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Matching Emotions Across Visual and Auditory Modalities in Children with Autism

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Abstract

Previous literature suggests that children with autism display a difference in recognising emotions, typically showing a unique pattern of processing, which can appear as a deficit in emotion recognition ability. These studies tend to be unimodal, which makes conclusions as to the location of these differences difficult. The current study presents an attempt to determine where autistic people differ in the emotion recognition process, and whether a higher-level processing difference, or many distinct modality-specific lower-level differences are responsible for modulating performance. It also aims to unpack what other elements could influence performance, such as age and gender. This was tested by assessing the performance of autistic (N = 29) and typically developing children (N = 74) to label and match emotions presented both visually and audibly. The autistic group showed no general impairment for the tasks, but each task had unique, significant emotion specific differences, these cannot be explained fully by any single theory currently, suggesting multiple factors play a small but distinct role in the effect of autism on emotional recognition. Furthermore, the autistic group demonstrated a strong, significant correlation for task performance across modalities which was not found in the typically developing group, suggesting the presence of a higher-level processing difference, possibly caused by changes to the amygdala. No gender differences were observed in any task or group, but a non-significant effect of age was observed in the multimodal matching task only, suggesting a developmental delay. Future suggestions of research, limitations of the methodology, and the implications of these findings are discussed.

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Introduction

Definitions

Autism is a single condition defined by two key criteria: “Persistent deficits in social communication and social interaction across multiple contexts” and “Restricted, repetitive patterns of behaviour, interests, or activities”. The former can cause difficulties in day to day life such as: a failure to initiate or respond to social interactions, reduced sharing of interests and emotions, a lack or reduction in nonverbal expression and difficulty forming, maintaining and understanding relationships (American Psychiatric Association, 2013).

One way this deficit in social communication can manifest in autism is a difficulty in recognising emotions in others, through face, voice, or body language (Uljarevic & Hamilton, 2013). Recognising emotions through these senses is crucial for effective social communication, as it enables the individual to effectively gauge other people’s intentions and reactions, as well as helping them gain important data that might not otherwise come across through words alone, such as sarcasm.

Speech is one way in which people communicate emotional information (Banse & Scherer, 1996). Communication via speech consists of more than words, it also conveys information through tone, stress, quantity, and others, these suprasegmental aspects of speech form prosody (Hirst & Cristo, 1998, Chapter 1). Affective prosody is how emotion is communicated non-verbally through speech and is the focus for this current study. Variances in these lower level qualities need to be detected for emotion to be conveyed through speech.

Visual emotion recognition is processed in a similar way, with emotional information being conveyed by subtle changes in the components of a face such as the mouth or eyes. This emotional processing appears to occur in a distinct pathway, separate from face processing as TMS (Pitcher, Garrido, Walsh & Duchaine, 2008) and lesion (Adolphs, Damasio, Tranel, Cooper & Damasio, 2000) and behavioural (Globerson, Amir, Kishon-Rabin & Golan, 2014) studies have all found a specific impairment to emotion recognition in faces, without a corresponding drop in other high level non-emotional face recognition, supporting a distinct emotion recognition impairment.

This emotional data from multiple sensory inputs is integrated early on and automatically in emotional processing. Once integrated, these different modalities can then influence each other (Vroomen, Driver & Gelder, 2001). Integrating multiple sensory modalities appears to cause an improvement in the recognition of emotions, both in speed and accuracy. This improvement is greater than if multiple unimodal stimuli were processed separately (Larocci & McDonald, 2006), suggesting this increase is due to the effect of integration (Kennedy & Adolphs, 2010).

If multiple sensory modalities are impaired in similar ways in autism, then a shared emotion processing system is a likely candidate for a cause of this impairment. However, if an impairment is found exclusively in one modality across emotional and non-emotional stimuli then it is possible, what is being observed, is not an emotional recognition deficit but is instead a deficit in the processing abilities of a particular modality. If multiple modalities are not included in a study, then it is more difficult to isolate the cause of this impairment.

Failure to recognise emotions in others can be a barrier to social acceptance (Trevisan & Birmingham, 2016). Elucidating the nature and source of this impairment, as well as how it manifests in autism, could help in developing the best course of action to help mitigate a deficit and improve quality of life for many.

General Emotion Recognition Deficit in Autism

A cross-modal emotional recognition difficulty has been commonly observed in autism (Uljarevic & Hamilton, 2013), and this difference cannot be explained by differences in non-emotional processing (Matsumoto et al., 2016; Globerson et al., 2014). Specifically, autism has been found to correlate with an overall decrease in performance on auditory emotional recognition tasks (Globerson et al., 2014; Rosenblau, Kliemann, Dziobek & Heekeren, 2017; Pickles et al., 2010; Golan, Sinai-Gavrilov & Baron-Cohen, 2015; Linder & Rosén, 2006; Phillip et al., 2010; Oerlemans et al., 2013; Doi et al., 2013; Wang & Tsao, 2015) and visual emotional recognition tasks (Globerson et al., 2014; Evers, Steyaert, Noens & Wagemans, 2015; Ma, Zhu & Xie, 2015; Lacroix, Guidetti, Rogé & Reilly, 2014; Song & Hakoda, 2018; Fridenson-Hayo, 2016; Kennedy & Adolphs, 2010; Lozier, Vanmeter & Marsh, 2014; Oerlemans et al., 2013; Doi et al., 2013; Golan, Gordon, Fichman & Keinan, 2017; Wingenbach, Ashwin & Brosnan, 2017). However, this effect was not found in all studies in either prosody (Eigsti, Schuh, Mencl, Schultz & Paul, 2011; Grossman, Bemis, Skwerer and Tager-Flusberg, 2009; Heikkinen et al., 2009; Pickles et al., 2010; Brennand, Schepman & Rodway, 2011) or visual modalities (Evers et al., 2014; Castelli, 2005; Grossman, Klin, Carter & Volkmar, 2000; Gepner, Deruelle & Grynfeltt, 2001) and there is a large degree of variance, both across papers and within autistic samples, making conclusive statements difficult.

Uljarevic & Hamilton (2013), a meta-analysis, collated data from 48 papers which investigated facial emotion recognition in autism and found that for autistic people, there was an overall decrease in facial emotion recognition performance even after publication bias had been corrected for (mean effect size of 0.41). However, happiness was found to be only marginally impaired overall in this meta-analysis, suggesting the impairment is not uniform. There was also a significant amount of heterogeneity across the studies included.

The Effect of Autism on Multimodal Emotion Recognition

This effect has also been observed when the emotional recognition ability of the same sample was tested across multiple modalities (Fridenson-Hayo, 2016; Charbonneau et al., 2013). When a second modality is included in experiments, both autistic and typically developing groups improve in their performance, but autistic people do not reach the same accuracy or speed as typically developing people (Golan, Gordon, Fichman & Keinan, 2017; Kennedy & Adolphs, 2010). Furthermore, the increase in performance between unimodal and multimodal stimuli was significantly less in autism (Charbonneau et al., 2013; Kennedy & Adolphs, 2010). It has been suggested that this could be due to an additional deficit to integration in autism (Smagt, Engeland & Kemner, 2007), something which would be supported by weak central coherence theory, which posits that autistic people over focus on details and struggle with integrating information (Silva, Da Fonseca, Esteves & Deruelee, 2015).

