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Facial Feedback and Laughter Contagion in Children with Autism Spectrum Disorders

Molly Helt, PhD

University of Connecticut, 2014

We tested sensitivity to facial feedback in 44 children with autism spectrum disorder (ASD), aged 8-14 years, and 44 typically developing children matched for mental age (6-14), in order to examine whether children with ASD use bodily feedback as an implicit source of information. Specifically, children were asked to view cartoons as they normally would (control condition), and to hold a pencil in their mouth forcing their smiling muscles into activation (feedback condition). The authors also explored the social function of laughter in children with ASD by investigating whether the presence of a caregiver or friend (social condition), or the presence of a laugh track superimposed upon the cartoon (laugh track condition) increased the children's self-rated enjoyment of cartoons or the amount of positive affect they displayed. Results indicate that whereas typically developing children experienced cartoons as more enjoyable under all three experimental conditions (feedback, social, laugh track) compared with the control condition, children with ASD experienced cartoons as more enjoyable only when viewing them with a caregiver or friend. Furthermore, within the ASD group, a strong relationship between blunted affect and insensitivity to facial feedback emerged, shedding light on the implications of restricted affect in ASD.

Facial Feedback and Laughter Contagion in Children with Autism Spectrum Disorders

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B.A., Smith College (2005)
M.A., University of CT (2008)

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APPROVAL PAGE

Doctor of Philosophy Dissertation

Facial Feedback and Laughter Contagion in Children with Autism Spectrum Disorders

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University of Connecticut
2014

Facial Feedback and Laughter Contagion in Children with Autism Spectrum Disorders

The face does more than express emotions; it also changes them (James, 1890). Darwin (1872) was the first to speculate that intensifying an emotional expression should intensify private emotional experience, while inhibiting emotional expression should moderate the experience. This speculation has been borne out by numerous experiments in which participants are asked to intensify or inhibit their facial expressions in response to emotional stimuli (e.g., Adelmann & Zajonc, 1989). When individuals wrinkle their noses, they rate odors as more noxious, and when they are asked to raise their eyebrows they judge information to be more surprising (Lewis, 2012). Participants judge cartoons to be funnier if they are asked to smile while viewing them (Laird, 1974), and report that sad photographs make them sadder when they are asked to knit their eyebrows together (Larsen, Kasimatis, & Frey, 1992).

These types of effects hold even when participants are unaware of the manner or reason their facial expressions are being manipulated. For example, reading aloud stories with a high frequency of vowel and consonant sounds that result in facial activity similar to a frown causes participants to report more negative feelings than reading stories with a low frequency of these sounds (Zajonc, Murphy, & Inglehart, 1989). Of particular importance to the current study design, Strack, Martin, and Stepper (1988) instructed three different participant groups to hold a pen in their teeth, lips, or non-dominant hand. The first produced a smile-like musculature configuration, the second inhibited such a configuration, and the third was a control condition. Individuals in the group that were instructed to hold the pen in their teeth (simulating smiles) rated scenes more positively

than those in the group instructed to hold the pen in their lips (inhibiting smiles). Soussignan and colleagues (2002) reported a partial replication of this experiment, in that holding a pencil in the mouth so as to facilitate a smile enhanced cartoon enjoyment *only* when participants engaged the muscles around their eyes (orbitis ocularis) as well as their mouths (zygomatic major). Andreasson and Dimberg (2008) also reported a partial replication of this experiment; they found that holding a pencil in the mouth so as to facilitate a smile enhanced enjoyment of humorous films, *only* for participants who rated themselves high on a scale of emotional empathy.

At the autonomic level, changes in facial expression lead to immediate changes in heart rate, skin conductance, skin temperature, and blood volume (Levenson, Ekman, & Friesen, 1990). Moreover, these same changes occur regardless of whether participants are instructed to evoke a memory that makes them feel a certain emotion, or whether their musculature is artificially “placed” by the experimenter into a position that corresponds to a basic emotion (Ekman, Levenson, & Friesen, 1983).

If facial feedback is important to emotional and social processing, what happens to individuals who have a restricted range of facial movement, and thus reduced or absent facial feedback? Individuals with facial paralysis often have symptoms of depression, and one study found that the degree of depression in a sample of adults with facial paralysis, was directly related to the restriction of their smile muscles (Twerski & Twerski, 1986), presumably because positive feedback was inhibited. Conversely, Finzi and Wasserman (2006) reported improvement in depressive symptoms among a small sample of depressed individuals who were treated with Botox injection into their frown lines (corrugator supercilli muscles), presumably because negative facial feedback was

inhibited. Clearly, facial action modifies the intensity of emotions during ongoing experiences; although specific manipulations may affect specific emotions more consistently, and certain individuals may be more susceptible to these effects than others.

What role does facial feedback play in social cognition?

Combined with the evidence that people mimic the emotional expressions of others, facial feedback provides a mechanism for one person's emotions to influence another's (e.g., Bush, Barr, McHugo, & Lanzetta, 1989; Hatfield, Cacioppo, & Rapson, 1994; Mclntosh et al., 1994). When two people interact, they engage in automatic, covert mimicry of one another's facial expressions, tone of voice, and posture (Hatfield et al., 1994; Niedenthal, 2007) Research with electromyography (EMG) has demonstrated that when viewing facial expressions of others, participants will experience activation of the same muscles used for forming the expression they are viewing, even though this activation is generally attenuated and unobservable to the naked eye (Dimberg 1982; 1990). This tendency is so pervasive and so rapid that it will occur even if slides of facial expressions are presented outside of conscious awareness (Dimberg, Thunberg, & Elmehed, 2000) Functional magnetic resonance imaging (fMRI) research confirms that when we view emotional stimuli, our brains respond "as-if" we were experiencing the emotions ourselves (Bechara, Damasio, Tranel, & Damasio, 2005). In other words, we engage our sensorimotor system as well as our limbic system, representing the emotions of others in our own musculature.

