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Emotion processing in high-functioning autistic children: a priming task

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A Priming Task

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Abstract

Although high-functioning autistic individuals demonstrate normative intelligence, profound deficits in social processing exist. Understanding emotions in faces can be particularly difficult for autistic individuals. In the present research a priming task was used to uncover the speed and strength of association between emotional faces and emotional words. Autistic individuals are often capable of explicitly recognizing emotion in faces but still demonstrate difficulty interpreting emotional situations. In the current study, emotional words were primed by quickly presented matching or mismatching emotional faces. This may be more similar to naturalistic social interactions in which facial expressions change quickly. The aim was to examine any differences in reaction times and error rates in the priming task between high-functioning autistic children and typical children. Groups were divided into older (8-16 years) and younger (7-11 years) groups to examine any developmental differences that might exist between the two groups. Overall, no priming effects were seen across groups. Younger typical children, however, did seem to be influenced by mismatching prime-target pairs. This may point to a differential developmental trajectory in face and emotion processing between autistic and typical children, as typical children were more influenced by face primes than were older and younger autistic children and older typical children.

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Autism is a developmental disorder marked by impairments in social interaction such as regulation of eye contact, recognition of facial expression, and a lack of social or emotional reciprocity (DSM-IV, APA, 2004). The CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network found that in 2007 as many as 1 in every 150 children were affected with the disorder. Between 1994 and 2006, the number of 6- to 17-year-old children classified as having an autistic disorder in special education programs increased from 22,664 to 211,610, demonstrating the substantial prevalence of autism and need for research concerning the disorder (CDC, 2008). Autism differs from other disorders in that its core deficit is in social interaction and this can be seen across the wide range of abilities found in the spectrum, from low-functioning autistic individuals to high-functioning, or Asperger's Syndrome (AS), individuals. Early indices of Autism Spectrum Disorder (ASD) include deficits in social initiation, social approach, social smiling, social orienting, social imitation, shared attention, and response to social reinforcers (Dawson, 2008). For those on the higher end of the spectrum, the only apparent deficit in functioning may be in their ability to empathize and socialize with others. With no explicit cognitive or language delay proven to cause this social impairment, it is difficult to pinpoint the underlying mechanism that produces social dysfunction in autistic individuals.

Impaired implicit processing of emotions in autistic individuals may provide evidence that underlying cognitive mechanisms are responsible for this overt social dysfunction. Specifically, understanding others' emotions by quickly reading their facial expressions and being able to associate that emotion with other concepts stored in semantic knowledge may be hindered in autistic children, including high-functioning autistic children. This impairment in quickly reading emotions may be more pronounced as the amount of available facial information decreases. Autistic individuals particularly tend to avoid the eye region of the face, making emotion processing from the eye region particularly difficult for autistic individuals (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001; Spezio, Adolphs, Hurley & Piven, 2007). The impaired implicit processing of emotions seen in this group of individuals as compared to typically-developing individuals may provide clues as to the automaticity needed to read and understand others' emotions (Critchley et al., 2000; O'Connor, Hamm & Kirk, 2007). Examining specific abnormalities in social processing of high-functioning autistic individuals may give insight into the root cause of social impairment that appears to afflict individuals at all levels of functioning on the autism spectrum.

High-functioning autistic (HFA) individuals as well as those diagnosed with Asperger's Syndrome (AS) and Pervasive Developmental Disorder Not-Otherwise-Specified (PDD-NOS) may appear functionally normative in everyday settings. The disorder becomes apparent, though, in social settings where impairment is pronounced. High-functioning autistic individuals do not differ from typical individuals in terms of intelligence. Autistic intelligence has been often overlooked and misinterpreted according to typical tests of intelligence such as the IQ test. According to Dawson (2008), high-functioning autistic individuals often have normal or even above normal intelligence. In the past these individuals have been pejoratively labeled as "idiot savants," implying that while they often excel in some areas, they lack greatly in others. This is especially indicative of high-functioning autistic or Asperger's Syndrome individuals who often display normative intelligence, but are profoundly socially impaired (Baron-Cohen, 2000). Social dysfunction may be a deficit universal to the autism spectrum regardless of intelligence. Why is it then that high-functioning autistic adults and children can perform tasks with normative levels of intelligence, but display such abnormalities in when it comes to social functioning? It may be that they are impaired in certain cognitive domains that facilitate this social understanding in typically-developing individuals.

Theory of Mind and Social Functioning

One of the main theories of interaction deficits in autism involves Theory of Mind (ToM), and proposes that social dysfunctions result from an inability to process and interpret mental states such as beliefs, desires, and emotions (Baron-Cohen, 2000). Theory of Mind tasks that have frequently been found in the literature to be impaired in autistic individuals include first and second order false belief tasks, recognition and conceptualization of mental state words, and tests to infer complex mental states from facial features such as the eye or mouth region of the face (Baron-Cohen, 2001). These are just a few of the many tasks that appear to be impaired in both autistic adults and children as compared to typically-developing individuals. Baron-Cohen (1991b) found that autistic children did not achieve mastery of Theory of Mind tasks at the same age as typically-developing children and that autistic children often displayed a pattern of attainment of ToM tasks that varied from that of typically-developing children.

In the Empathising-Systemising (E-S) theory of autism, Baron-Cohen (2000) referred to ToM as simply the cognitive aspect of empathy in relating to the social world. In this approach, he listed a second component as necessary in social functioning, that of having an appropriate response to an affective social situation. It is here that autistic individuals may fall short. They have the capacity to cognitively process incoming social information, but they may not have the ability to infer an appropriate social response. Correlations have been found between tests of ToM and empathic ability measures, such as recognition of emotional faces or conceptualization of emotional words (Buitelaar & van der Wees, 1997; Dyck, Ferguson, & Shochet, 2001). Social IQ, measured by tests of social situation interpretation and the WAIS Picture Arrangement subtest to measure perspective taking ability, has been found to be a mediating factor in emotion identification tasks (Teunisse & de Gelder, 2001).

The fact that cognitive and affective components of social processing are related and impaired in autism may indicate that some underlying cognitive processing may produce such impairments in empathic ability. Theory of Mind has been shown to be a specific social cognitive impairment in autistic individuals apart from other cognitive abilities (Baron-Cohen, 1991a). When given tests of social cognition that do not involve attainment of ToM understanding such as relationship recognition, interpersonal reciprocity, and understanding of the animate-inanimate distinction, autistic children perform just as well as typically-developing children (Baron-Cohen, 1991a). Apart from other cognitive abilities, being able to understand specifically what is going on in another person's mind seems to be particularly difficult with autistic individuals.