Comparing Performance Across Modalities

By comparing emotion recognition performance in autism across multiple groups it is possible to gain an insight into which areas are most responsible for the emotion recognition impairment. If the impairment manifests in all modalities and the pattern of impairment is the same, then it is possible that the processes which are shared across all modalities are responsible. This deficit was found across modalities in Globerson et al. (2014). Globerson et al. (2014) tested the emotion recognition abilities of 20 male adults with autism for both visual and auditory modalities, as well as equivalent non-emotional tasks. This study found that autistic people were significantly worse on both vocal and facial emotion recognition compared with control groups. Furthermore, performance in a facial emotion recognition task predicated performance on an auditory emotion recognition task, only in autism. This suggests that the difference in performance in both modalities may be linked in autism, in a way it is not in typically developing people. Globerson et al. (2014) did not find these correlations with similar, non-emotional recognition tasks, suggesting the differing area is located in a cross-modal emotion processing centre.

Specific Emotional Differences

The potential emotion recognition deficit might not affect all emotions equally, some emotions may be more impaired than others, compared to the typically developing population. When these differences between emotions are examined, differences tend to be found, but which emotions are specifically impaired in autism is highly heterogenous across studies. For facial emotion recognition, anger, fear and sadness are most frequently found to be more impaired in autism than the other emotions (Evers et al., 2015; Lacroix et al., 2014; Tsang, 2018; Uljarevic & Hamilton, 2013; Boraston, Blakemore, Chilvers & Skuse, 2007; O'Connor, Hamm & Kirk, 2005; Pelphrey et al., 2002; Howard et al., 2000), whereas, happiness is commonly found to be the only emotion not significantly impaired in autism (Lacroix et al., 2014; Tsang, 2018; Uljarevic & Hamilton, 2013; O'Connor et al., 2005). This implies that whatever is causing this difference only affects negative or neutral valence emotions. Whether emotion recognition through affective prosody has a similar pattern is unknown, as few studies investigated these potential specific emotion deficits.

Any theory which attempts to explain why this potential emotion recognition impairment occurs in autism must be able to explain why this impairment correlates across modalities in autism. This theory must also be able to explain why this specific pattern of emotion recognition deficit occurs, and why it is unique to autism (Nuske, Vivanti & Dissanayake, 2012).

Altered Gaze Theory

One of the more compelling theories which attempts to explain this difference in emotional recognition is the theory of altered gaze and eye/mouth emotions. Faces are processed holistically in typically developing populations (Richler, Mack, Gauthier & Palmeri, 2009), but some, like Evers et al. (2014) theorise that specific emotions are eye based or mouth based, meaning that those individual components are the most important when determining which, if any emotion is present. For Evers et al (2014) 22 boys with autism and 22 boys without (aged 6-8) were asked to label photographs of faces with the correct emotion. Some of the displayed faces were hybrids of different emotions, in order to test which part of the face was used to recognise each emotion. It was concluded that happiness and disgust were found to rely mostly on the mouth whereas sadness, fear, neutral, surprise and anger were eye-based. This could potentially affect the specific pattern of deficit in autism as autistic people look less at the eyes when judging facial expressions (Kliemann et al., 2012; Tanaka & Sung, 2016; Corden, Chilvers & Skuse, 2008; Zürcher et al., 2013).

When typically developing people look at a face, eye tracking data shows an inverted triangle of fixations, focusing on the eyes and mouth. In autistic people, the pattern of fixations is far less consistent (Pelphrey et al., 2002) but some studies have found a tendency to fixate in a rough line down the centre of the face, not including the eyes, such as Tsang (2018). Tsang (2018) observed the fixation patterns of 11 autistic children (Mean age = 9.6), 15 children with autism and ADHD (Mean age = 9.7) as well as 29 control children (Mean age = 10.0) when they viewed pictures of faces. Participants were asked to label the emotions displayed by these stimuli as well as to rate the valence and intensity while eye tracking data measured the pattern of fixations. It was found that autistic children had a different pattern of fixations to the control group, following a rough line down the centre of the face rather than fixating specifically on the eyes and mouth. This may cause problems with emotional recognition for eye-based emotions such as fear, anger, sadness and surprise as autistic participants are fixating less on the most salient feature for these emotions (according to Evers et al., 2014), potentially explaining why this impairment is only present in some emotions.

Altered gaze is modality specific and unable to explain why similar patterns are found in other modalities, or why an autism-specific correlation across modalities has been observed (Globerson et al., 2014), as altered gaze relies on features specific to emotional face processing. Instead altered gaze may be an aspect of a deeper change in emotion recognition in autistic people, one which affects multiple modalities in similar ways. Such a difference would have to be cross-modal, exclusive to emotion processing, and would affect the recognition of positive valence emotions less than negative emotions.

The Amygdala Theory

The amygdala theory is another theory which attempts to explain this difference in emotional recognition found in autism, first developed by Baron-Cohen et al. (2000). This theory suggests that a difference in the amygdala is one of the primary factors influencing emotion recognition in autism, as the amygdala is involved in social processing for multiple sensory modalities, and displays stronger activation for the recognition of fear and other negative emotions (Baron-Cohen et al., 2000; Corbett et al., 2009), making a difference in the amygdala a compelling explanation for the differences found in autistic emotion recognition.

Damage to the amygdala correlates with an increased difficulty recognising all negative emotions, with the recognition of fear in particular being especially affected (Adolphs et al., 1999; Ashwin, Chapman, Colle, Baron-Cohen, 2007; Howard et al., 2000; Evers et al., 2015; Pelphrey et al., 2002; Howard et al., 2000; Baron-Cohen et al., 2000 for a review). This pattern is similar to that displayed by autistic participants (Uljarevic & Hamilton, 2013) which supports the idea that the amygdala plays a role in the emotion recognition differences in autism and could explain why negative emotions are more frequently found to be impaired in autism.

Uljarevic & Hamilton (2013) found evidence of a general deficit to all negative emotions, but fear was the only emotion that proved to be significantly worse than happiness, which was used as the baseline. The pattern from this meta-analysis matches what would be predicted by the amygdala theory. However, the evidence from this meta-analysis is far from conclusive, as many studies did not find this pattern of deficit (Kuusikko et al., 2009; Boraston et al., 2007; Jones et al., 2010; Doi et al., 2013; Wang & Tsao, 2015; Golan et al., 2017), counter to the predictions of the amygdala theory.