Once the musculature associated with an emotion has been activated via mimicry during interaction with a social partner, the feedback effects from this mimicry cause the brain to interpret and experience the specific emotion being expressed. Thus together,

mimicry and feedback lead us to feel in our bodies at least a small amount of what our social partners are feeling. This moment-to-moment emotional information that feedback provides may be critical for smooth social interactions (Cappella, 1993). Indeed, both greater tendency to mimic, and greater sensitivity to feedback are linked with greater empathy on the part of the participant, measured both as a trait via self-ratings on an emotional empathy scale (Andreasson & Dimburg 2008; Laird, 1994) and tendency to engage in prosocial behaviors in the moment (Balconi & Canavesio 2013).

Meanwhile, restriction of facial muscles, and thus opportunity for facial feedback, is associated with slower, less accurate, and less intense, emotional processing. For example when Botox is injected into frown muscles, participants read angry and sad (but not happy sentences) more slowly (Havas & Matheson 2013). Another study demonstrated that dampening facial feedback signals through Botox injection impaired participants' ability to read others' emotions, whereas amplifying facial feedback signals by applying restrictive gel to the face (the resistance of which makes individuals more sensitive to and aware of their facial movements) improved emotion recognition (Neal and Chartrand, 2011). fMRI research demonstrates that when participants are asked to imitate angry facial expressions after Botox injection to frown lines, they show attenuated activation of the left amygdala and its functional coupling with brain stem regions associated with the bodily expression of of emotional states (Hennenlotter et al. 2009).

Individuals with Moebius Syndrome, which involves congenital complete or partial facial nerve palsy, tend to struggle with social competence (Rives-Bogart & Matsumoto, 2010), and a diagnosis of Moebius Syndrome significantly increases risk for ASD. One study found that 40% of participants with Moebius Syndrome displayed most

or all of the traits of ASD (Gillberg & Steffenburg, 2008). Difficulty accessing somatic feedback has been implicated in various other psychiatric and neurological conditions that impair social function, including depression (Steele, Kumar, & Ebmeier, 2007), traumatic brain injury (Dethier et al. 2013) and sociopathy (Damasio, 2000).

Individuals with schizophrenia, although retaining control of their facial muscles, display flatter affect and a restricted range of facial expressions (Hofer et al. 2009). Individuals with schizophrenia who display flat affect do not report less intense private emotional experience (Gur & Johnson, 2006); however, the extent of individuals' blunted affect has been shown to correlate with their difficulty on tasks of emotion recognition, as well as general social competence and outcome (Gur & Johnson, 2006). Notably, affect recognition in participants with schizophrenia can be improved by inducing mimicry and facial feedback (Penn & Combs, 2000). Individuals with ASD also display flatter and more neutral affect compared with their developmentally disabled peers (Yirmiya, Kasari, Sigman, & Mundy, 1989). However, to our knowledge, the relationship between restricted range of affect and performance on emotional processing tasks has not been directly tested in this population.

Mimicry and Facial Feedback in ASD

Children with ASD appear *capable* of engaging in mimicry and reaping its rewards under circumstances where emotional cues are heightened; however, they engage in mimicry much less frequently than their typically developing peers, perhaps because of diminished social attention (Kinsbourne & Helt, 2011). Since mimicry increases rapport (Lakin & Chartrand, 2003), empathy (Sonnby-Borgstrom, 2002) and perhaps even eye

contact (Striano, Henning, & Stahl, 2005), early deficits in social attention and the failure to engage in frequent mimicry may lead children with ASD to miss out on some of the most crucial components of social emotional learning. Indeed, the tendency to engage in mimicry under naturalistic conditions is negatively associated with autism symptom severity (McIntosh et al. 2006).

Even when children with ASD do engage in mimicry, there is little evidence about whether they are able to make use of information from feedback in the same manner as their typically developing peers. Feedback from facial muscles affects ongoing emotional experience, evaluation of emotional stimuli, and even recognition of emotional expressions (Neal & Chartrand, 2011). Individuals with ASD have trouble attending to, and interpreting social and emotional signals, especially from the face (Dawson, Webb, & McPartland, 2005), and show qualitative impairments in social interaction (American Psychiatric Association, 2013).

To date, there has been only a single study of facial feedback in children with ASD. Using Strack et al.'s (1988) between groups paradigm (see above), Stel and colleagues (2008) asked children with ASD and typically developing children to hold a pen in their teeth, engaging their zygomatic major (smile) muscles, or in their hand, while viewing illustrations. Children were then asked to rate how much they liked the illustrations. Typically developing children in the feedback (pen in teeth) condition rated the pictures as more likable than typically developing children in the control (pen in hand) condition, whereas children with ASD in the control condition rated the illustrations as more likeable than children with ASD in the feedback condition. Stel and colleagues (2008) hypothesized that in children with ASD, the reciprocal link between

emotion and expression may be weak. However, the relationship between facial feedback sensitivity and clinical features such as flat affect and social functioning were not measured. Moreover, cutoff for participation in the experimental group in this study was an IQ of 50 and the control group was not matched to this sample for IQ or mental age. The current study seeks to replicate and extend these findings by directly investigating the relationship between feedback effects and range of facial expression, as well as autism severity, in a well-characterized sample, using a within groups design.