Explicit vs. Implicit Tests of Emotional Understanding

While autistic individuals perform similarly to typical individuals in some cognitive tasks, differences between groups can be found in explicit versus implicit tests of emotion processing. Tasks of social competence of autistic individuals often involve explicit instructions, such as matching emotional faces or words to other emotional faces or words, and are usually performed with the same accuracy as typically-developing individuals (Humphreys, Minshew, Leonard & Behrmann, 2007). Some researchers have argued that these tests of social functioning simply illustrate the ability of autistic individuals to develop compensatory strategies when asked to perform such explicit tasks, and that underlying deficits in social cognition are masked by use of these compensatory strategies (Grossman, Klin, Carter & Volkmar, 2000; Teunisse & de Gelder, 2001). It is when these social cognitive tasks require that the participant have an intuitive understanding of the other person's internal mental state that autistic individuals demonstrate impaired performance. Compensatory strategies developed over time by high-functioning autistic individuals may mask actual implicit abilities of social functioning.

These implicit deficits could be uncovered through the use of face and emotion processing tasks. Autistic children show a different pattern of comprehension from typically-developing children when interpreting facial cues. Child and adult studies, though, can provide very different findings and interpretations of results. Many studies utilize various methodologies in which identification of emotions differs from matching of emotions. Emotion identification tasks require that participants look at a face and choose from a list of emotions the most appropriate answer (i.e., happy, sad, angry, etc.). Emotion matching tasks, on the other hand, require that participants discriminate between two faces presented as to which face displays a particular emotion (e.g., "Which face looks angry?"). In explicit tests of emotion identification and emotion matching tasks, autistic adults are able to *match* emotions with no difficulty, but show poor performance in comparison to typically-developing participants when asked to *identify* emotions explicitly (Humphreys et al., 2007).

Autistic children, however, show a different pattern of results. In a battery of face processing tasks, autistic children performed worse than verbal mental age-matched and chronological age-matched children, especially when asked to match emotional expression and eye gaze direction as seen in faces (Deruelle, Rondan, Gepner & Tardif, 2004; Riby, Doherty-Sneddon, & Bruce, 2008). Riby, Doherty-Sneddon, and Bruce (2008) found emotional expression, lip-reading, and eye gaze direction identification tasks to be easier than matching tasks for autistic children. For example, when asked to indicate which face was "happy" or "sad," autistic children performed just as well as typical children. When asked to indicate which face "feels the same way" as another face, however, autistic children's performance was impaired. It seems that autistic children are explicitly able to recognize and identify emotion seen in faces. When asked to match these concepts to other emotional faces or words, however, autistic children fail in comparison to typically-developing children (Deruelle et al., 2004; Riby et al., 2008). On the surface this ability to recognize emotion is unimpaired, but implicit understanding may fall short when high-functioning autistic children must apply these concepts to other similar stimuli.

These findings suggest that autistic adults may have had ample time over the years to establish conscious compensatory strategies in social situations, especially those involving emotional understanding. Children may have not had the time or social training to be able to mask their social impairment. O'Connor, Hamm, and Kirk (2005) did not find any differences in emotion recognition abilities between autistic and typical children. However, parent reports of autistic children indicated that these children were significantly more socially inept than their typically-developing counterparts. O'Connor et al. (2005) pointed out that this particular sample of autistic children had received social skills training that may have contributed to their equivalent performance on the explicit emotion task but may not have helped with the children's overall social awareness. In studying the effect of age on emotional comprehension strategies, Grossman, Klin, Carter and Volkmar (2000) divided their sample of high-functioning autistic children into a younger and older group. When high-functioning autistic children were asked to explicitly name the emotion seen in a face that was simultaneously paired with either a matching (e.g., happy face/ "happy") or mismatching label (e.g., happy face/ "sad"), younger autistic children made significantly more errors than typical controls when the emotional face was paired with a mismatched word. Grossman et al. (2000) found that older AS children were less likely to be thrown off by a mismatched label. These older children, then, may have had time to establish working compensatory strategies and use them in their everyday social functioning. Compensatory strategies, whether acquired through specific social training programs or from years of experience in the social world, can have a confounding effect when determining the true capabilities of emotional understanding in autistic individuals. Nonetheless their true capabilities may be distinguished in the high-functioning autistic individual's ability to interpret and categorize facial expressions in real time.

Neurological/Biological Evidence for Impaired Face Processing

In order to tease apart this potential confound of compensatory strategies used in social functioning, some researchers have employed the combined use of explicit and implicit measures in face perception. When autistic subjects are asked to perform explicit tasks in emotion recognition from faces, their performance is comparable to typically-developing individuals. However, this may veil the differential brain activity that is occurring in performing explicit emotion recognition tasks. While able to perform similarly to typical subjects in an explicit emotion recognition task from both whole face and reduced features faces (such as faces with only eyes or mouth visible), O'Connor, Hamm and Kirk (2007) found through ERP data that autistic subjects actually took longer to process this facial information. This delay did not occur while processing objects. MRI data has also revealed a differential pattern of brain activity in autistic individuals when implicitly processing emotional faces, but a normative pattern of brain activity when asked to perform an explicit emotion recognition task (Critchley et al., 2000). When high-functioning autistic adults were shown emotional faces they processed these faces differently when asked to consciously identify the specific emotion displayed than when they were asked to identify gender only. In this way, Critchley et al. (2000) showed that underlying brain functioning was different when consciously and unconsciously perceiving and interpreting affective faces. Differential brain activation patterns according to MRI data have also been found in autistic individuals compared to typical subjects when asked to make judgments of both faces and objects (Schultz et al., 2000). In face processing, autistic individuals tend to activate the inferior temporal gyrus, an area of the brain that is normally activated in typical subjects when processing objects, as opposed to the fusiform gyrus that is normally activated when viewing faces. In this way, brain activation patterns suggest that autistic individuals tend to process faces more like objects. Brain processing is even found to be different in autistic toddlers who do not show a varied brain activation pattern when viewing either their mother's or an unfamiliar person's face as compared to typically-developing children who do show differential brain activation (Dawson et al., 2002). These autistic children did, however, demonstrate differential brain activation when viewing a favorite toy versus an unfamiliar object. The face, therefore, is not treated as a special category requiring special brain processing for autistic individuals as it might be for typically-developing persons.

Impaired/Unimpaired Implicit Understanding of Faces

Researchers have examined the interference and facilitation effects that emotional faces may have on other cognitive tasks. In a variation on the basic Stroop task, Ashwin, Wheelwright, and Baron-Cohen (2006) laid colors over pictures of neutral or angry faces as well as over pictures of chairs. They found that Asperger's individuals showed an attentional bias to pictures of faces rather than to non-social stimuli in that they took longer to name the color laid over these pictures than did typical subjects, but this delay in response latency was not found for pictures of chairs. Perhaps faces, regardless of the specific emotion displayed, take longer to process for autistic individuals and therefore are harder to categorize according to affect.