Furthermore, autistic people have been observed to have a decreased activation in the amygdala when viewing emotional stimuli (Rosenblau et al., 2017; Kliemann et al., 2012; Corbett et al., 2009). Baron-Cohen et al. (1999) asked adults with and without autism to match the mental state of a photographed person's eyes and compared this to a similar task, where these participants had to match the gender to the eye stimuli. It was found that the autistic participants did not activate the amygdala when looking at emotional stimuli, instead increased activation was found in the superior temporal sulcus. This possibly indicates that autistic people have developed an alternate pathway for emotion recognition as a workaround for this difference. Decreased activation of the amygdala in autism was also found to significantly correlate with performance in this study. This correlation was far less important in the control group, suggesting certain locations in the brain are being relied on more heavily for emotion recognition rather than the amygdala in autistic participants. This could be evidence of a different emotion recognition process occurs in autism or a sign that alternate strategies are being used as a workaround to compensate for a deficit. There is also evidence of a structural difference in the amygdala in autistic participants, with Grossman et al. (2000) finding an increase in cell density in the amygdala compared to the typically developing group. More differences were found in the neurological structure of the amygdala in autism (Dziobek, Bahnemann, Convit, & Heekeren, 2010) and unlike in typically developing people, the volume of their amygdala did not increase with age (Schumann, 2004), reinforcing the idea that a developmental delay is present (which will be explored later in the introduction).

The stimuli of Baron-Cohen et al. (1999) consisted of images of faces where only the area around the eyes was visible. The goal of this was to make sure participants were using this area alone to make emotional inferences. Kliemann et al. (2012) displayed face stimuli after a fixation cross, positioned so that the participants initial fixation would be on either the eyes or the mouth and asked participants to match this face to either a happy, fearful or neutral label. Counter to the findings of Baron-Cohen et al. (1999) Kliemann et al. (2012) reported an increase in activation in the amygdala. This may be due to the differences in task demands or stimuli, as participants in Kliemann et al. (2012) were not required to look at the eyes to identify the emotions they display, and most autistic participants fixated away from the eyes much sooner than non-autistic participants.

Overall this is one of the more compelling explanations for the emotion recognition differences in autism, but it also does not appear to be the only factor at play, and there may be other neurological differences in the parts of the brain responsible for social functioning which could also impact performance. Before any conclusions can be made, more research needs to be done to determine if this effect is present in all autistic people and if the observed effect is present across modalities.

The Amygdala and Altered Gaze

One possible explanation for the presence of altered gaze is that, in autism, the amygdala is being over stimulated by eyes rather than under stimulated, causing autistic people to purposely avoid fixating on eyes. For instance, when participants were made to initially fixate on the eyes, autistic participants showed higher activation in the amygdala compared to the typically developing group (Kliemann et al., 2012). Autistic participants fixated on eyes significantly less. When the initial fixation was on the eyes, they would be more likely to fixate away from the eyes than typically developing people. This shows an adverse effect to eye fixations in autistic people, that appears to correlate with activity in the amygdala. Kliemann et al. (2010) found evidence of reduced orientation to the eyes, suggesting both hypersensitivity and hyposensitivity may play a role in the performance of autistic people. Moreover, in the autistic group, the number of fixations to the eyes correlated with performance on the emotional recognition task, strengthening the hypothesis that this is one of the factors influencing emotion recognition performance in autism. Reduced orientation and avoidance behaviours need not be mutually exclusive across autism either, as Cuve, Gao & Fuse (2018), a meta-analysis of 21 eye tracking and emotional recognition studies suggests, with some autistic people displaying hypoarousal and not orienting to faces, whereas others might display hyperarousal and purposefully avoid fixating on eyes due to the high arousal they cause, but this might be due to various differences in task demands across studies, rather than differences in participants.

These findings suggest a link between this behaviour, autism and the amygdala, however, it is less clear to what extent this behaviour has on emotion recognition performance. Many facial emotion recognition tasks did not track gaze and found a deficit in disgust (Uljarevic & Hamilton, 2013) which altered gaze would predict is unaffected by the deficit in autism. Future research should attempt to observe if similar patterns of deficit occur across modalities in order to assess if altered gaze is one of the primary causes for the difference in emotion recognition processing or if it is just an effect of a more general difference changing gaze behaviour.

Decreased Sensitivity Theory

Autistic people confuse emotional stimuli with neutral stimuli more than typically developing groups, suggesting a decrease in salience for emotional stimuli overall (Eack, Mazefsky & Minshew, 2014; Wingenbach et al., 2017). It has also been found that autistic people are less sensitive to social and emotional stimuli (Kennedy & Adolphs, 2010). A decrease in sensitivity to emotional stimuli in autism could potentially explain the cross-modal emotional recognition deficit as autistic people would need a higher intensity of emotion to pass the threshold needed for accurate recognition. Overall, this would appear as a general decrease in emotion recognition ability in studies without variable intensity stimuli.

Supporting this idea, Song & Hakoda (2018) asked participants (14 autistic children with a mean age of 11.49 and 17 control children with a mean age of 11.52) to match facial stimuli with one of six basic emotions, it was found that autistic people required a significantly stronger intensity of emotions in order to accurately recognise them. Similarly, Charbonneau et al. (2013) asked 32 autistic adults and 18 typically developing adult controls to label auditory, visual and audio-visual stimuli as displaying either disgust or fear. For each correct answer the level of noise in the stimuli was increased and for each wrong answer the noise was decreased, with the aim for the participant to get an 80% accuracy rating. It was found that autistic people required a higher signal to noise ratio for accurate emotion recognition. The findings of Charbonneau et al. (2013) were further reinforced by Kennedy & Adolphs (2010), who asked 17 adult males with autism and 19 age, gender and IQ matched controls to rate emotional face stimuli for how salient each of the six basic emotions (happiness, sadness, surprise, fear, disgust, anger) were in the stimuli. They found that autistic participants rated the intended emotion as less intense and rated the unintended emotions as more intense. Kennedy & Adolphs (2010) supports Charbonneau et al. (2013) and Song & Hakoda (2018) in two distinct ways, first, it suggests that the noise in the emotion recognition signal is stronger in autism (as they rated unintended emotions as more intense) and secondly, it shows that the primary signal was diminished, which would shrink the signal to noise gap and would necessitate a higher signal to noise ratio for accurate recognition. Similar findings have been found in typically developing participants with high levels of autistic traits (Poljac, Poljac & Wagemans, 2012).

This decrease in sensitivity was also found in eye-tracking studies, with autistic people orienting to faces (Kircher, Hatri, Heekeren & Dziobek, 2010; Tsang, 2018; Kliemann et al., 2012) and other social stimuli (Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998) less than typically developing people. A similar effect was also found in voices, with autistic people being less able to notice vocal stimuli in general and changes in voice specifically, though this was not emotion specific (Blasi et al., 2015; Grice, Krüger & Vogeley, 2016; Blasi et al., 2015; Hsu & Xu, 2014).

This decrease in sensitivity is a compelling hypothesis, however, a general decrease in sensitivity to emotional stimuli alone cannot explain the lesser impairment found for happiness. Rather than being the sole explanation for this impairment, it is possible that this (and other mentioned theories) all contribute in some way, similar to what was found in Wingenbach et al. (2017). This could explain the higher heterogeneity in autism and reinforces the need for multimodal, high sample size studies to make clear this complex pattern of results found in autism.

The Effect of Age on Children with Autism

Age has commonly been found to influence emotional recognition performance in typically developing children, with a strong correlation between the two (Pons, Lawson, Harris & Rosnay, 2003). This linear development does not appear to be completely uniform for all emotions, with Lawrence, Campbell & Skuse (2015) finding no significant improvement for sadness or anger, possibly due to a skill ceiling for these emotions.