What is the social function of laughter?

Laughter appears to be primarily a social vocalization that binds people together (Provine, 1996). For example, people are 30 times more likely to laugh in a social context than on their own (Provine, 1992). Even administration of nitrous oxide doesn't usually make people laugh if they are not with others (Ruch, 1997). However happy or silly we may feel, laughter appears to be primarily a signal that we send to an audience and that virtually disappears when we are on our own.

Laughter increases feelings of warmth and connection between individuals (Provine, 2001). Laughter is also contagious, meaning that the sound of others laughing is often enough to cause us to laugh (Provine, 1992). Laugh tracks have been accompanying television sitcoms for the past 60 years, because seeing and hearing the laughter of others makes us more likely to laugh ourselves, as well as to judge materials as funnier (Bush, McHugo, & Lanzetta, 1989). In one study, typically developing children were shown to rate humorous materials as more humorous if they were paired with another child who appeared to be amused (Chapman, 1974). In another, Warren and colleagues (2006) demonstrated that when participants hear the sound of laughter, they automatically make

orofacial gestures that prepare them to laugh. Thus, mimicry and facial feedback provide a plausible mechanism for laughter contagion.

Previous research on ASD and laughter is scant, but very suggestive. Compared with children with Down's syndrome, children with ASD laugh just as frequently, but engage in more private, idiosyncratic laughter, and less shared, social laughter (Reddy, Williams, & Vaughan, 2002). Another study found that children with ASD exhibit voiced laughter more than unvoiced laughter (Hudenko, Stone, & Bachorowski, 2009). Although research is still ongoing as to the function of these two types of laughter (voiced and unvoiced), one hypothesis is that unvoiced laughter is more often used to navigate social situations, whereas voiced laughter more purely represents an internal positive state (Bachorowski & Owren, 2001). In other words, although children with ASD do laugh, they may not exhibit or benefit from the social aspects of laughter. The current study seeks to investigate whether children with ASD will judge cartoons to be funnier in a social context than on their own, and whether children with ASD will be influenced by the presence of a laugh track.

Current Study

Existing research suggests that children with ASD may have diminished sensitivity to facial feedback (Stel et al. 2008), which is hypothesized to be a key part of the emotion contagion process, but this finding has yet to be replicated or related to autism symptomology in any way. Research has also begun to suggest that children with ASD may not experience the same benefits of laughter as a social signal that facilitates bonding as do their typically developing peers (Hudenko et al. 2009; Reddy et al., 2002), and that they are less susceptible to contagion inducing stimuli (Helt, Eigsti, Snyder &

Fein, 2010). However, several studies suggest that children with ASD show typical or near typical emotional processing when target stimuli are personally familiar people, such as parents and friends, indicating the need to include a condition that tests these empathic processes with familiar individuals (e.g., Pierce, Haist, Sedaghat, & Courchesne, 2004). Thus, the current study seeks to investigate four questions: 1) Will children with ASD benefit from positive facial feedback? 2) If feedback deficits are found, will they correlate to ASD symptomology, such as symptom severity or emotional expressiveness? 3) Will children with ASD rate cartoons more positively and smile and laugh more when they are exposed to a laugh track? 4) Will children with ASD rate cartoons more positively and smile and laugh more when they are with someone personally meaningful to them, such as a parent or friend?

Methods

Participants

Participants were 45 children with a diagnosis of an Autism Spectrum Disorder (ASD) (M=11.6 years), in addition to 50 typically developing (TD) (M=10.2 years) children matched for mental age. The data of one child with ASD was excluded due to his high level of distraction while viewing the cartoons, leaving a final sample of n = 44 children with ASD. Children with ASD were recruited via flyers that went home with children at several local schools and programs geared toward children with ASD, as well as a list of families interested in being informed about ongoing autism research at the University of Connecticut. ASD diagnosis was confirmed by the experimenter, (MH), using the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2000), and DSM-IV criteria (American Psychiatric Association, 1994); see Table 1

for participant characteristics. The ethnic background of this group was: one Asian child, one Latino child, and 42 Caucasian children.

TD children were mainly recruited through flyers sent home at one local elementary school, one local middle school, and an electronic flyer circulated on the Uconn listserv. The ethnic background of this group was as follows: two African American children, one biracial child, two Asian children, five Latino children, and 34 Caucasian children. Each member of the TD control group was matched to a member of the ASD group on mental age (within 6 months). Mental Age was determined for each child by administration of the abbreviated IQ battery associated with the Stanford Binet Intelligence Scale, Fifth Edition (Roid, 1993) by the examiner. The data of six TD children were not analyzed because they could not be matched for mental age (within 6 months) to any of the children with ASD, leaving a final sample of n=44 TD children in the control group.

Measures

Autism Diagnostic Observation Scale (Lord et al., 2000). The ADOS consists of a structured play session that provides participants opportunities to engage in conversation, narrative, problem-solving, and imaginative tasks. The ADOS is scored according to DSM–IV criteria for the autism spectrum diagnoses. The ADOS was administered only to the ASD group and each participant met the cutoff score for an autism spectrum disorder. All participants were administered Module 3, which is intended for verbally fluent children.

Stanford–Binet Intelligence Scale: Fifth Edition (Roid, 2003). In the Stanford–Binet Abbreviated IQ scales, children provide word definitions, yielding a verbal IQ

score, and solve a series of picture puzzles, yielding a performance IQ score. The composite IQ can be converted to a mental age. This measure provided an index of mental age for both ASD and TD groups.