This implicit difficulty in emotional processing may not be so easy to recognize in high-functioning autistic individuals because these individuals are performing at normative levels with regards to simple face perception processing. Contrary to initial evidence from Langdell (1978) and Hobson, Ouston, and Lee (1988), recently researchers have suggested that high-functioning autistic adolescents perform similarly to typically-developing adolescents on a face inversion task. Specifically, Teunisse and de Gelder (2003) found that both autistic and typically-developing participants performed worse when asked to match one of two faces to a previously shown face when these faces were presented upside-down as opposed to right-side up. They also did not find impairment in what they termed a "Composite Effect". To demonstrate this, the researchers cut pictures of faces in half horizontally and skewed the bottom half either to the left or the right of the upper half, altering the presentation of faces to participants with regards to their juxtaposition. Teunisse and de Gelder (2003) found that autistic individuals were just as good at recognizing faces when given aligned and non-aligned upper and lower portions of faces. Typically-developing individuals, however, performed worse when given non-aligned faces compared to aligned faces. Presentation of the whole face may not be as important in face processing for autistic individuals. Instead Teunisse and de Gelder (2003) suggested a more feature-based as opposed to configural-based search strategy may be employed by autistic individuals when viewing and interpreting affect in faces.

Reduced Feature Face Processing

High-functioning autistic individuals have been shown to perform nearly or just as well as typically-developing control subjects in correctly recognizing emotion when presented with a whole face stimuli (Adolphs, Sears, & Piven, 2001; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Critchley et al., 2000; Hobson, Ouston, & Lee, 1988; Langdell, 1978; Spezio, Adolphs, Hurley, & Piven, 2007, Lopez, Donnelly, Hadwin, & Leekam, 2004). As available facial cues decrease, however, the ability to determine emotion becomes more difficult for autistic individuals. This is demonstrated specifically when autistic subjects are given stimuli involving only the eye region of a face and asked to determine both basic and complex emotions (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001; Spezio, Adolphs, Hurley, & Piven, 2007). In comparison to controls, autistic subjects have an especially difficult time reading and interpreting emotion from the eyes. Typical subjects rely on this information from the eyes as indicators of specific affect during social situations, although this may not be the case for autistic individuals, who may show a particular avoidance from the eye region in processing faces.

Some of the first research concerned with face processing in autism indicated a preference for the mouth region in autistic children. Langdell (1978) found that autistic children were better able to recognize their peers when given features from the lower half of the face as opposed to typically-developing children who preferred to rely on features from the upper half of the face. Recently, through the use of visual scanpath data, Pelphrey et al. (2002) found that when autistic and typical participants were given pictures of emotional faces and asked to name the emotion, autistic participants tended to view nonfeature areas of the face significantly more often and core features areas of the face (i.e., eyes, nose, mouth) significantly less often than controls. Facial expressions are often complex and interpretation of them could vary depending on whether focus is placed on the mouth region, eye region, or some other area of the face. This differential processing of facial features alone could account for some of the variability seen in overall emotion understanding in autistic children.

Interpreting and Applying Emotion

Interesting findings arise when face processing involves both comprehension and application of related emotions to be used in social interactions. It is here that autistic individuals may display implicit differences between themselves and typically-developing participants. Autistic individuals may be able to recognize emotion as seen in faces, but may not be capable of correctly interpreting exactly what this emotion means during a social situation (Bolte & Poustka, 2003; Golan, Baron-Cohen, & Golan, 2008; Klin et al., 1999). Recently, Golan, Baron-Cohen, and Golan (2008) asked autistic and typically-developing children to interpret and predict emotional reactions of actors to specific situations seen in a short film clip. Participants were given background information from the scene leading up to the point where the actor was to respond to the situation in an affective manner. Children were asked to indicate what they thought the actor would do or say next. Autistic children, compared to typically-developing children, were impaired in this task, as it was difficult for them to interpret the next sequence of events that should occur. At the behavioral level, very young autistic children have also shown atypical responses to affective situations. Sigman, Kasari, Kwon, and Yirmiya (1992) found that autistic toddlers looked significantly less at an adult showing negative affect than did typically-developing toddlers. The autistic children played with a toy more and appeared less concerned about the adult's negative affect than did other children. It appears that autistic children are aware of the existence of other people's reactions and emotions to certain situations, but have a difficult time understanding what that means in terms of social functioning.

Theories of Emotion Activation and Association

Autistic children may be able to recognize a social cue as emotional, but may not know how to use this information in a social context. According to a categorical theory of relatedness that may be applied here to emotional understanding, pairs of items may prime each other due to their mutual semantic relationship (McNeill & Burton, 2002). Bruce and Young (1986) established a theory of person recognition that involves, at the first level, Face Recognition Units (FRUs), that code a familiar person's face. Next, Person Identity Nodes (PINs) recognize that person as familiar or unfamiliar, therefore representing the recognition of that person. Finally, there is activation of Semantic Information Units (SIUs), which represent all categorical information related to that person. It is in going from the Person

Identity Nodes to the Semantic Information Units, argued Bruce and Young (1986), that semantic categorization decisions and responses are made after activation of recognition of that person.

As with person recognition, this model may be applicable to emotion recognition. Emotions must be perceived, recognized, and identified by a person for efficient social functioning. Within this framework, recognition of emotion must be able to activate other concepts stored in the semantic pool of knowledge to be associated with that particular emotion so that social responses made to the emotion are appropriate. Autistic individuals may be able to explicitly recognize emotion seen in facial affect, but be unable to then transfer this knowledge to activation of other associated concepts. So even though this model pertains to person recognition, it is also relevant for emotion recognition and can provide a basis for abnormalities seen in face processing and emotion comprehension in autistic individuals, especially autistic children who have not yet developed social compensatory strategies. The uneven profile of face perception skills seen in autistic children (Riby, Doherty-Sneddon, & Bruce, 2008) may lead to differential activation of semantic categorization, which would ultimately lead to misinterpretation of cues in the social environment and overall social impairment.

The Present Research

In the present research, I attempted to tap into the speed and strength of association of emotional facial cues and emotionally associated words through an affective priming task involving quick presentation of facial affect. Affective priming tasks are designed to uncover the strength of automatic associations between two affective concepts stored in memory (Banaji & Hardin, 1996; Fazio, Sanbonmatsu, Powell, & Kardes, 1986). On a computer participants are first shown a prime, consisting of either a word or picture, for a short time (1000 msec), are then shown a word or picture either related, unrelated, or neutral in valence (positive or negative) with the previously shown prime, and are then asked to categorize the target as positive or negative. Reaction times in responding to the target word are dependent upon the target's associated strength with the prime. Highly associated primes and targets should result in faster response latencies, whereas primes and targets with weak associations should produce slower response latencies (Meyer & Schvaneveldt, 1971). This process of affective priming taps into the strength of association of related concepts and can give a relative indication as measured by reaction times as to the automaticity involved in the evaluation of those primes.