Little research has been done comparing the emotional recognition abilities of autistic children at different ages to age-matched controls (Harms et al., 2010). Harms et al. (2010) was a meta-analysis which investigated 44 studies on the effect of age on autistic children. They found that typically developing people tend to improve in their ability to recognise emotions as they age, whereas autistic children either improve at a lesser rate or are not found to significantly improve at all, suggesting a disruption in the process of learning emotion recognition abilities (Rump, Giovannelli, Minshew & Strauss, 2009; Lozier et al., 2014; Greimel, 2014; O'Connor et al., 2005).

When multimodal stimuli was included in Ozonoff, Pennington & Rogers (1990) an effect of age was observed in the autistic group (mean age = 6.4, typically developing mean age = 4.1) only in the multimodal tasks, suggesting that some process exclusive to multimodal recognition develops with age in autism, such as integration.

A lot of studies in this area which are not specifically investigating the effect of age fail to control for it, potentially explaining some of the heterogeneity found in autistic performance on emotion recognition tasks. There is also a significant amount of variation in which age ranges are studied, which needs to be considered if predictions about a specific age range are to be made, despite significantly decreasing the amount of studies available for those predictions.

Support for a deficit in facial emotion recognition for autistic children is mixed, and the studies which do find evidence for this deficit find differing developmental trajectories, further complicating this issue (Harms et al., 2010) with some finding no improvement in performance with age (Rump et al., 2019). Longitudinal research is needed in order to assess how exactly emotional recognition changes over time in autistic children (Harms et al., 2010).

The Effect of Gender on Autism

Like age, research into the effect of gender and emotional recognition for typically developing children is limited. Typically developing female children tend to perform better at emotion recognition tasks than males (Lawrence et al., 2015; Gregorić et al., 2014; Mancini, Agnoli, Baldaro, Ricci Bitti & Surcinelli, 2013; Kothari, Skuse, Wakefield & Micali, 2013; Kuusikko et al., 2009; Lawrence et al., 2015; Keshtiari & Kuhlmann, 2016). This is supported by neurological studies (Keshtiari & Kuhlmann, 2016; Yan, Zheng, Liu & Lu, 2017) and is found cross-culturally (Keshtiari & Kuhlmann, 2016) (for prosody).

To study the interaction between gender and autism, this already small pool of studies is reduced even further, making conclusive statements difficult, nevertheless, gender does appear to influence emotional recognition performance in autism, with Kothari et al. (2013) finding a visual emotion recognition deficit only in boys, though all genders showed a link between autistic traits and emotion recognition difficulties. This difference appears to be primarily due to a difference in socialisation, rather than an inherent difference in the autistic phenotype across gender (Constantino & Todd, 2003). This might be another possible factor influencing the presence and severity of an emotion recognition deficit in autism. There is often an imbalance of gender in autistic studies, and a potential effect of gender is not always checked and controlled for, potentially contributing to the heterogeneity of studies.

The Influence of Autistic Traits on Typically Developing Populations

Broader autism phenotype (BAP) is a term used to describe people that display autistic traits, but at subclinical levels. This group of people have existed in research as long as autism itself, first described in Kanner (1943), who observed that the parents of autistic children typically displayed more autistic-like traits than the parents of non-autistic children. This has been observed in more than anecdotal circumstances, with Bishop et al. (2008) finding a strong correlation between being a parent to a child with autism and an increased autism quotient score for the subscales: social skills and communication. This link was also observed in siblings of children with autism (Palermo, Pasqualetti, Barbari, Intelligente & Rossini, 2006).

While people with BAP display many autistic traits, there are some autistic traits which appear to be more consistently represented than others. For instance, social cognition differences similar to those found in autism have been found consistently in BAP, including in areas of emotion recognition, whereas executive functioning and global processing differences are found much less consistently (see Sucksmith, Roth & Hoekstra, 2011, for a review on autistic traits).

Like autism, BAP has been shown to correlate with a decrease in the ability to recognise basic emotions as well as the ability to determine 2emotion from complex social scenes (Sucksmith et al., 2011), including in parents and siblings of children with autism (Richler et al., 2009; Palermo et al., 2006). This decrease in performance scales with the strength of autistic traits, with higher scores in the autism quotient (AQ) correlating with worse emotional recognition even in subclinical populations (Poljac et al., 2012; McKenzie et al., 2018).

The combination of a genetic link between the BAP and autism and the similar pattern of deficit displayed by those who fit into a BAP lends credence to the theory that the BAP is an expression of subclinical autistic traits rather than a similar but distinct condition and should be treated as such by the literature. It also supports the idea that the emotional recognition deficit is distinctly connected to autism and autistic traits.

Summaries and Hypothesises

To summarise, autism has been found to correlate with a decrease in emotional recognition. This has been found in multiple single modalities including auditory and visual (Berggren, 2017; Charbonneau et al., 2013; Fridenson-Hayo, 2016; Ioannou et al., 2017; Rosenblau et al., 2017; Evers et al., 2015; Ma et al., 2015; Xaiver et al., 2015; Smith, Montagne, Perrett, Gill & Gallagher, 2010; Kuusikko et al., 2009) as well as when these are combined (Uljarevic & Hamilton, 2013; Globerson et al., 2014; Fridenson-Hayo, 2016; Gepner et al., 2001; Oerlemans et al., 2013; Doi et al., 2013; Golan et al., 2017; Berggren, 2017; Ioannou et al., 2017; Golan, Baron-Cohen, Hill & Golan, 2005). Because of this, it is hypothesised that the autistic group will have a significantly lower accuracy percentage on both the labelling tasks and the matching tasks, and that the impairment will be multimodal (Hypothesis 1).

While there are many theories that attempt to explain this pattern of deficit none can fully encapsulate the unique pattern found in autism. It is predicted that happiness will be far less impaired, but there may be other specific emotion differences (Hypothesis 2).

Age strongly correlates with emotional recognition in typically developing children, (Pons, Lawson, Harris & Rosnay, 2003; Lawrence et al., 2015) but this does not appear to be the case in autism (Rump et al., 2009; Lozier et al., 2014; Greimel, 2014; O'Connor et al., 2005). Furthermore, the difference between typically developing and autistic group appears to widen as age increases. It is predicted that age differences will be found, and they will interact with group, with the gap between the autistic and control groups widening as they age (Hypothesis 3).

This decrease in emotional recognition task performance is shared by those with a high score on an autism quotient (Sucksmith et al., 2011). It is predicted that a higher autism quotient score for typically developing participants would correlate with a decrease in the percentage of correct responses which participants will give on all tasks (Hypothesis 4), as autistic traits are suggested to form a continuum with clinical autism.

Methods

Participants

103 native English speakers between the ages of 3 and 11 participated in this study, 29 children with autism (24 males, five females, mean age = 8.62, SD = 1.678) and 74 typically developing children (35 males, 39 females, mean age = 6.45, SD = 2.215). The typically developing children were collected at the Summer Scientist event at the University of Lincoln in 2018 (Summer Scientist is an annual event which uses games to attract children to participate in research studies). The autistic group was recruited through Gosberton House Academy, a specialist school for pupils with special educational needs. Autistic participants were defined as those which had an official diagnosis of autism on record at the school.