Procedure

All children were seated in a quiet room; either in their home, in the lab at the University of CT, or at their school. After an introduction and discussion of the procedure, the experimenter administered the Stanford–Binet and (for the ASD group) the ADOS. Using the same cover story as Strack and colleagues (1988) but simplifying for a younger audience, the children were told that the authors were investigating how to make remote controls for people with disabilities and were interested in how using different devices might affect enjoyment of watching TV. The children were then shown a series of 8 Tom & Jerry cartoons, each lasting between 90 seconds and 2 minutes.

Tom & Jerry cartoons (also used by Soussignan et al. 2002 with their adult participants) were chosen after piloting of a variety of cartoons (Pixar shorts, Animaniacs, SpongeBob Squarepants, Tom & Jerry) in 40 children ages 6-14, recruited from one elementary school and one middle school, revealed that Tom & Jerry induced the most uniform amount of laughter across all ages of elementary and middle school children.

Children viewed the cartoons in 4 conditions: 1) alone, 2) with a parent or friend (a friend for children who were tested at their school, n = 13 in ASD group and n = 13 in control group, a parent for children who were tested in their home or in our lab, n = 31 for ASD group and n = 31 for TD group), 3) listening through headphones to a laugh

track superimposed onto the cartoon audio, and 4) holding a pencil in their mouth laterally between their teeth as they watched. Soussignan and colleagues (2002) reported that the eye muscles had to be engaged simultaneously with the zygomatic muscles (a "Duchenne smile") in order for a feedback effect to be observed. These experimenters also found that having the examiner demonstrate a smile while holding the pencil in his/her mouth, increased the subjects' tendency to smile with their eyes as well as their mouths, thus the same demonstration was offered by the experimenter in this study. Each child was exposed to each condition two times, and the scores across the two exposures were averaged to create a summary score for each child for each condition. Conditions were randomized, as were cartoon clips, so that each child received a different condition order, and different pairings of cartoon clips with condition. After each cartoon clip, the child was asked to rate his/her enjoyment of the cartoon on a 7 point Likert Scale. The scale had pictures of expressive drawn faces above the numbers 1, 2, 3, and 4 along with anchors ("hated it," "it was okay," "liked it," "loved it".) Each child's face was recorded during viewing in order to check attention before proceeding with statistical analysis. As noted above, the data of one child with ASD had to be excluded due to high distractibility.

Participants' faces were videotaped during viewing and later coded for 1) whether or not the participant was primarily smiling or not during each 5s block of each cartoon, and 2) number of laughs during each cartoon. Laughs were counted whenever a participant demonstrated a) rapid intensification of positive facial expression accompanied by b) a voiced or unvoiced exhalation of breath and c) observable shaking or vibration of throat and shoulders. Rapid intensification of emotional expression was

impossible to discern in the feedback condition (in which participants held a pencil in their mouths) and thus, laughter and smiles were coded for the remaining three conditions only: control, laugh track, and social. Inter-rater reliability was 93% for the 75% of videos that were double coded. Laughter and smiling were then collapsed into a “positive affect” variable.

Results

Self-Reported Cartoon Enjoyment

A mixed between-within subjects analysis of variance with a 2 (Diagnosis) x 4 (Condition) design, covaried for age, was conducted to assess the impact of viewing condition across both ASD and TD groups on self-rated enjoyment. There was a significant interaction between condition and group, Wilks Lambda = .831, F (3, 84) = 4.057, p = .011, partial eta squared = .169. There was also a main effect for condition, Wilks Lambda = .865, F (3, 84) = 3.11, p = .033, $ή^2$ = .135, with both groups showing differences across conditions. An inspection of the means shows that, whereas the TD group found the cartoons more enjoyable in the laugh track and feedback conditions than in the control condition, the ASD group found the cartoons less enjoyable under those conditions.

Because there was a significant interaction effect between group and condition, further ANOVAS and post-hoc tests were run on each group separately to assess the main effects of condition. A one-way repeated measures ANOVA was conducted on the self-ratings of the TD group across all 4 conditions in order to examine whether the experimental conditions had an effect on cartoon enjoyment. Consistent with our hypotheses, there was a significant effect for condition, Wilks’ Lambda = .62, F (3, 30) =

10.26, $p < .001$, multivariate $ή^2 = .38$. Pairwise comparisons (Bonferroni-adjusted) indicate that self-ratings of cartoon enjoyment in all 3 of the experimental conditions were higher than self-ratings in the control condition ($p < .001$ for the laugh track condition, $p = .001$ for the social condition, and $p = .025$ for the feedback condition). The self-ratings among the three experimental conditions were not significantly different from one another. In other words, all three experimental conditions boosted the self-rated enjoyment of cartoons in the TD group; however, no experimental condition appeared to provide a greater boost than any other (see Figure 1).

Another repeated measures ANOVA was conducted on the self-ratings of the ASD group across all four conditions in order to examine whether the experimental conditions had an effect on cartoon enjoyment. Again there was a significant effect for condition, Wilks' Lambda = .81, $F (3, 30) = 3.119$, $p = .037$, multivariate $ή^2 = .19$. Pairwise comparisons (Bonferroni-adjusted) indicate that social condition was significantly higher than the feedback condition ($p = .022$) and the laugh track condition ($p = .025$), but that none of the experimental conditions were significantly different from the control condition ratings (although the social condition approached significance, $p =$ 0.06).

