and Emotion, 22*, 1569–1587.

567    Braverman, M., Fein, D., Lucci, D., & Waterhouse, L. (1989). Affect comprehension in

568    children with pervasive developmental disorders. *Journal of Autism and*

569    *Developmental Disorders, 19*, 301–316.

570    de Bruin, E.I., Ferdinand, R.F., Meester, S., de Nijs, P.F.A., & Verheij, F. (2007). High

571    rates of psychiatric co-morbidity in PDD-NOS. *Journal of Autism and*

572    *Developmental Disorders, 37*, 877–886.

573    Calder, A. J., Lawrence, A. D., & Young, A. W. (2001). Neuropsychology of fear and

574    loathing. *Nature Reviews Neuroscience, 2*, 352–363.

575    Castelli, F. (2005). Understanding emotions from standardized facial expressions in

576        autism and normal development. *Autism, 9*, 428–449.

577    Catani M., Howard, R. J., Pajevic, S., & Jones, D. K. (2002). Virtual in vivo interactive

578        dissection of white matter fasciculi in the human brain. *Neuroimage, 17*, 77-94.

579    Celani, G., Battacchi, M. W., & Arcidiacono, L. (1999). The understanding of the

580        emotional meaning of facial expressions in people with autism. *Journal of Autism*

581        *and Developmental Disorders, 29*, 57–66.

582    Corona, R., Dissanayake, C., Arbelle, S., Wellington, P., & Sigman, M. (1998). Is affect

583        aversive to young children with autism? Behavioral and cardiac responses to

584        experimenter distress. *Child Development, 69*, 1494–1502.

585    Ekman, P. (2003). *Emotions revealed.* New York: Times Books

586    Ekman, P. and Friesen, W.V. (1975). *Unmasking the face: A guide to recognizing*

587        *emotions from facial clues.* Englewood Cliffs, NJ: Prentice-Hall.

588    Ekman, P., & Friesen, W.V. (1976). *Pictures of facial affect.* Palo Alto, CA: Consulting

589        Psychologists Press.

590    Freyd, J. J., & Finke, R. A. (1984). Representational momentum. *Journal of*

591        *Experimental Psychology: Learning, Memory and Cognition, 10*, 126–132.

592    Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing.

593    *Proceedings of the Royal Society of London B: Biological Sciences, 358*, 459–473.

594    Fujita, K., Maekawa, H., Dairoku, H., & Yamanaka, K.. (2006). *Japanese Wechsler*

595    *adult intelligence scale—III.* Tokyo: Nihon-Bunka-Kagaku-sha.

596    Gepner, B., Deruelle, C., & Grynfeltt, S. (2001). Motion and emotion: A novel approach

597    to the study of face processing by young autistic children. *Journal of Autism and*

598    *Developmental Disorders, 31*, 37–45.

599    Grossman, J. B., Klin, A., Carter, A.S., & Volkmar, F. R. (2000). Verbal bias in

600    recognition of facial emotions in children with Asperger syndrome. *Journal of Child*

601    *Psychology and Psychiatry, 41*, 369–379.

602    Haxby, J. V., Hoffman, E. A., & Gobbini M. I. (2000). The distributed human neural

603    system for face perception. *Trends in Cognitive Sciences, 4*, 223–233.

604    Hubbard, T. L. (1990). Cognitive representation of linear motion: Possible direction and

605    gravity effects in judged displacement. *Memory and Cognition, 18*, 299–309.

606    Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonseca, D., et

607    al. (2007). Recognition of emotional and non-emotional biological motion in

608    individual with Autistic Spectrum Disorders. *Journal of Autism and Developmental*

609    *Disorders, 37,* 1386–1392.

610    Hudson, M., Liu, C. H., & Jellema, T. (2009). Anticipating intentional actions: The

611     effect of eye gaze direction on the judgment of head rotation. *Cognition, 112*,

612     423-434.

613   Iacoboni, M. (2005). Neural mechanisms of imitation. *Current Opinion in Neurobiology,*

614     *15*, 632–637.

615   Kessels, R. P. C., Spee, P., & Hendriks, A. W. (2010). Perception of dynamic facial

616     emotional expressions in adolescents with autism spectrum disorders (ASD).

617     *Translational Neuroscience, 1*, 228-232.