The typically developing group had an average Autism Quotient (AQ) score of 4.07 (SD = 1.407). Any typically children in the typically developing group which had an AQ score of 7 removed from the group analysis.

Materials

The visual stimuli was taken from Farkas (2017) and was comprised of 14 cartoon images, two for each type of emotion (Happiness, Anger, Fear, Surprise, Sadness, Disgust and Neutral, as described in Ekman, Sorenson & Friesen, 1969) as well as neutral, with each emotion having male and one female image. This set was validated using three different pilot studies where participants had to rate each image for emotional intensity in each of the six emotions.

These visual stimuli were printed out and displayed one at a time in the visual labelling task. Participants were asked to name the emotion displayed by the image which the experimenter then wrote down for later categorisation. Once the participant had given a definite answer the next image was displayed. To prevent order effects these images were shuffled after every participant. There was no time limit for each trial.

Like the visual stimuli, the auditory stimuli consists of 14 total sounds, two for each emotion as well as neutral, with one being male and one being female and was part of a set created for Sauter, Eisner, Calder & Scott (2010). These sounds consisted of short, non-verbal utterances performed by native English speakers with no formal training. Non-verbal means that the sounds were produced by a human and had an emotional meaning associated with them but were not identifiable words. These stimuli were pilot tested so that the average recognition rate for each emotional category was 78%, which controlled for any emotion specific differences in recognition among typically developing adults.

For the auditory labelling task itself, each stimulus was presented sequentially in a randomised order similar to the presentation of the visual labelling task. Each stimulus was presented twice, once on initial presentation and once again after a short pause. For each trial the experimenter asked the participant what emotion that stimulus was and recorded the answer on an attached sheet, which listed all the auditory stimuli. The question was rephrased if needed. When the auditory stimulus was displayed, a corresponding number was shown in the top right-hand corner of the screen, to allow easy identification of the emotion and gender of the stimulus for the experimenter. There were 14 trials in total with no repetitions. Since some of the children tested were likely to be hypersensitive or hyposensitive to auditory stimuli no fixed volume was used, instead volume was adjusted as needed to be at a comfortable level for the participant. The typically developing group was not able to complete this task, so this was only used to determine if performance correlated between modalities in the autistic group.

Both labelling tasks were coded in the same way. Participants' responses were separated from the stimuli and randomised so that experimenters could not guess as to the correct response. Two experimenters then independently categorised every response into the seven emotional categories (if none of the emotions adequately fit then it was given the category "None"). Once completed, the categories given by both experimenters were compared. If both experimenters categorised a response as "none" it was removed, likewise if the categories conflicted and no consensuses could be reached. Once combined, the final categories were matched up with their original stimuli and inputted into SPSS for analysis.

The matching task is a computerised task made in SuperLab which consisted of 14 number of trials with two practice trials before them. In each trial one of the visual stimuli was displayed, which the participant had to match to one of two auditory stimuli, one of which shared the same emotion as the visual stimulus. These stimuli are the same that were used in the labelling task. First, the visual stimuli was presented, then the auditory stimuli played one after the other, with playback controlled by the experimenter. The participant's answer was recorded by pressing "S" if they said the first sound and "K" if they said the second.

The autism quotient score of typically developing participants was measured prior to the experiment by asking the parents of participants to complete the child version of the AQ-10 (Autism Research Centre, 2012), to allow the measurement of autistic traits. This questionnaire Is not a diagnostic tool but is used as a quick referral guide for specialist diagnostic assessment. If a participant scores a 6 or above on the AQ-10, then further diagnostic assessment for autism should be considered.

Procedure

Before the experiment began, the experimenter checked that the parents of the participant had completed the consent form, after this, the participant was told the aim of the study and its potential impact. The three tasks were then described to the participant. Once the participant had been given this information, they were told that they could withdraw from the experiment if they requested so. They were then asked if they wanted to continue, if they did, the first task began.

The first task participants completed was the matching task. In this task, one of the cartoon emotional images (Farkas, 2017) was displayed on the monitor and two emotional sounds (Sauter et al., 2010) were played, one after the other. The participant was then asked which of these two emotional sounds best matched the emotion displayed by the visual stimulus. Once the participant had provided an answer the experimenter would press the button corresponding to that sound, which would move the task on to the next trial. The first few of these trials were practice trials and were not recorded.

If the participant was unable to match either auditory stimuli to the visual stimuli then the researcher would rephrase the question, for example, the researcher might say: “if you felt that way which sound would you make?”. Usually, this only needed to be done once during the practice and was done carefully as to lead the participant to the right answer. There were 14 trials in total for this task and it took 5 minutes to complete.

The second task for this experiment was the visual labelling task. For this, participants were presented with the visual stimuli again, one at a time, they were then asked to label what emotion they believed each stimulus was expressing. If the participant gave a non-name descriptor of the emotion such as a sentence, then they would be asked what emotion that descriptor represented. If they could not name the emotion, then this sentence was recorded by the experimenter instead. This was repeated until all the stimuli had been presented.

The final task was the auditory labelling task. For this task the same auditory stimuli from the matching task was presented and the participant was asked to name what emotion they believed that sound represented. Each sound was played a total of two times, first, when the stimulus was initially presented and secondly after a short delay. Once the participant had provided a label for the emotion (or given a non-name example like the previous task) the experimenter recorded the given label and proceeded to the next trial. This was repeated until all the stimuli had been presented. In total, the labelling tasks took 10 minutes to complete.

Once this was completed, participants were thanked for their time and told that they performed well in the tasks. The reasons for the study and its aims were also restated.

Design

Participants were split into two matched-pair groups, based on the presence of a diagnosis of autism. They were matched on age and which version of the counter-balanced test the participant completed. The environment of the study could not be controlled as the autistic group were tested in-situ at Gosberton House Academy rather than at the University of Lincoln (where the typically developing group were tested).

For the third hypothesis a 2x3 independent group design was used, with the addition of age, grouped into ages 5-6, 7-8, and 9-10 alongside the presence of a diagnosis of autism.

For the fourth hypothesis, only the typically developing group was used. This group was split by their score on the AQ-10 test (scores ranged from 1-6).

Multiple percentage accuracy scores were calculated for each participant. These were calculated generally for each task, as well as separately for each emotion. In total each task generated 8 accuracy percentages, one for each emotion (including neutral expressions) as well as a total accuracy percentage for each task.

Accuracy for the visual and auditory labelling tasks was determined by comparing the given answer with a list of accepted answers for each displayed emotion. If the label unambiguously fitted the correct emotion then this trial was marked as correct, if not it was marked as incorrect. It was also marked as incorrect if the participant gave multiple answers or gave a label that could fit multiple emotions. Each individual emotion was measured separately for a specific emotion accuracy score and then the mean was used to form a general accuracy score.

For the matching task, percentage accuracy was recorded for each emotion separately, with the mean used for a general accuracy percentage.