To demonstrate the relative speed needed for interpretation of facial cues, an affective priming task was administered to both typically-developing children and high-functioning autistic children. Primes consisted of emotional faces presented for one second and participants were asked to judge the positive/negative valence of target words following primes. The ability to connect words on the basis of meaning through priming has been shown to be intact in autistic children relative to normal children (Hala, Pexman, & Glenwright, 2007; Lopez & Leekam, 2003; Toichi & Kamio, 2001), and semantic priming has been shown to be effective across picture-word modalities with autistic participants as well (Kamio &Toichi, 2000). However, Lopez, Leekam, and Arts (2008) found a significant inverse correlation between face recognition in a semantic priming task and a semantically associated object categorization task in autistic children. The autistic children in their study were either good at face recognition or semantic categorization of objects, but not both, which may suggest that autistic children cannot integrate perceptual and categorical information into one semantic store.

In the present research I attempted to demonstrate a deficit in face processing leading to impaired affective categorization of information in autistic children compared to typical children. I examined both error rates and reaction times of matching and mismatching prime-target pairs. Performance in the affective priming task was then examined relative to children's severity of autistic traits and social impairment. Those children who displayed more autistic traits and who were more socially impaired were expected to perform worse on the priming task overall. For typically-developing children, emotional faces were expected to facilitate reaction times to matched emotional word targets and to inhibit reaction times to mismatched emotional word targets. Since the current affective priming methodology involving facial feature primes and emotional target words has not been previously used with high-functioning autistic children, predictions of performance in this group were relatively speculative. If reaction times of autistic children relative to typically-developing children were slower overall regardless of face type presentation, this would support either an overall deficit in face perception, or a deficit in affective association of concepts activated by emotional faces. If autistic children performed just as well as typically-developing children with whole face presentation, but performed worse than typically-developing children when given eyes only or mouth only stimuli, then this pattern of results would suggest a particular deficit in feature-based recognition of emotions that leads to a deficit in activation of related concepts. Neutral primes (presentation of a black box in place of an emotional face) provided a neutral condition that did not involve face processing. These predictions were further analyzed according to younger and older autistic and typically-developing children.

This was done to examine the presence of any age differences between the two groups and assess whether face processing follows a similar developmental trajectory between autistic and typical children. The hope with the present research was to highlight a specific developmental deficit in the ability to affectively associate and categorize emotionally-laden social cues in autistic children relative to typically-developing children and whether or not this varied with age. Even though the literature has shown that autistic individuals are capable of explicitly recognizing emotion, they are still socially dysfunctional. This dysfunction, therefore, may arise out of an inability to efficiently and quickly relate emotional faces to other concepts stored in memory, resulting in the overarching symptom of autism, which is social impairment.

Method

Participants

Ten high-functioning children with autism spectrum disorder (ASD) ages 7 to 16 were recruited from local schools, autism support groups, and parent associations in the Bellingham, Washington area. Only those children diagnosed by a clinician as either High-Functioning Autistic (HFA), Asperger's Syndrome (AS), or Pervasive Developmental Disorder Not-Otherwise-Specified (PDD-NOS) were included in the study. Clinician diagnoses were confirmed via parent report. Ten typically-developing children, matched on verbal, nonverbal, and composite IQ, as well as chronological age, acted as a control group and were recruited from the CLASP project participant pool at Western Washington University. Participants' nonverbal, verbal, and composite IQ were measured according to the Kaufman Brief Intelligence Test Second Edition (K-BIT-2; Kaufman & Kaufman, 1997) to ensure that both experimental and control groups were matched according to overall IQ. Autistic and typical children were categorized as younger if they were ages 7 to 11 and were categorized as older if they were ages 12 to 16. Younger and older typical and autistic groups, therefore, consisted of 5 participants each.

Materials

Autism Spectrum Quotient

The AQ-Child (Auyeung, Baron-Cohen, Wheelwright, & Allison 2007) is a 50-item parent-report questionnaire used to quantify autistic traits in children aged 4-11 years. The Likert-type measure ranges in scores from 0-150, with higher scores indicating greater severity of autistic traits. A score of 76 or above on the AQ-Child indicates a level of severity associated with both HFA and AS, with 95% of children diagnosed as HFA or AS scoring at or above this designated score. The AQ-Child has demonstrated good test-retest reliability ($r = 0.85$, $p < 0.001$), and high internal consistency ($\alpha = 0.97$). AQ-Adolescent Version (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006) is similar to the AQ-Child, but is used to indicate severity of autistic traits in adolescents aged 11-16 and has shown good test-retest reliability ($r = 0.92$, $p < 0.001$) and high internal consistency ($\alpha = 0.79$). Scores on this measure range from 0-50. This measure includes a cutoff score of 30 or above to indicate severity of autistic traits.

Social Responsiveness Scale

The Social Responsiveness Scale (SRS; Constantino et al., 2005) is a 65-item parent-report questionnaire that measures the autistic child's social impairments according to social awareness, social information processing, capacity for reciprocal social communication, social anxiety/avoidance, and autistic preoccupations and traits ($\alpha = 0.80$). The scale is appropriate for children aged 4-18, and includes a wide-range of severity of social impairment across the autism spectrum. Higher scores on the SRS indicate a greater severity of social impairment. Scores range from 0-120, with scores above 80 indicating severe social dysfunction associated with high-functioning autism.

Stimuli

Face primes were obtained from *Pictures of Facial Affect* (POFA; Ekman, 1993) and the semantic priming stimuli set consisted of 36 different faces taken from this collection. Of these, 12 different faces were included in each condition of the semantic priming task (6 positive/6 negative whole face condition; 6 positive/6 negative eyes only condition; 6 positive/6 negative mouth only condition). A neutral stimulus consisting of a black rectangle in place of a face was also included 6 times per condition trial. Eyes only and mouth only conditions were produced by removing all other core facial features from the picture so that only the target feature remained. For example, the hair line, ears, and everything below the eyes were not included in eyes only pictures of faces (See Figure 1). Positive faces included those that portray happiness, and negative faces included those that portray sadness. Faces were chosen according to specific norms outlined in the POFA and included faces that were judged by at least 90% of raters as being happy or sad.

In addition to the 36 facial stimuli used in the semantic priming task, another 16 faces were chosen from the POFA stimulus set for use in an explicit emotion recognition task. Four different faces for each basic emotion of happiness, sadness, anger, and disgust were included and counterbalanced between groups in a pencil and paper forced choice emotion recognition task.

Words used as targets during the semantic priming task included 18 items total, with 9 positively associated (see Appendix A) and 9 negatively associated (see Appendix B) words randomly counterbalanced across trials, and were developed by the researcher and piloted prior to the present study. All children included in the study were able to read these words.

Procedure

To accommodate parent and child comfort levels, participants either came into the lab for evaluation or a researcher visited them in their home.

One parent of each child completed either the AQ-Child or AQ-Adolescent version, the Social Responsiveness Scale, and a demographics questionnaire. Next, a trained researcher conducted the K-BIT-2 IQ test in a quiet room away from distraction.

