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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**

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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, & Grynfeldt, 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 \pm *SD* = 21.04 \pm 2.67) were comparable to those of Japanese individuals
249 with Asperger's disorder in a previous study (mean \pm *SD* = 22.22 \pm 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 1024×768 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 \times presentation \times 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 ($F < 2.37, ps > 0.10$).

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

525

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527

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538

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- 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

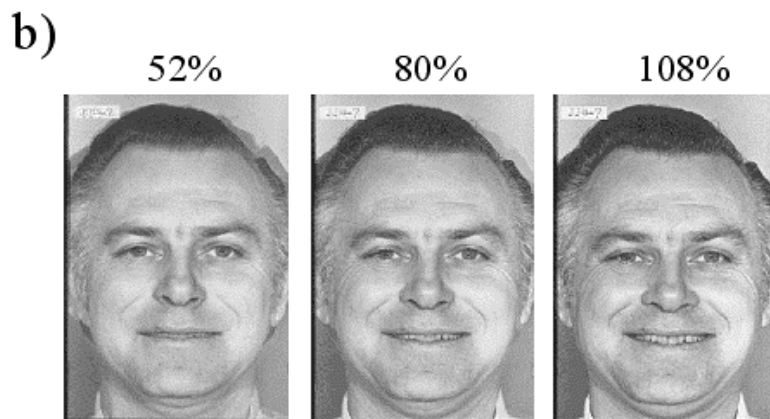
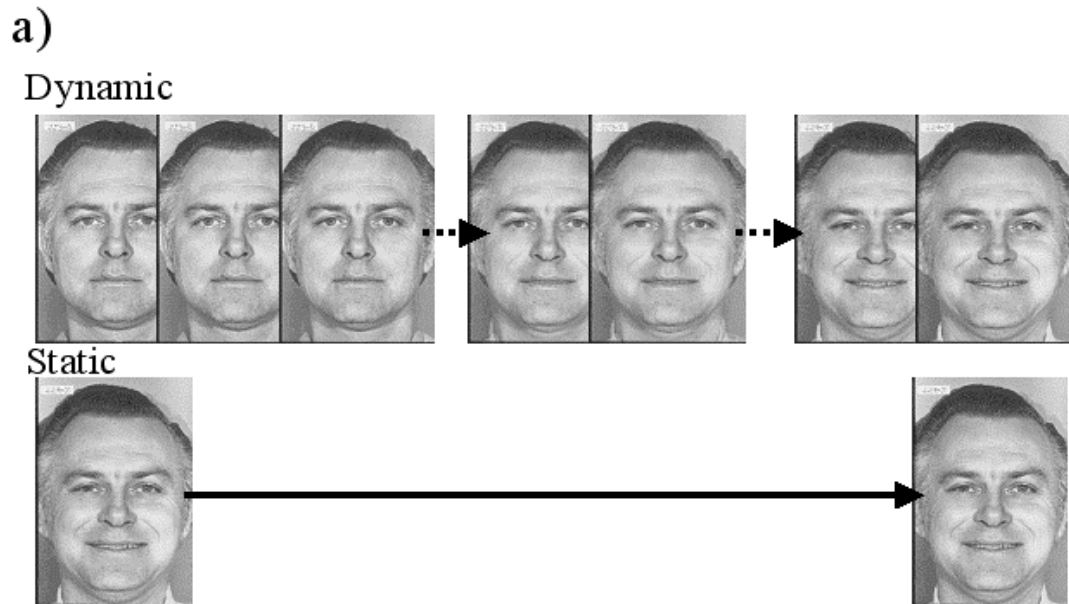
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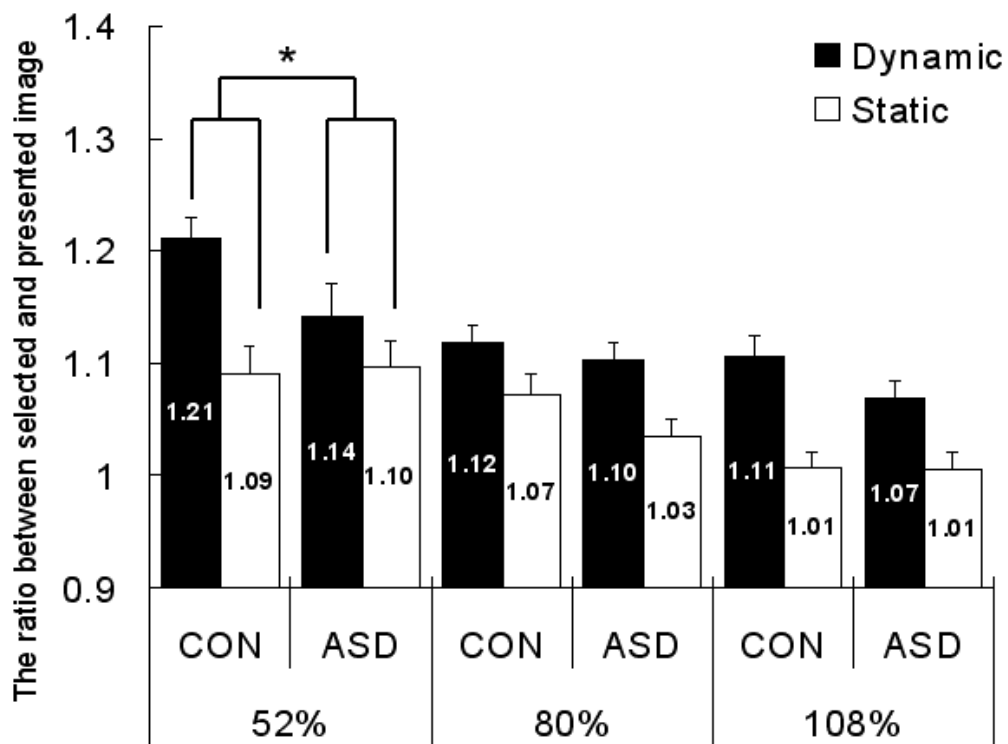
732 Fig. 1