Independent t tests across groups indicated that the TD and ASD groups differed on their initial baseline ratings of cartoons in the control condition, $t (86), = 2.58$, $p = .05$. ASD and TD group also differed significantly in their reported enjoyment of cartoons in the feedback, $t (86) = 3.11$, $p = .01$, and laugh track conditions, $t (86) = 3.95$, $p = .01$, with the ASD group reporting significantly less enjoyment than the TD group across both conditions. However, the ASD and TD groups did not significantly differ in their ratings

of cartoons in either the control or the social condition when they viewed them with a friend or a caregiver, *t* (86) = 1.41, p = .20. In other words, whereas watching the cartoon with a friend or caregiver offered nearly the same enjoyment boost to children with ASD as it did to their TD peers, children with ASD appeared to gain no enjoyment boost from either the feedback or laugh track conditions and, in contrast to the TD group, these conditions seemed to depress the self-rated enjoyment of the ASD group (see Figure 1).

Observed Laughter and Smiles

A second mixed within (x2 groups) x3 (control, laugh track, and social conditions) ANOVA was conducted for observable positive affect. There was a significant interaction between condition and group, Wilks Lambda = .619, F (2,87) = 26.7, p < .001, $ή^2$ = .381. There was also a main effect for condition, Wilks Lambda = .130, F (2, 86) = 291..115 , p < .001 , $ή^2$ = .87, with both groups showing differences across conditions. Finally, there was a main effect for group, F (1,87) = 5.2, p = .025, partial eta squared = .056.

The ASD group showed significantly more positive affect while viewing cartoons in the control condition, t (43) = 5.39, p = .025. Otherwise, observable positive affect followed largely the same pattern as the self-reported experience of each group. There were no significant between groups differences in the social condition, t (43) = .89, p = .86. However, the typically developing group showed much more positive affect in the laugh track condition than did the ASD group, t (43) = 5.69, p = .001. Within groups, whereas the typically developing group demonstrated significantly more positive affect in the laugh track condition than in the control condition, t (43) = 9.01, p = .001, the ASD

group demonstrated significantly less positive affect in the laugh track condition than in the control condition, t (43) = 4.56, p = .001. (See Figure 3.)

The relationship between autism severity and sensitivity to the various study conditions was examined using a correlation matrix for the experimental group. Sensitivity to feedback for each child was measured by computing the difference between the child's cartoon rating in the control condition versus the feedback condition (creating a "feedback rating change" score). Sensitivity to laugh track, and to presence of caregiver were similarly measured (i.e. by calculating the difference in the children's cartoon ratings and observable positive affect between control and experimental conditions). These variables were entered into the correlation matrix, along with the children's ADOS scores.

ADOS scores were negatively correlated with sensitivity to facial feedback, r = -.446, p = .002, sensitivity to laugh track, measured via both "laugh track rating change," r = -.324, p = .032, and "laugh track affect change", r = -.346, p = .021. In other words, the more autistic symptoms the child displayed (measured via higher ratings on the ADOS), the less likely he/she was to be positively affected by the feedback and laugh track conditions. ADOS scores were unrelated to sensitivity to caregiver's presence in the social condition, measured via both "social rating change", r = -.210, p = .171, and "social affect change", r = .132, p =, .392. However, the children's change in ratings across all three experimental conditions (feedback, laugh track, social) were significantly correlated (see Table 2).

In order to assess the relationship between range of facial affect (coded for children with ASD via the ADOS) and sensitivity to facial feedback, a binary logistic

regression was performed. The "feedback change" scores of each child with ASD—that is, the amount that his self-rated carton enjoyment changed between his control conditions and his feedback conditions— represented sensitivity to facial feedback and acted as the independent variable(s). Each child's score on the "range of affect" item was recoded as either "0" (normal) or "1" (abnormal) to create a dichotomous variable. This model was statistically significant, χ^2 (2, N= 49) = 30.906, p < .001. The model correctly predicted which children had normal or abnormal range of affect, based on sensitivity to feedback, in 94.3% of cases. When ADOS raw scores on the range of affect item (0-3 with increasing scores indicating increasingly restricted range of affect) were entered into a correlation with each child's "feedback change" score, the results were equally striking: the greater the abnormality in the child's range of affect, the less he/she was impacted by facial feedback (see Figure 2), r = -.431, n = 44, p = .007. This provides support for the hypothesis of Stel et al. (2008) that the link between expression and emotion is underdeveloped in individuals with ASD.

Discussion

The overall pattern of results indicates that children with ASD show diminished capacity for facial feedback and emotional synchrony with strangers (heard on a laugh track), but not with a live, familiar, co-audience. Our finding that children with ASD experience more enjoyment of cartoons with their caregivers and friends is somewhat surprising given previous findings that children with ASD may laugh more for private than social reasons (Reddy et al 2006; Hudenko et al. 2009). However, this finding is consistent with repeated findings that children with ASD are securely attached to their

caregivers (Capps, Sigman, & Mundy, 1994; Rogers, Ozonoff, & Maslin-Cole, 1991) and tend to show more typical social and emotional processing with regard to people who are personally meaningful to them (Oberman, Ramachandran, & Pineda, 2008; Pierce et al. 2004; Van Hecke, Lebow, Bal, & Lamb, 2009; Wilson, Pascalis, & Blades, 2007). Clearly, children with ASD are sensitive to their audience and feel happier in the presence of loved ones. However, despite these social tendencies, children with ASD appear to be significantly less impacted by peripheral emotional cues (hearing laughter of others on a laugh track) as well as their own bodily cues (sensitivity to facial feedback).