The semantic priming task involved a 2 x 3 x 2 design in which group (autistic vs. typical), prime face presentation (whole face, eyes only, mouth only), and prime-target valence (matching vs. mismatching) were counterbalanced between groups. Neutral primes (black rectangles) were included as a neutral control condition that did not involve faces to evaluate reaction times for primes that were not faces. Six randomized experimental blocks were administered in which 18 trials of each condition (6 neutral, 12 whole face etc.) were presented. Within these blocks, one third of the prime-target pairs were matching (e.g., happy face prime, positive target word), one third were mismatching (e.g., happy face prime, negative target word), and the remaining third consisted of equal numbers of positive and negative target words following neutral stimuli. Equal numbers of positive and negative faces were presented. The semantic priming task was administered on a laptop with Inquisit software (Inquisit, 2002). Within each trial participants first see an orienting stimulus (+)

for 500 msec, then a prime face stimulus (either whole face, eyes only, mouth only, or a neutral black box) for 1000 msec, followed by a blank screen for 200 msec, and finally a target word (matching or mismatching) appears on the screen until a response is made (See Figure 2). Because face primes were presented for 1000 msec, which is above the threshold of conscious awareness, participants were instructed to simply look at the first picture, and only make judgments of the word that appeared next on the screen. Studies involving autistic adult participants have included prime display times from as few as 600 msec (O'Connor, Hamm, & Kirk, 2007) up to as many as 2000 msec (Toichi & Kamio, 2001). In the present research I employed, in conjunction with similar research involving autistic children (O'Connor, Hamm, & Kirk, 2005; Teunisse & de Gelder, 2001), a prime stimulus time of 1000 msec to ensure that the prime information was perceived adequately by children, especially those who may have attention difficulties. Participants who displayed difficulty maintaining focus or who displayed discomfort during the task as judged by the researcher completed only 3 blocks of trials as opposed to 6. One younger autistic child and two younger typical children completed 3 blocks of trials as opposed to 6. All other children completed 6 blocks of trials. Participants were asked to indicate whether the following target word was positive or negative by pushing a button labeled with a smiling face for positive and a frowning face for negative on the keyboard. No indications of incorrect responses were given to the subject throughout trials as this may have distracted from the task and could cause unnecessary frustration with the task that could interrupt reaction times. The inter-trial interval was 1 second. To ensure that the task was understood, a practice block of 8 trials was conducted before experimental trials were run so that the child could become accustomed to the computer program and use of the keyboard. All participants indicated an understanding of the task after practice trials and continued on to experimental trials. Error rates and reaction time (RT) measures only for correct responses were analyzed between groups and among conditions for the semantic priming task.

The last task involved an explicit forced-choice emotion recognition task. This paper and pencil test included 16 additional faces taken from the POFA stimulus set. Each page included one face displaying one of four emotions and participants were asked to choose from four choices provided (angry, sad, happy, disgusted) as to which emotion they believed the face was displaying. There was no time limit for this task and errors were scored. This test was administered to ensure that each group explicitly understood basic emotional affect as seen in faces. All participants provided informed parental consent and were debriefed at the conclusion of testing.

Results

Descriptive Data

Autistic and typically-developing children were matched according to chronological age, nonverbal IQ, verbal IQ, and composite IQ. Autistic children scored significantly higher than typically-developing children on the Social Responsiveness Scale (SRS), indicating greater social impairment in this group of children, t (18) = 12.50, $p < .001$, d = 5.59. Autistic children's average scores on the SRS indicated a level of social impairment deemed profoundly socially impaired according to the measure, while typical children's scores indicated normative social functioning. Autistic children also scored significantly higher on the Autism Spectrum Quotient (AQ) than typically-developing children, indicating a greater level of autistic traits, t (18) = 9.27, $p < .001$, d = 4.14. Typical children's average scores for this measure did not exceed the cutoff for autistic functioning. See Table 1 for means and standard deviations of these measures.

Reaction Time

Overall, no priming effects were found for either autistic or typically-developing children. Face primes did not affect reaction time for the following target words. Faces and target words matching in valence did not produce faster reaction times than mismatching prime-target pairs (See Figure 3). (Initially, a Windsor method of calculating average reaction time scores was used, but this included a great number of outliers which added to overall variability. Instead, median reaction time scores were used as an appropriate reflection of average reaction time.)

A mixed-model ANOVA was conducted in which face presentation (eyes, mouth, or whole face) and prime-target match (matching vs. mismatching) were within-subjects factors, while group (autistic vs. typical) and age (younger vs. older) were between-subjects factors. The analysis revealed a main effect of age on reaction time such that older children responded faster than younger children, F (1, 16) = 10.82, $p < .01$, $\eta^2 = .40$, MSE = 6744783.75 (See Figure 3). The ANOVA also revealed an interaction between face presentation and prime-target match, F (2, 32) = 3.80, $p < .05$, $\eta^2 = .19$, MSE = 63748.43, and an interaction between face presentation, prime-target match, and age on reaction time, F (2, 32) = 3.37, $p < .05$, $\eta^2 = .17$, MSE = 56501.18. The 4-way interaction between face presentation, prime-target match, age, and group approached significance, F (2, 32) = 3.06, $p = .06$, $\eta^2 = .16$, MSE = 51347.75.

An additional ANOVA was conducted to look at differences between groups with regards to neutral prime conditions. The ANOVA revealed a main effect of face presentation on reaction time for neutral prime-target pairs, F (2, 32) = 4.06, $p < .05$, $\eta^2 = .20$, MSE = 295033.03. There was no interaction between face presentation and group, F (2, 32) = 0.21, p = .81, no interaction between face presentation and age, F (2, 32) = 2.36, p = .11, and no interaction between face presentation, group, and age, F (2, 32) = 1.60, p = .22 (See Figure 4). When neutral primes were presented within blocks of trials involving whole face presentation reaction times were significantly slower than neutral primes presented in blocks of eyes and mouth only presentations, regardless of group and age. It seems that trials involving whole faces took longer overall to process, whether it was a face or a neutral prime. See Table 2 for means and standard deviations.

To further investigate the interactions, repeated measures ANOVAs (face presentation x prime-target match) were conducted within each of the four groups: older autistic, older typical, younger autistic, and younger typical children. For older autistic children, younger autistic children, and older typical children there was no effect of face presentation, no effect of prime-target match, and no interaction between face presentation and prime-target match on reaction time.

For younger typical children, there was no effect of face presentation, F (2, 8) = 0.47, p = .64, and no effect of prime-target match on reaction time, F (2, 8) = 1.71, p = .26. The ANOVA did indicate, however, a significant interaction between face presentation and prime-target match, for younger typical children's reaction time, F (2, 8) = 4.57, $p < .05$, η^2 = .53, MSE = 204396.63. Younger typically-developing children took longer to react when eyes only prime-target pairs did not match. They showed an opposite pattern, though, with mouth only trials. When mouth prime-target pairs matched, younger typical children took a longer time to react than when mouth prime-target pairs were mismatched. Mismatching eye prime-target pairs seemed to produce some interference with regards to reaction time. Mismatching mouth prime-target pairs, though, seemed to produce some facilitation of reaction time scores. Thus the interactions indicate that only younger typically-developing children were influenced by the match between face primes and words (See Figure 5).