618   Kirk, R. E. (1995). *Experimental design: Procedures for the behavioral sciences* (3rd

619     ed.). Pacific Grove, CA: Brooks/Cole.

620   Kodama, H., Shinagawa, F., & Motegi, M. (1982). *Japanese Wechsler intelligence scale*

621     *for children—revised.* Tokyo: Nihon-Bunka-Kagaku-sha.

622   Koyama, T., Tachimori, H., Osada, H., Takeda, T., & Kurita, H. (2007). Cognitive and

623     symptom profiles in Asperger's syndrome and high-functioning autism. *Psychiatry*

624     *and Clinical Neuroscience, 61*, 99–104.

625   LaBar, K. S., Crupain, M. J., Voyvodic, J. T., & McCarthy, G. (2003). Dynamic

626     perception of facial affect and identity in the human brain. *Cerebral Cortex, 13*,

627     1023–1033.

628   Mesibov, G. B., Schopler, E., Schaffer, B., & Michal, N. (1989). Use of the Childhood

629 Autism Rating Scale with autistic adolescents and adults. *Journal of the American*

630 *Academy of Child and Adolescent Psychiatry, 28*, 538–541.

631 Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H., & Plaisted, K. (2002).

632 High motion coherence thresholds in children with autism. *Journal of Child*

633 *Psychology and Psychiatry, 43*, 255–263.

634 Moore, D. G., Hobson, R. P., & Lee, A. (1997). Components of person perception: An

635 investigation with autistic, non-autistic retarded and typically developing children

636 and adolescents. *British Journal of Developmental Psychology, 15*, 401–423.

637 Motley, M., & Camden, C. (1988). Facial expression of emotion: A comparison of

638 posed expressions versus spontaneous expressions in an interpersonal

639 communications setting. *Western Journal of Speech Communication, 52*, 1–22.

640 Mukaida, S., Kamachi, M., Kato, T., Oda, M., Yoshikawa, S., & Akamatsu, S. (2000).

641 *Foolproof utilities for facial image manipulation.* Kyoto: ATR [unpublished

642 computer software].

643 Niedenthal, P. M., Brauer, M., Halberstadt, J. B., & Innes-Ker, Å. H. (2001). When did

644 her smile drop? Facial mimicry and the influences of emotional state on the

645 detection of change in emotional expression. *Cognition and Emotion, 15*, 853–864.

646 Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh

647    inventory. *Neuropsychologia, 9*, 97−113.

648    Pellicano, E., Gibson, L., Maybery, M., Durkin, K., & Badcock, D. R. (2005). Abnormal

649    global processing along the dorsal visual pathway in autism: A possible mechanism

650    for weak visuospatial coherence? *Neuropsychologia, 43*, 1044–1053.

651    Pelphrey, K. A., Morris, J. P., McCarthy, G., & Labar, K. S. (2007). Perception of

652    dynamic changes in facial affect and identity in autism. *Social Cognitive and*

653    *Affective. Neuroscience, 2*, 140–149.

654    Rilling, J.K., Glasser, M.F., Preuss, T. M., Ma, X., Zhao, T., Hu, X., et al. (2008). The

655    evolution of the arcuate fasciculus revealed with comparative DTI. *Nature*

656    *Neuroscience, 11*, 426–428.

657    Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus prototype matching:

658    Strategies of perception of emotional facial expressions in the autism spectrum.

659    *Journal of Autism and Developmental Disorders, 37*, 187–196.

660    Sato, W., Kochiyama, T., Yoshikawa, S., Naito, E., & Matsumura, M. (2004). Enhanced

661    neural activity in response to dynamic facial expressions of emotion: An fMRI study.

662    *Brain Research: Cognitive Brain Research, 20*, 81–91.

663    Sato, W., Toichi, M., Uono, S., & Kochiyama, T. (2012). Impaired social brain network

664    for processing dynamic facial expressions in autism spectrum disorders. *BMC*

665 *Neuroscience, 13*, 99.

666 Sato, W., & Yoshikawa, S. (2007a). Enhanced experience of emotional arousal in

667 response to dynamic facial expressions. *Journal of Nonverbal Behavior, 31*,

668 119–135.

669 Sato, W., & Yoshikawa, S. (2007b). Spontaneous facial mimicry in response to dynamic

670 facial expressions. *Cognition, 104*, 1–18.