733

734

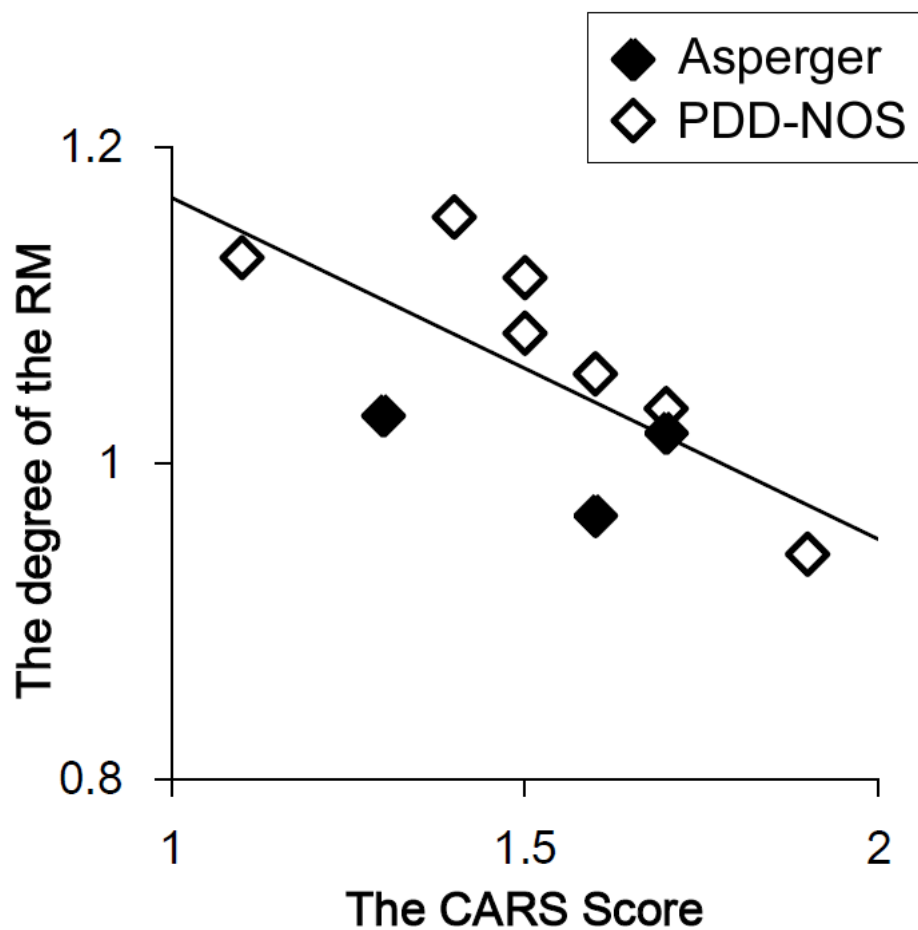
735 Fig. 2



736

737

738 Fig. 3



739