Error Analysis

In terms of the priming task error data, ANOVA analyses did not reveal any effects of group, F (1, 16) = 0.74, p = .40, age, F (1, 16) = 1.38, p = .26, or an interaction between group and age, F (1, 16) = 1.03, p = .32, on error rates.

In terms of the explicit emotion recognition task error data, ANOVA analyses did not reveal any effects of autism, F (1, 16) = 0.10, p = .76, age, F (1, 16) = 0.39, p = .54, or an interaction between autism and age, F (1, 16) = 0.00, p = 1.0, on error rates. See Table 3 for error rates.

Discussion

While both autistic and typically-developing children were matched in age and intelligence according to verbal, nonverbal, and composite IQ, the two groups differed in social functioning. Autistic children were profoundly socially impaired according to the Social Responsiveness Scale, whereas typical children displayed social functioning in the normative range. Autistic children also displayed greater severity of autistic traits according to the Autism Spectrum Quotient than typical children displayed. The two groups, therefore, were matched according to age and IQ, but differed in that autistic children were clearly more socially impaired than typical children. Any differences of scores in the priming task could then be attributed to group membership, either autistic or typical.

Overall though, no priming effects were found for either autistic or typical children regardless of age. Matching prime-target pairs did not produce faster reaction times than mismatching prime-target pairs. There was also no difference in error rates in the priming task between autistic and typical children. Error rates in the priming task were very low for every group, which may suggest that the task was too simple. Also, the lack of reaction time and error rate findings could be the result of a prime duration that was simply too long. Banaji and Hardin (1996) have emphasized the importance of automaticity to facilitate associations between prime and target within a priming task. A prime duration of one second is well above the threshold of conscious awareness, allowing ample time to process a prime and determine its relative usefulness to the task. Within one second children may have been consciously able to process faces and then discard this information as useless when it came time to judge the target words. Target words also remained on the screen until a response was made, allowing an unlimited time to process the words. Perhaps if greater demands had been imposed on children while processing target words, there would have been a tradeoff in accuracy for speed. For example, allowing children only 2 seconds to process the target word and make a subsequent judgment could have potentially produced differences in terms of error rates.

There was, however, an interaction between face presentation type and prime-target match that was apparent only for younger typically-developing children. Younger typically-developing children seemed to have been affected by face primes when processing emotional target words, although they did so inefficiently. It could be that at a young age typical children are attempting to cognitively associate emotional faces with other emotional concepts, but are not doing so efficiently. As they develop, however, typical children may use the face more efficiently, thereby diminishing any priming effects that may be evident at younger ages. Both older typical and autistic children regardless of age may have ignored faces altogether. Faces may not have been helpful to older typical children as they primed only 33% of trials. Autistic children, on the other hand, may not have processed faces as useful or not, but rather ignored faces completely regardless of their priming appropriateness. There were no effects of prime-target match or face presentation for older typical children. Also, both groups of younger children displayed high variability in reaction times, but for the older typical children this variability decreased. The same was not true for autistic children, who displayed large amounts of variability regardless of age. Perhaps face processing becomes more stable over time for typical children, but remains an idiosyncratic process for autistic children regardless of age. At older ages, face processing may become more automatic rather than effortful for typical children.

Previously, researchers have explored the idea that autistic individuals may process emotion with the help of compensatory strategies learned over years through social programs and therapies (Grossman et al., 2000; Teunisse & de Gelder, 2001). This idea of compensatory strategies being used by autistic children was not fully supported in the current research. Both younger and older autistic children demonstrated similar reaction time performances and error rates to typical children, and were not influenced by face primes or prime-target match. It may be that rather than an inability to conceptualize and associate emotional faces and words, autistic children are simply not paying attention to faces to begin with, which would lead to the current lack of a priming effect seen in this group. Autistic children may be ignoring faces and only processing words, while typical children are processing faces, deeming them useless, and then processing target words. Both proposed routes would lead groups to rely less on the influence of the face information when processing target words.

Aversion to faces in autistic children may lead to an inability to quickly process emotion in faces (Baron-Cohen, Wheelwright, & Jolliffe, 1997; Pelphrey et al., 2002; Sigman et al., 1992; Spezio et al., 2007). Therefore, activation of other associated concepts in memory is simply not possible because no emotional concept is activated in the first place. Thus two cognitive routes may differentiate emotion processing in autistic and typical children. Autistic children do not pay attention to faces and are unable to activate any other emotionally relevant information, leading to social responses that may be considered inappropriate. Typical children, on the other hand follow a developmental trajectory of face processing in that early in life faces are effortfully used to infer emotion. This process becomes more automatic with age so that faces are processed more quickly and efficiently.

The present priming task may have also imposed demands which exceed the true capabilities of processing faces for autistic children in terms of speed and accuracy. O'Connor, Hamm, and Kirk (2007) found through ERP data that autistic subjects took longer than typical subjects to process faces. This delay did not occur while processing objects. Ashwin, Wheelwright, and Baron-Cohen (2006) also found that autistic individuals took longer to process emotion in faces as opposed to categorizing objects. The current priming task presented primes for one second. Future studies could vary this prime presentation time to examine the relative attention paid to faces by autistic children. If autistic individuals simply take longer to process faces then priming effects might be seen when the prime presentation time is extended. Older typical individuals may process the face so quickly that it becomes useless in terms of facilitating or inhibiting categorization of words, and therefore a priming effect may not be found with extended prime presentation times.

Schultz et al. (2000) found that when viewing faces, autistic individuals tend to activate the area of the brain that is normally activated when viewing objects in typical individuals. This suggests that autistic individuals process the face like an object. It could be that autistic individuals take longer to process emotion in faces because they first activate the face like an object and then must process the stimuli as a face while extracting emotion from it. In addition, autistic individuals may be using some other form of compensatory mechanism that does not rely on the face to make up for their inability to process emotion in faces. This would support findings that autistic individuals take longer to process emotion in faces because they follow a different cognitive route than do typical individuals. Future studies could incorporate objects as well as faces into an emotional priming task with varying prime presentation speeds to further delve into this speed of processing. In addition, researchers could vary the usefulness of the primes with the idea that objects might be more useful to autistic individuals, whereas faces would be more useful to typical individuals in processing socially emotional targets. Also, using emotional faces as primes as well as targets could be more useful and produce some facilitation or inhibition in a future priming task. Similarly, differences between autistic and typical participants may be seen if objects are incorporated as primes and targets into a priming task. Autistic individuals may be able to process objects more quickly, whereas typical individuals may be able to process faces more quickly. Varying the prime presentation speeds of object and face primes could help to uncover how useful these stimuli are to each group. In real life, facial expressions change rapidly, sometimes within hundredths of a second. Varying prime presentation speeds would be necessary to tap into this idea that face processing can become automatic over time. This may be particularly relevant for typical children who may demonstrate a developmental trajectory of face processing.