Statistical Analysis

To eliminate the effect of age, participants were matched on chronological age as well as which version of the counterbalanced task the participant completed. An independent t-test was used to assess the group differences in performance for both tasks. Independent t-tests were also used to assess each emotion individually to measure any emotion specific group differences. A Pearson test of correlation was conducted to assess the effect age had on either group as well as to assess the effect AQ had on the typically developing group. Pearson's test was also used to observe correlations in performance across tasks for each group separately. Finally, the effect of gender was measured using a t-test for all tasks and groups.

Ethics

Consent forms were sent via post to the legal guardians of the autistic children attending Gosberton House Academy. Included with the consent form was an information sheet, which contained the full aims of the experiment, as well as background information on this field, and contact information of the researchers so that they could ask any follow up questions they may have.

The control group were collected as part of the summer scientist event at the university of Lincoln. Like the autistic group they were provided with a consent form and information sheet for their legal guardians to read prior to the start of the study and were given the opportunity to ask any questions they might have about the nature of the experiment.

Before the experiment began, the experimenters obtained verbal assent from the participant after explaining the true aims of the experiment. The participant was also informed that they could stop the experiment at any time for any reason with no issue. If the participant showed any signs of distress during the experiment they would be asked if they wanted to continue and reassured that they could stop the experiment if they wished.

Teachers from Gosberton House Academy were trained as experimenters for the autistic group while volunteers from the university collected data for the control group. This was done because these teachers are more experienced in detecting signs of distress in this population. This meant that they would be more likely to detect if a participant does not want to continue, even if that participant does not verbally state as much. Because of this, it was believed that they would be more able to ethically administer the experiment.

This study was approved by the University of Lincoln ethics committee via LEAS (ethics reference: 2019-Mar-0247).

Results

Initial tests

First, autism quotient score (AQ) and age were collected and tested for normality. Results from a Shapiro-Wilk's test indicated that there was a normal distribution of AQ score, but not age, because of this, parametric tests were used for examining AQ score within the research. As age was not normally distributed, non-parametric tests of correlation were used within the research.

Group Differences in the Matching and Labelling Tasks

Participants were individually matched on age as well as which version of the counter balanced tasks they completed. This was done in order to mitigate the effects of task order and age.

An independent t-test found that there was no significant difference in the scores of autistic (M = 80.6, SD = 18.5, N = 18) and non-autistic (M = 81.0, SD = 16.3, N = 21) children for the matching task; $t(37) = 0.071$, $p = .944$. There was also no significant difference in the scores of autistic (M = 62.9, SD = 24.3, N = 21) and non-autistic people (M = 72.5, SD = 19.7, N = 21) for the visual labelling task; *t*(40) = 1.40. Overall, the two groups performed similarly on both tasks, counter to the first hypothesis.

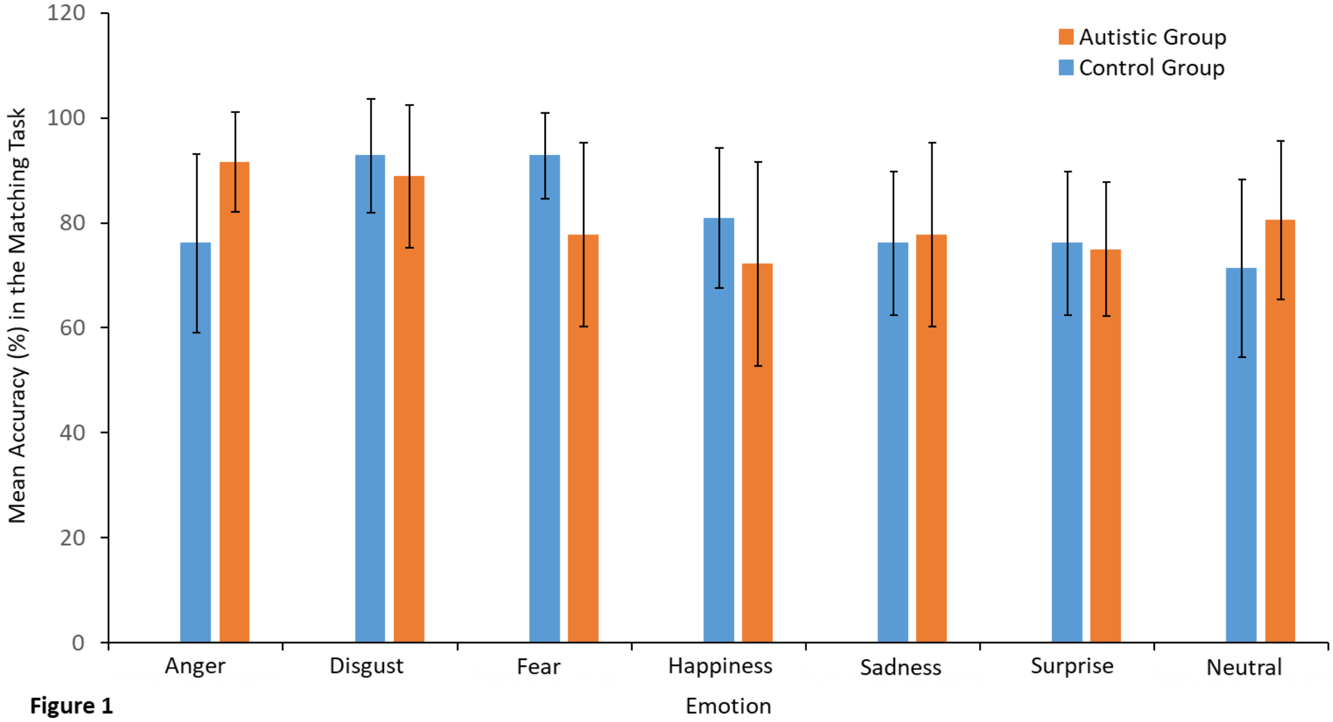

Figure 1

Mean accuracy percentage for the matching task for both groups, across individual emotions. Error Bar: 95% Confidence Interval

Group Differences for Individual Emotions in the Matching Task

Independent t-tests were used to elucidate differences between groups for each emotion. For specific emotions, group differences in the matching task were found for the recognition of fear ($t(37) = 1.72$, $p < .001$, autistic group: $M = 77.7$, $SD = 35.2$, control group: $M = 92.9$, $SD = 17.9$) and anger ($t(37) = -1.58$, $p < .001$, autistic group: $M = 91.6$, $SD = 19.2$, control group: $M = 76.2$, $SD = 37.5$). No group differences in the matching task were found for disgust ($t(37) = 0.48$, $p = .39$), happiness ($t(37) = 0.79$, $p = .10$), sadness ($t(37) = -0.152$, $p = .61$), surprise ($t(37) = 0.13$, $p = .41$) and neutral ($t(37) = -0.83$, $p = .19$). These findings support the second hypothesis and are also shown in figure 1.