The ASD and TD groups significantly differed in their ratings in both the laugh track and the feedback conditions (see Figure 1). Specifically, children in the TD group rated cartoons as more positive under both of these conditions, compared to the control condition. Children in the ASD group showed the opposite pattern; they rated cartoons as slightly less positive under both of these conditions, compared with the control condition. It is not clear why facial feedback or a laugh track should have a negative impact on the ASD group; however, it is possible that in the absence of experiencing benefits of feedback and social contagion, children with ASD simply felt bothered or annoyed by the extra stimulation. It is also possible, given that children with ASD show more unusual facial expressions (Yirmiya et al. 1989) that their natural feedback was disrupted by these conditions. The correlation between sensitivity to the laugh track and sensitivity to the feedback condition was strong across both the TD and ASD groups, consistent with previous research that has shown a close relationship between mimicry and feedback processes at the individual level (Laird, 1994). Generally, these findings are consistent with previous research showing that children with ASD are less prone to emotion

contagion (Bacon, Fein, Morris, & Waterhouse, 1998; Helt, Eigsti, Snyder, & Fein, 2010; Scambler, Hepburn, Rutherford, Wehner, & Rogers, 2007), and facial feedback (Stel et al. 2008) as well as research demonstrating that mimicry, feedback, and contagion tend to be strongest in individuals with a high level of trait empathy (Andreasson & Dimberg, 2008; Laird, 1994); something individuals with ASD tend to display at lower levels (Baron-Cohen & Wheelwright, 2004).

The deficit in facial feedback demonstrated by most members of the ASD group showed a modest correlation to overall autism severity (ADOS total score), once again implicating the importance of facial feedback in social cognition. However, the single most important aspect of each child's social functioning to predict insensitivity to facial feedback was the child's range (or lack thereof) of facial expressions. Children with the most restricted range of affect were the least likely to have their rating scores impacted by the feedback or laugh track conditions. The strong relationship between blunted affect and insensitivity to facial feedback found in this study sheds light on the implications of restricted affect in ASD.

In typical development, emotional representations grow in tandem with a child's social and emotional experience. It can be speculated that a child who frequently experiences a positive internal state along with a positive emotional expression will develop significant neural connections linking these two representations. Over time, the link will become so well established that it operates in both directions – the internal emotion may trigger the facial expression or the facial expression may trigger (at least to some degree) the emotion. Children with ASD may not develop this link easily. Many children with ASD display a restricted range of affect (APA, 1994; Yirmiya et al., 1989).

Thus, children with ASD may not experience early and frequent pairings between their inner emotional states and their facial expressions. As a result, the link between their expression and emotions may remain underdeveloped, so that even as they age, internal emotion may not trigger corresponding expression, and emotional expression (in this study, induced via pencil in teeth) may not trigger a corresponding internal emotion. In other words, sensitivity to facial feedback may not develop, or may develop more slowly and less accurately.

Children with ASD, although capable of mimicry (Magnee, deGelder, van Engeland, & Kemner, 2007; Stel, van den Heuvel, & Smeets, 2008), engage in it less frequently than their typically developing peers (McIntosh, 2006; Scambler et al. 2007); (a finding supported in the current study by the lack of response to hearing laughter over the cartoons). Perhaps one reason for this reduced tendency to mimic is that mimicry, when activated, does not lead to rewarding emotional resonance with others because children with ASD fail to be influenced by the feedback generated by mimicry.

Mimicry and feedback provide an automatic mechanism for others' emotions to affect us. These processes may be important developmentally, in that continuously feeling a resonance of what others around one are feeling may be crucial for developing empathy and affective attunement with others. These processes may also be important for online social processing. Behavior occurs in the context of a stream of feedback information, (Ridderinkhof et al., 2004), which provides us moment-to-moment guidance in social interactions.

Disruption of these processes has important implications for understanding ASD.

For example, helping young children with ASD to experience heightened affect and become more facially expressive, may be important components of early intervention if it facilitates developing a stronger link between emotion and expression. This involves both creating an environment where a child is likely to experience more frequent and more intense emotions, but also simultaneously ensuring that the child is aware of his facial expression (perhaps through the use of a mirror). That way, he will learn to pair the feeling of his own musculature forming an expression with his internal experience. If this emotion-expression link were strengthened, then children with ASD might be more likely to experience the benefits of facial feedback when they mimic, and they might be more likely to trigger facial mimicry in others when they express their own emotions, both of which should lead to greater emotional resonance with others.

Similarly, it may be crucial for a developing child to experience his own emotions in tandem with the facial and vocal expressions of shared emotions in others. Over time, these emotional signals in others will trigger his own resonant expressions (mimicry), and allow for an automatic mechanism for understanding and feeling the emotions of others. If children with ASD are not engaged in frequent shared emotions with those around them, or are unable to attend to the emotional signals of those around them, these connections may develop in a more limited fashion (e.g., only with familiar people, only in certain contexts, etc.) Thus, these data are consistent with the current view of most empirically validated interventions for children with ASD, that teaching social attention to faces and facial imitation skills early in life may be crucial to social outcome in ASD.