Flaws in the current research should be considered before designing another priming study using face primes and word targets. The very small sample size of each of the four groups makes it difficult to interpret patterns in results and results should be treated with caution. Future studies would benefit from having larger groups and by making a uniform diagnosis of autism within each group. The current study included High-Functioning Autistic (HFA), Asperger's Syndrome (AS), and Pervasive Developmental Disorder Not-Otherwise-Specified (PDD-NOS) children. Although all three diagnoses fall under the Autism Spectrum, it is important to consider the individual characteristics of each that may influence results. As seen in Table 2, the small sample produced a large amount of variability in reaction times. Concentrating on one diagnosis of either HFA, AS, or PDD-NOS may reduce the amount of variability in scores and lead to a different pattern of findings.

In general, the priming task did not work, and therefore no differences between autistic and typical individuals can be accurately drawn. Future researchers may consider varying prime duration and incorporating different prime stimuli to produce a priming effect. It is important though, to first establish an effective methodology for typical participants first, before administering such a task to autistic individuals. If the priming task does not work in typical individuals, then administering it to special populations and drawing conclusions from any differences found between groups would be invalid.

Although the current study's findings must be considered with caution, some conclusions can be inferred. In conjunction with findings from O'Connor, Hamm, and Kirk

(2005), I did not find any differences in explicit emotion recognition between autistic and typical children. However, according to the SRS, autistic children are profoundly more socially impaired than their typical counterparts. It could be that when asked to explicitly pay attention and name emotion in faces that autistic and typical children do not differ. However, in a priming task that quickly presents faces as primes it could be that autistic children simply choose not to pay attention to the face. This may be done as a coping mechanism to combat any discomfort that emotional faces cause in autistic children. Since they are not able to quickly and efficiently process faces they simply pay no attention to them at all. This is not to suggest that autistic children are consciously choosing not to process faces, but rather that faces are inherently difficult and somewhat unimportant to the autistic individual's processing of his or her world.

In general, it is of interest to note that younger typical children were affected by the face presentation and whether or not the face matched the target word. This would imply some emotional activation and association of faces with other concepts in memory. These effects were not seen at older ages in typical children, indicating some sort of developmental trajectory of face and emotion processing. What is most interesting, however, is that no effects were seen across the board for autistic children, further supporting the idea that autistic individuals show a specific aversion from processing emotion in faces. Future intervention and therapy research should as a first step consider the autistic child's aversion to faces. Once attention is learned and regulated enough to be able to accurately perceive and recognize the face as emotional, then the autistic child can delve further into processing emotion. This could potentially ameliorate some of the inappropriate social affect and difficulty in social interactions for autistic children.

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Table 1

Descriptive data measures between older/younger typical/autistic participants

	Autistic		Typical	
Measure	Younger	Older	Younger	Older
Chronological Age	8.76(1.06)	14.05(2.09)	8.80(0.83)	13.52(2.30)
Verbal IQ	106.40(18.93)	113.20(18.51)	112.20(18.51)	109.20(24.28)
Nonverbal IQ	106.60(21.23)	100.20(16.23)	106.80(24.04)	96.40(8.20)
Composite IQ	107.40(22.94)	108.00(19.66)	111.00(22.17)	103.20(15.82)
SRS Total*	119.20(26.24)	104.40(14.48)	10.60(7.09)	20.80(13.42)
AQ Total*	100.20(14.75)	109.20(17.44)	34.80(19.89)	33.60(18.26)

SRS = Social Responsiveness Scale; AQ = Autism Spectrum Quotient; * $p < .05$

Table 2

Reaction time data between older/younger typical/autistic participants

Face Presentation/ Prime-Target Match	Autistic		Typical	
	Younger	Older	Younger	Older
<u>Match</u>				
Eyes	1099.67(402.48)	923.86(826.82)	1194.92(222.39)	700.97(74.17)
Mouth	1127.57(504.91)	683.45(301.86)	1211.99(378.41)	689.48(112.40)
Whole	1089.93(300.51)	735.37(386.30)	1219.60(424.61)	662.58(71.87)
<u>Mismatch</u>				
Eyes	1168.133(355.91)	726.73(319.03)	1218.73(251.38)	684.42(83.41)
Mouth	1094.82(336.56)	685.50(278.82)	1000.55(238.99)	679.62(113.28)
Whole	1195.00(532.37)	822.44(497.58)	1254.45(436.91)	683.30(90.57)
<u>Neutral</u>				
Eyes	1024.10(333.68)	687.10(206.13)	1088.10(317.23)	648.60(53.09)
Mouth	1024.50(298.03)	633.00(222.67)	1078.40(345.28)	677.70(99.03)
Whole	1219.10(671.29)	795.10(450.58)	1629.50(909.86)	628.00(56.34)

Table 3

Error data in percentages between older/younger typical/autistic participants

	Autistic		Typical	
Type of Error	Younger	Older	Younger	Older
Explicit Emotion Recognition	19%	16%	18%	15%
Priming	5%	5%	8%	2%

Figure 1. Example of whole face, eyes only, and mouth only prime stimuli.

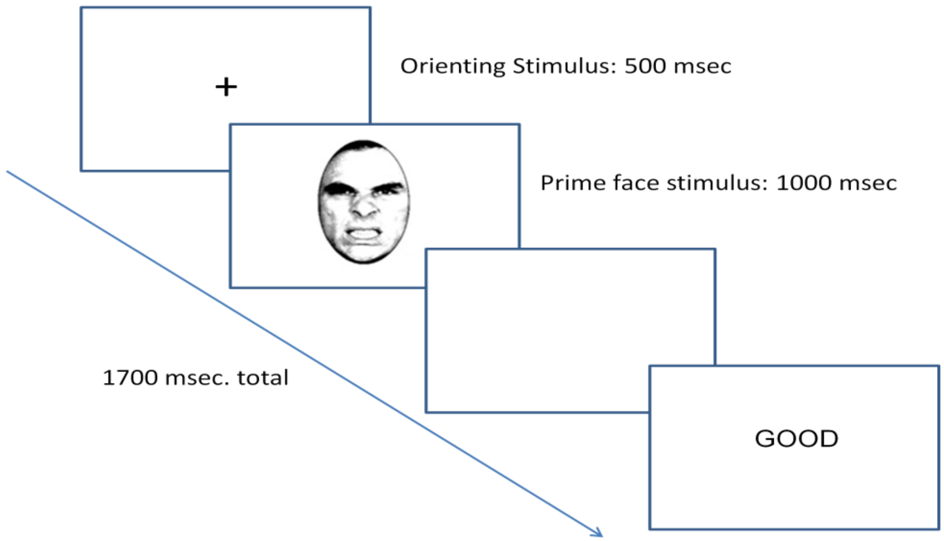

Figure 2. Example of priming task sequence.