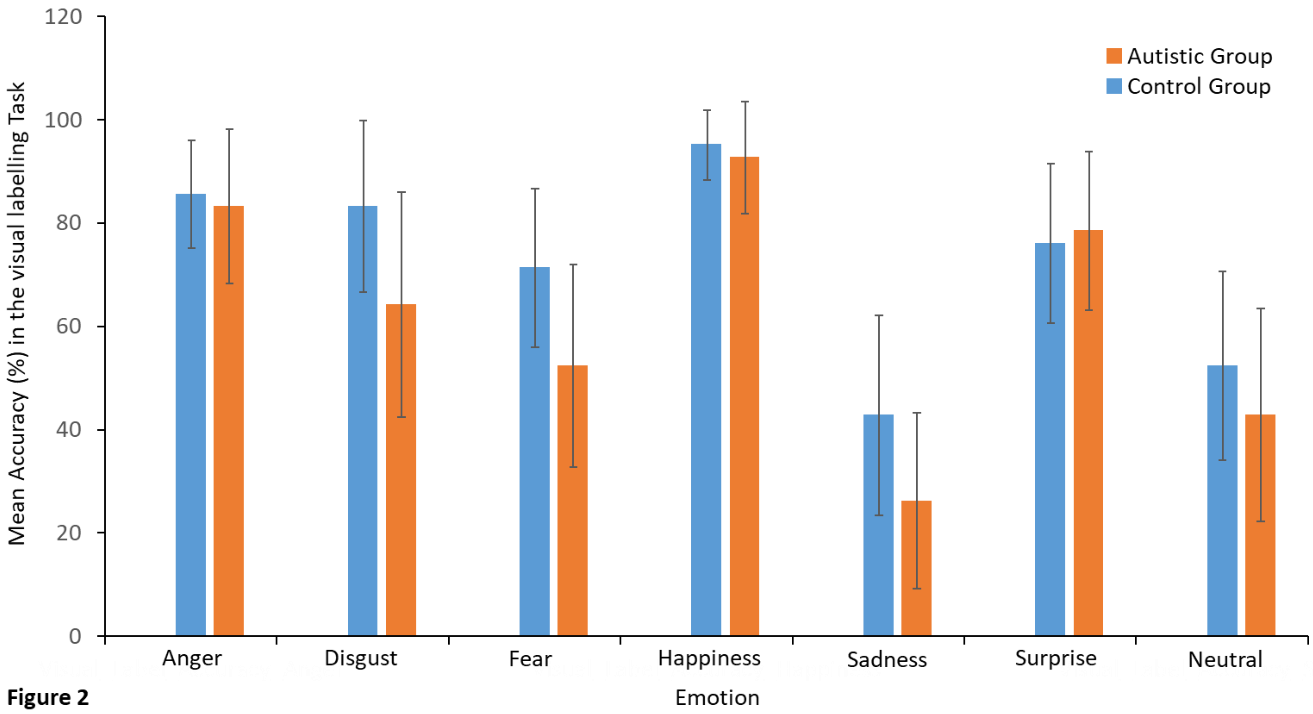

Figure 2

Mean accuracy percentage for the visual labelling for both groups, across individual emotions. Error Bar: 95% Confidence Interval

Group Differences for Individual Emotions in the Visual Labelling Task

Independent t-tests were used to examine the differences between the typically developing and autistic groups for the visual labelling task. For the visual labelling task, significant differences in performance between groups were found only for the recognition of Disgust ($t(40) = 1.45$, $p = .008$, autistic group: $M = 64.3$, $SD = 47.8$, control group: $M = 83.3$, $SD = 36.5$) where the autistic group performed worse. No significant difference were found for Anger ($t(40) = 0.27$, $p = .32$), Fear ($t(40) = 1.59$, $p = .27$), Neutral ($t(40) = 0.46$, $p = .46$), Sadness ($t(40) = 0.86$, $p = .86$), Happiness ($t(40) = 0.39$, $p = .40$) and or Surprise ($t(40) = 0.17$, $p = .17$). These findings further support the second hypothesis and, as this pattern is different to that found in the matching task, it suggests that different factors are influencing performance on both tasks and that these factors are influenced by the presence of autism. This is also shown in figure 2.

The Effect of Age on Performance and its Interaction with Autism

A Spearman test of correlation was conducted to evaluate the effect of age on performance in the matching task and the visual labelling task for both groups. For the matching task, no significant association was found between age and performance for the typically developing group ($r_s(19) = 0.19$, $p = .42$) or the autistic group ($r_s(19) = 0.30$, $p = .23$). For the visual labelling task, a significant effect of age was found for the typically developing group ($r_s(19) = 0.48$, $p = .27$) as well as for the autistic group ($r_s(19) = 0.49$, $p = .26$). From this, it can be concluded that, counter to the third hypothesis, the effect of age is task dependant and is not influenced by group.

There was a non-significant interaction between age and individual emotions in the matching task for the typically developing group, $F(7.7, 75.5) = 1.148$, $p = 0.344$, and the autistic group, $F(12, 90) = 1.189$, $p = 0.319$. There was also a non-significant interaction between age and individual emotion in the visual labelling task for the typically developing group, $F(12, 108) = 0.980$, $p = 0.472$ and the autistic group, $F(12, 108) = 1.315$, $p = 0.220$. Figures 3 and 4 also show this and suggest that this interaction may not have been observed in part due to the high performance of the participants, particularly older participants.