The current study is limited in several respects. First, the friend or caregiver was given no a priori instruction and so the laughter, or general affect, of these individuals

was not controlled for across groups. Second, in order to participate in this study, children with ASD had to be willing to sit still and attend to cartoons for roughly 15 minutes, so children with greater attentional impairments were not represented. Third, as stated in the discussion, the children with ASD may have found the additional stimulation inherent in the laugh track condition aversive, and thus their lower scores in this condition may be due to sensory overload rather than social insensitivity. Furthermore, the effects captured by cartoon ratings were subtle. Future studies should explore the effects of feedback on negative stimuli and emotion, as well as the effects of inhibiting feedback in a group of individuals with ASD.

In conclusion, children with ASD, although capable of warm, affiliative social connections, are less attuned to the socio-affective signals not only of others, (especially strangers), but of their own bodies. We speculate that fundamental social tendencies to mimic and to be affected by facial feedback develop in response to experience and inform our social emotional lives. Symptoms of ASD such as restricted range of affect, reduced social attention, and reduced tendency to mimic deprive children with ASD of important social experiences in development, resulting in children with ASD having impoverished social percepts. More research is needed on the development of mimicry and facial feedback in young children in order to shed light on its potential importance in understanding ASD.

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Table 1.

Demographic characteristics of Autism Spectrum Disorder (ASD) and Typically Developing (TD) participants

	ASD (n= 44)	TD (n= 44)
Chronological Age	M= 11.6 (2.1); 8-14 years	M= 10.2 (2.5); 6-14 years
Mental Age (Stanford Binet)	M= 10.6 (2.7); 6-14 years	M= 10.4 (2.5) 6-14 years
Gender	5/44 female (11%)	8/44 female (18%)
ADOS	M = 12 (2.8); 7-18	

Note: Results given as mean (standard deviation); range

Table 2. Correlations between ASD severity, and the effect of each condition on participants' cartoon ratings.

	ADOS	LT Rating Change	Social Rating Change	Feedback Rating Change	LT Affect Change	Social Affect Change
ADOS Pearson Sig 2-t N	 1 44	 -.446** .002 44	 -.210 .171 44	 -.324* .032 44	 -.346* .021 44	 .132 .392 44
LTRC Pearson Sig 2-t N		 1 88	 .368* .014 88	 .613** .000 88	 .336* .026 88	 -.054 .727 88
SRC Pearson Sig 2-t N			 1 88	 .155 .317 88	 -.025 .871 88	 .068 .662 88
FRC Pearson Sig 2-t N				 1 88	 .325* .032 88	 -.058 .707 88
LTAC Pearson Sig 2-t N					 1 88	 .331* .028 88

1. Laugh Track Rating Change (LTRC) = The difference between each child's baseline (control condition) cartoon rating, and their cartoon ratings in the laugh track condition
2. Social Rating Change (SRC) = The difference between each child's baseline cartoon rating and their cartoon ratings in the social condition
3. Feedback Rating Change = The difference between each child's baseline cartoon rating and their cartoon ratings in the feedback condition
4. Laugh Track Affect Change = The difference between each child's baseline (control condition) observed positive affect, and the amount of positive affect displayed in the laugh track condition

Figure 1. Self-Ratings of Children's Enjoyment of Cartoons, by Experimental Group and Condition.