671 Schopler, R., Reichler, R. J., & Renner, B. R. (1986). *The Childhood Autism Rating*

672 *Scale (CARS) for diagnostic screening and classification of autism.* New York:

673 Irvington.

674 Shinagawa, F., Kobayashi, D., Fujita, K., & Maekawa, H. (1990). *Japanese Wechsler*

675 *adult intelligence scale¬revised.* Tokyo: Nihon-Bunka-Kagaku-sha.

676 Sigman, M. D., Kasari, C., Kwon, J. H., & Yirmiya, N. (1992). Responses to the

677 negative emotions of others by autistic, mentally retarded, and normal children.

678 *Child Development, 63*, 796–807.

679 Tardif, C., Lainé, F., Rodriguez, M., & Gepner, B. (2007). Slowing down presentation

680 of facial movements and vocal sounds enhances facial expression recognition and

681 induces facial‑vocal imitation in children with autism. *Journal of Autism and*

682 *Developmental Disorders, 37*, 1469–1484.

683    Taylor, N., & Jacobson, L. (2010). Representational momentum in children born

684        preterm and at term. *Brain and Cognition, 72*, 464–471.

685    Thiebaut de Schotten, M., Ffytche, D. H., Bizzi, A., Dell'Acqua, F., Allin, M., Walshe,

686        M., et al. (2011). Atlasing location, asymmetry and inter-subject variability of white

687        matter tracts in the human brain with MR diffusion tractography. *NeuroImage, 54*,

688        49–59.

689    Uono, S., Sato, W., & Toichi, M. (2010). Brief report: Representational momentum for

690        dynamic facial expressions in pervasive developmental disorder. *Journal of Autism*

691        *and Developmental Disorders, 40*, 371–377.

692    Uono, S., Sato, W., & Toichi, M. (2011). The specific impairment of fearful expression

693        recognition and its atypical development in pervasive developmental disorder.

694        *Social Neuroscience, 6*, 452-463.

695    Uono, S., Sato, W., & Toichi, M. (2013). Common and unique impairments in

696        facial-expression recognition in pervasive developmental disorder-not otherwise

697        specified and Asperger's disorder. *Research in Autism Spectrum Disorders, 7*,

698        361-368.

699    Warren, G., Schertler, E., & Bull, P. (2009). Detecting deception from emotional and

700        unemotional cues. *Journal of Nonverbal Behavior, 33*, 59–69.

701   Yirmiya, N., Kasari, C., Sigman, M., & Mundy, P. (1989). Facial expressions of affect in

702       autistic, mentally retarded and normal children. *Journal of Child Psychology and*

703       *Psychiatry, 30*, 725–735.

704   Yoon, K. L., Joormann, J., & Gotlib, I. H. (2009). Judging the intensity of facial

705       expressions of emotion: Depression-related biases in the processing of positive

706       affect. *Journal of Abnormal Psychology, 118*, 223–228.

707   Yoshikawa, S., & Sato, W. (2008). Dynamic facial expressions of emotion induce

708       representational momentum. *Cognitive, Affective & Behavioral Neuroscience, 8*,

709       25–31.

710

711

**Table 1**

Mean (with SE) intensities of the selected images in individuals with ASD and typically developing controls (CON)

| Group | Presentation | Intensity | | |
|-------|--------------|-----------|-----------|------------|
| | | 52% | 80% | 108% |
| ASD | Dynamic | 59.3 (1.5) | 88.1 (1.3) | 115.4 (1.6) |
| | Static | 57.0 (1.2) | 82.7 (1.3) | 108.7 (1.6) |
| CON | Dynamic | 63.0 (0.9) | 89.5 (1.2) | 119.4 (2.1) |
| | Static | 56.7 (1.3) | 85.7 (1.5) | 108.8 (1.5) |

712

713

714    Figure Captions

715    Fig. 1 a) Examples of the morphing image sequence for dynamic facial expressions of

716    emotion. b) Final image of dynamic facial expressions under each intensity condition.

717

718    Fig. 2 Mean ratio between the intensity of the selected and presented images under each

719    condition. The asterisk represents a significant interaction between group and

720    presentation, indicating reduced RM for subtle dynamic facial expressions in ASD.