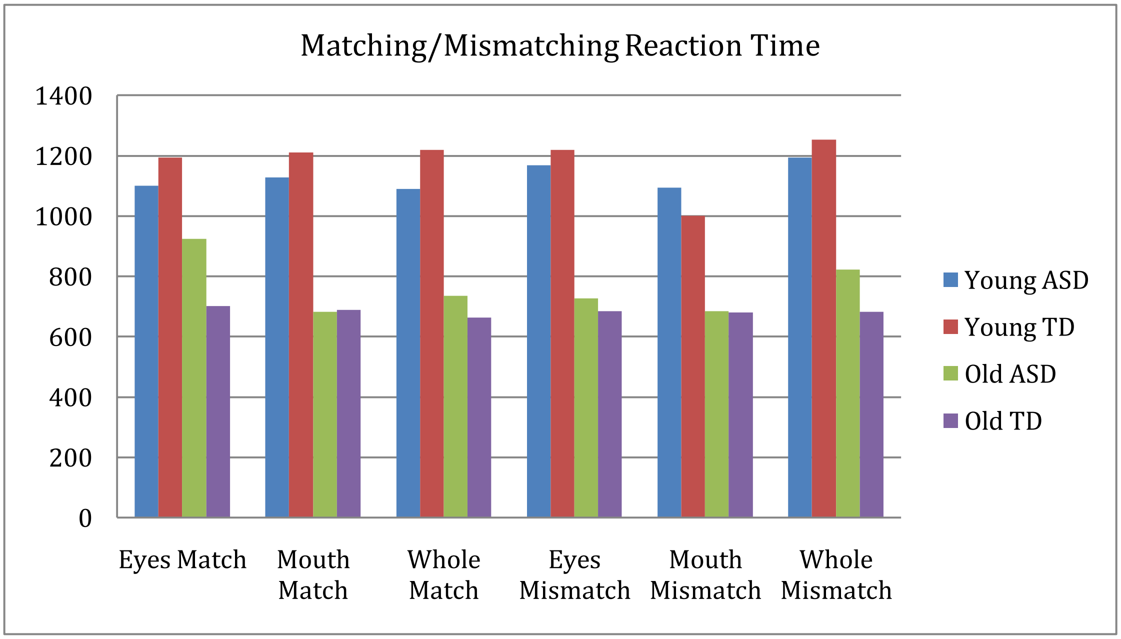

Figure 3. Reaction time data demonstrating no priming effects but a main effect of age.

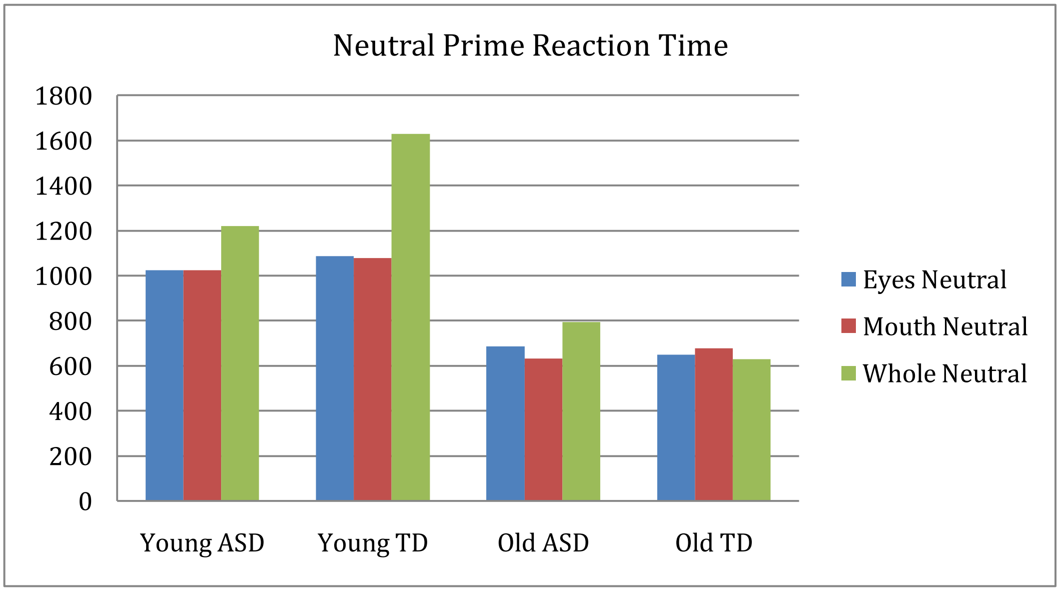

Figure 4. Neutral prime reaction time data.

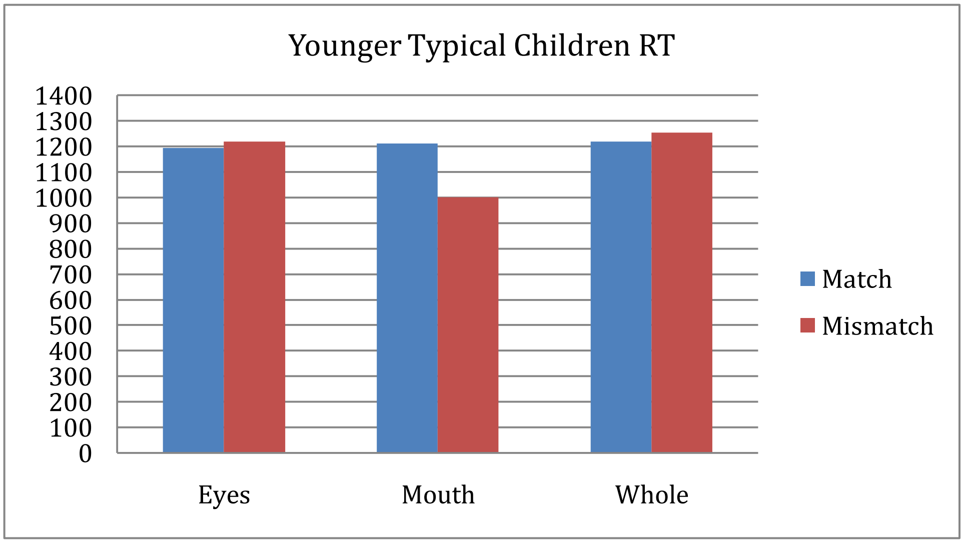

Figure 5. Reaction time data for younger typical children.

Appendix A

Positive Words

Great

Love

Lucky

Joyful

Sweet

Wonderful

Awesome

Amazing

Super

Appendix B

Negative Words

Rejected

Depressed

Terrible

Miserable

Shame

Horrible

Suffering

Awful

Sorrow