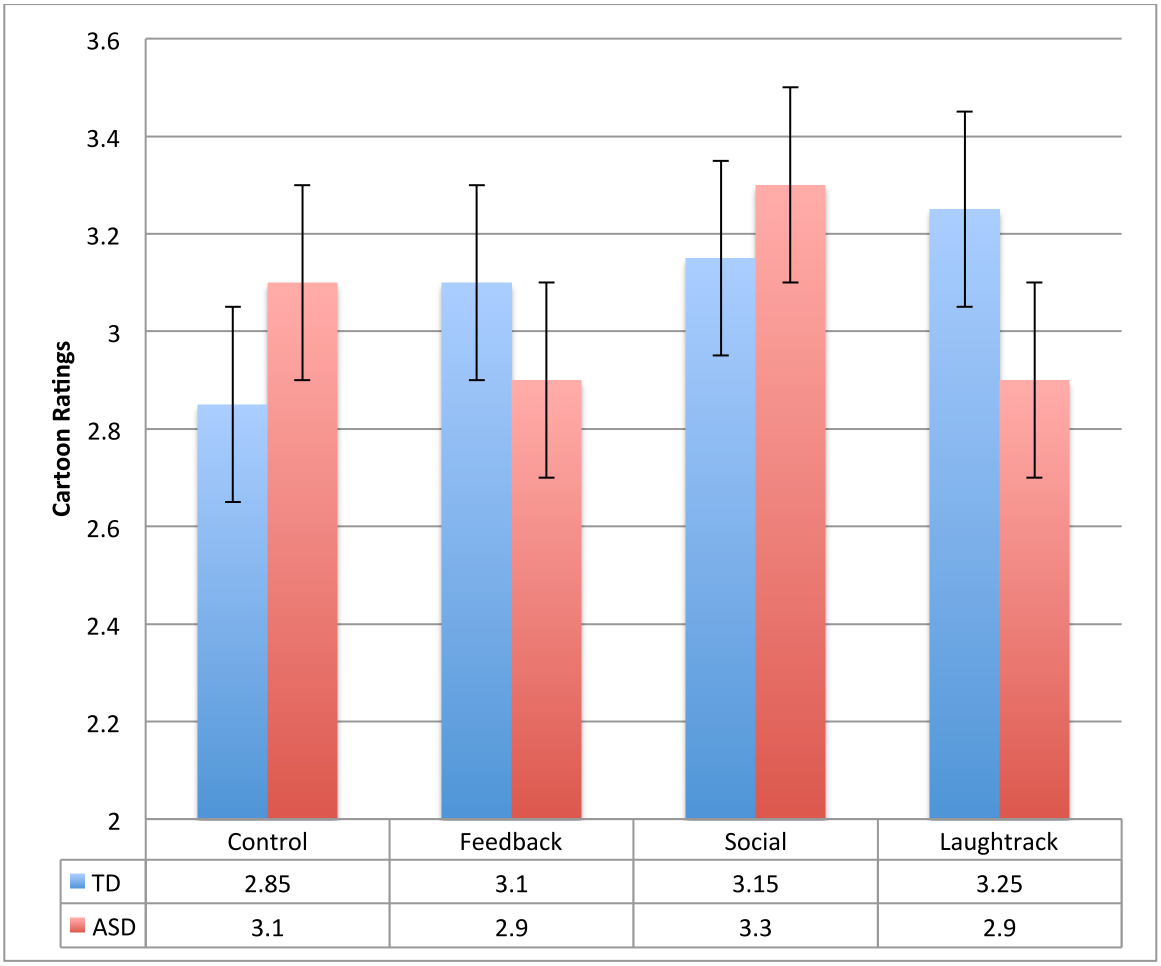

Figure 2. Relationship between sensitivity to facial feedback and abnormality of facial affect as rated on ADOS. The X axis represents the children's scores on the ADOS item that codes for range of affect (numbers higher than 0 indicate increasingly restricted range of affect). The Y axis represents the difference between children's cartoon ratings in the feedback condition versus the control condition (scores higher than zero indicate increasingly positive effect of feedback on self-rated enjoyment).

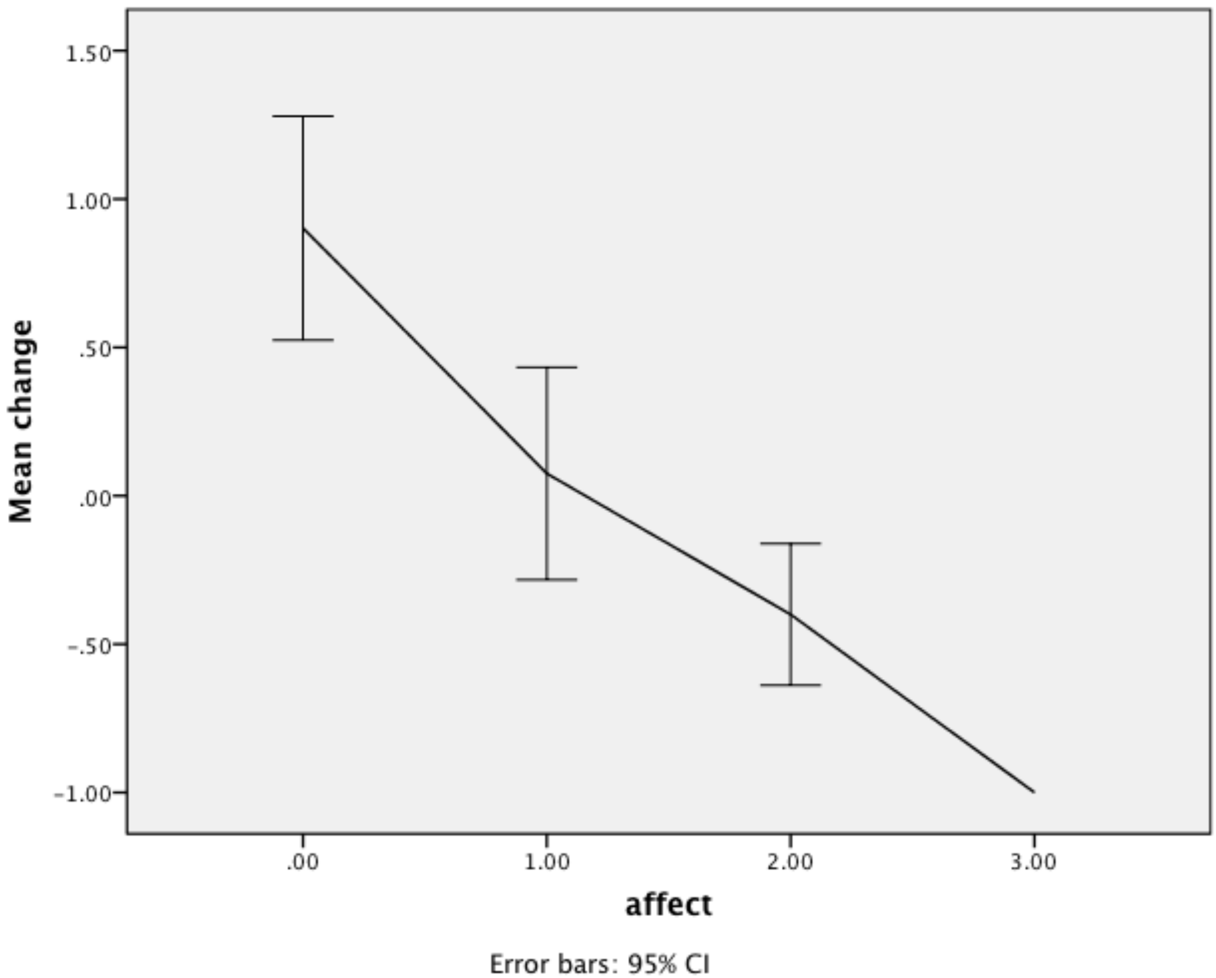

Figure 3. Percentage of viewing time for which each group displayed observable positive affect, displayed by condition.