721    Error bars show the SE.

722

723    Fig. 3 Correlation between degree of RM and CARS scores under the 52% condition.

724    Black and white diamonds show participants with Asperger's disorder and PDD-NOS,
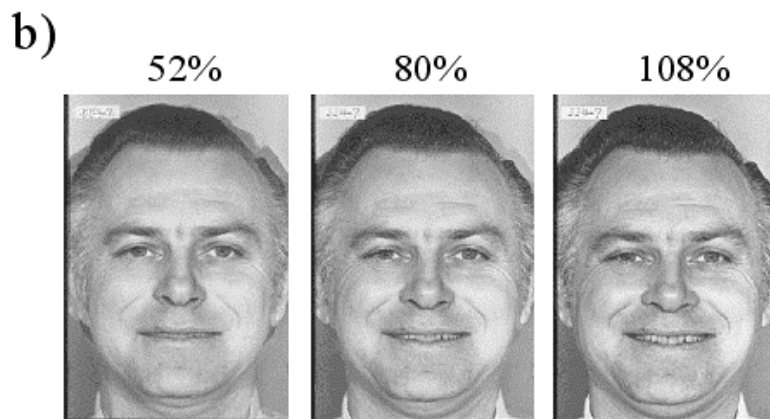
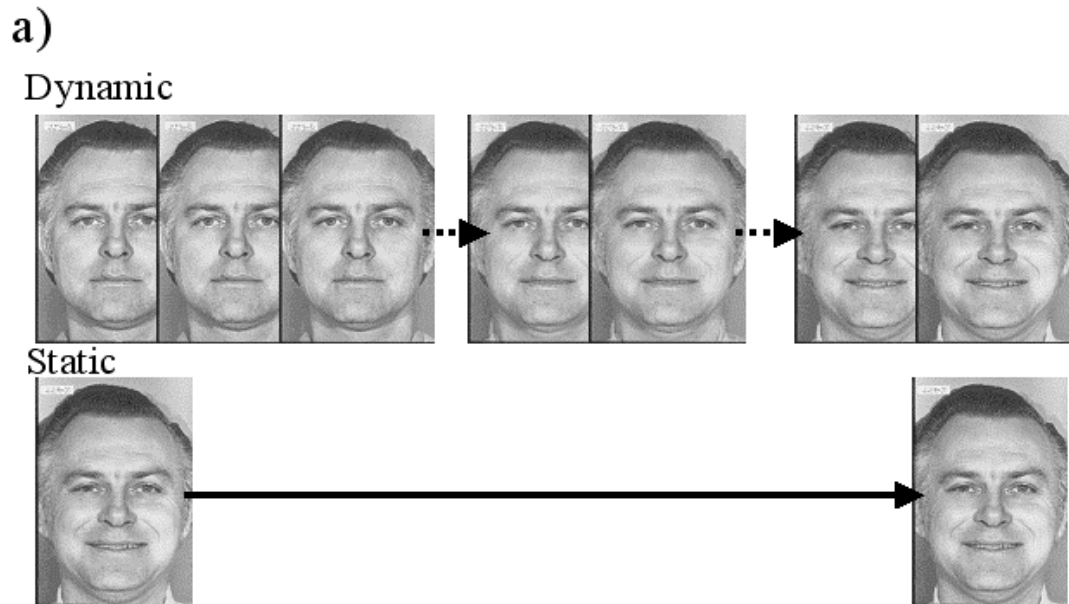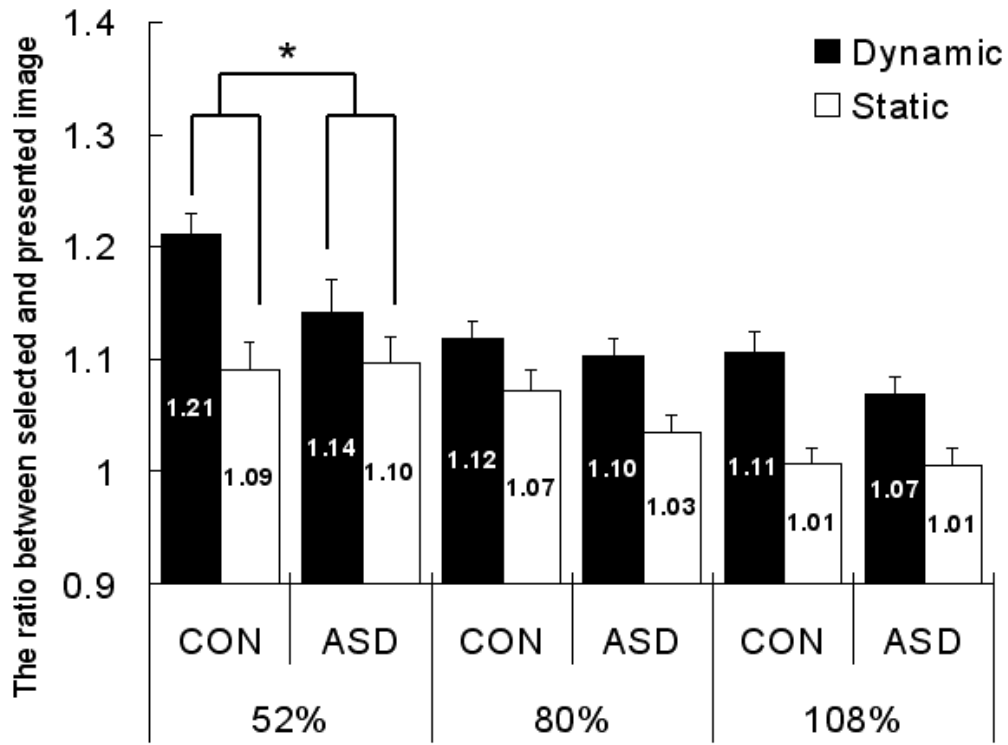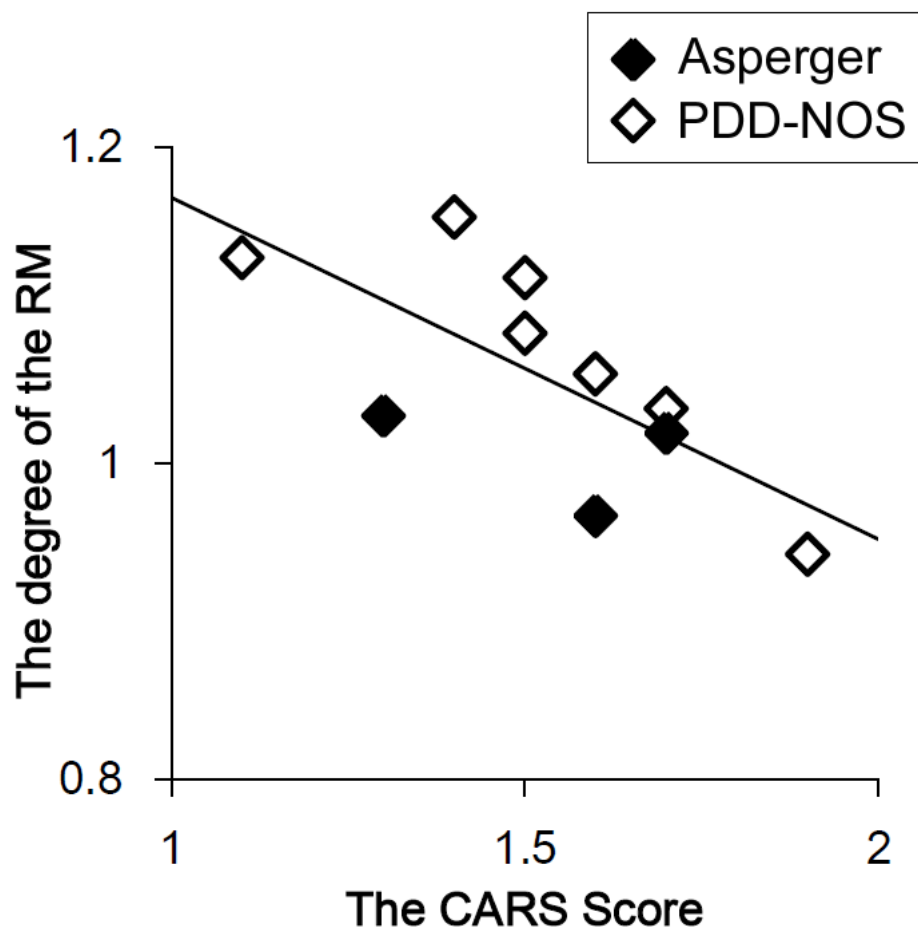725    respectively.

726

727

728

729

730

731

732    Fig. 1



733

734

735    Fig. 2



736

737

738    Fig. 3



739