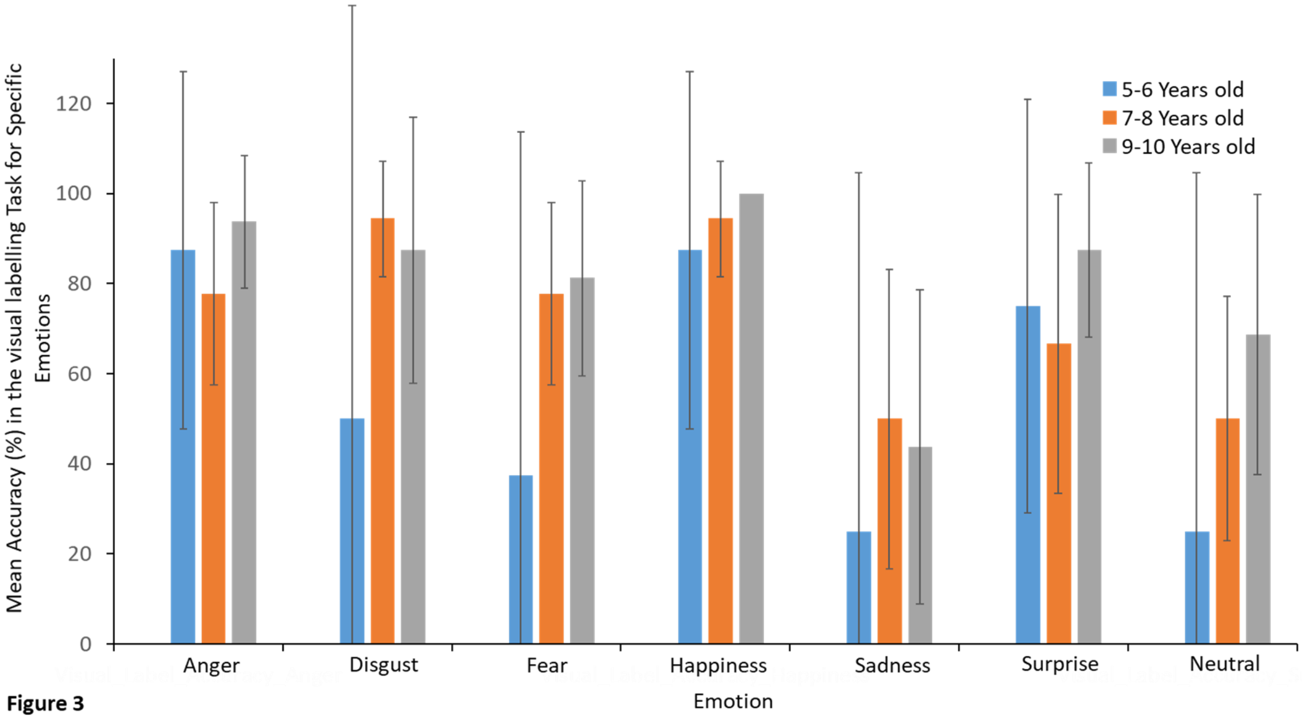

Figure 3

Mean accuracy percentage for the visual labelling task for the typically developing group, for each emotion, split by age groups. Error Bar: 95% Confidence Interval

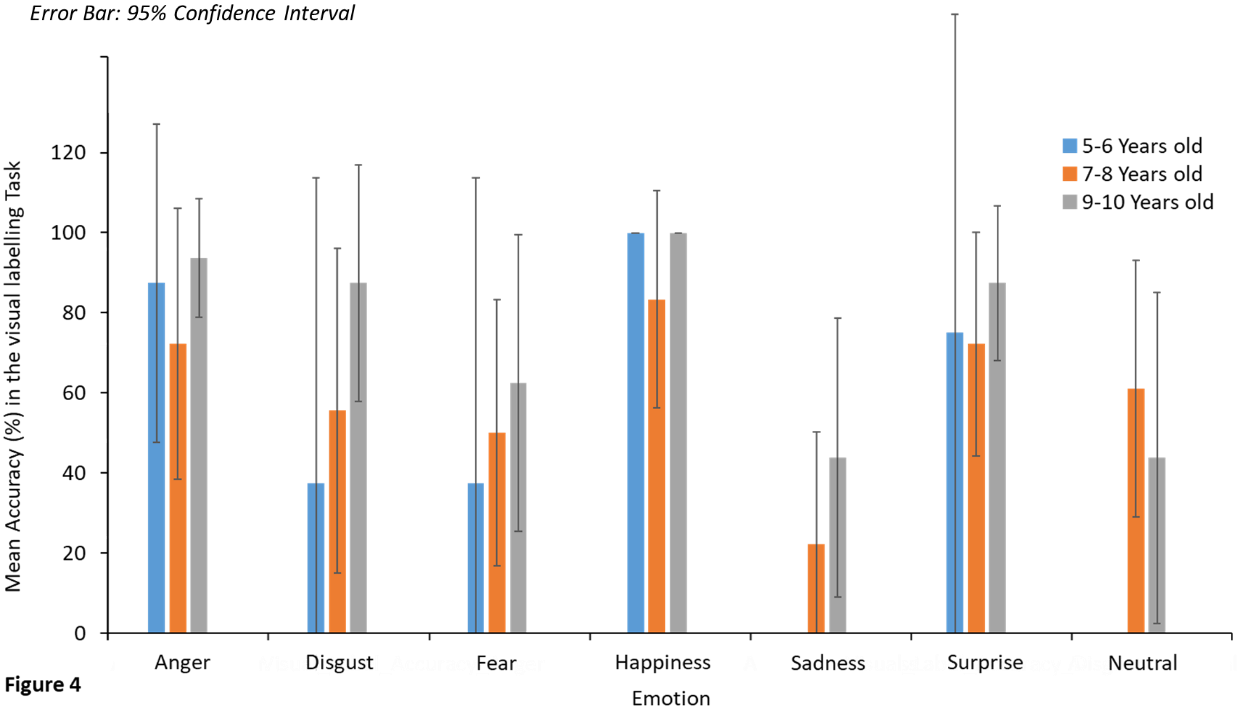

Figure 4

Mean accuracy percentage for the visual labelling task for the autistic group, across individual emotions, split by age. Error Bars: 95% Confidence interval

The Effect of Autism Quotient Score on Performance in Typically Developing Participants

A correlation between AQ score and performance for the matching task and visual labelling task was performed using the full unmatched typically developing dataset. For the matching task, a Pearson correlation found no significant correlation between overall performance on the task and AQ score ($r(65) = -.168$, $p = .181$). Whereas for the visual labelling task, results of a Pearson correlation indicated that there was no significant negative correlation between overall performance on the visual labelling task and AQ score in the typically developing group ($r(66) = -.102$, $p = .415$). This does not support the fourth hypothesis and is explored further in the discussion. Figures 5 and 6 show the relationship between AQ and performance on both the matching task and the visual labelling task.

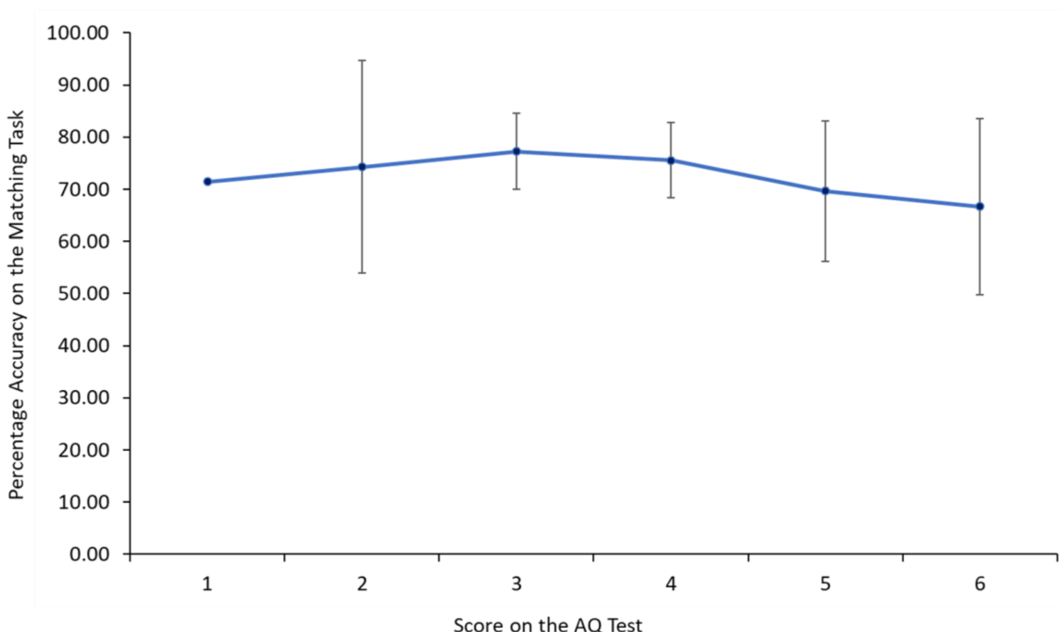

Figure 5

Mean Accuracy on the Matching Task for Typically Developing Participants Across AQ scores. Error Bars: 95% confidence interval

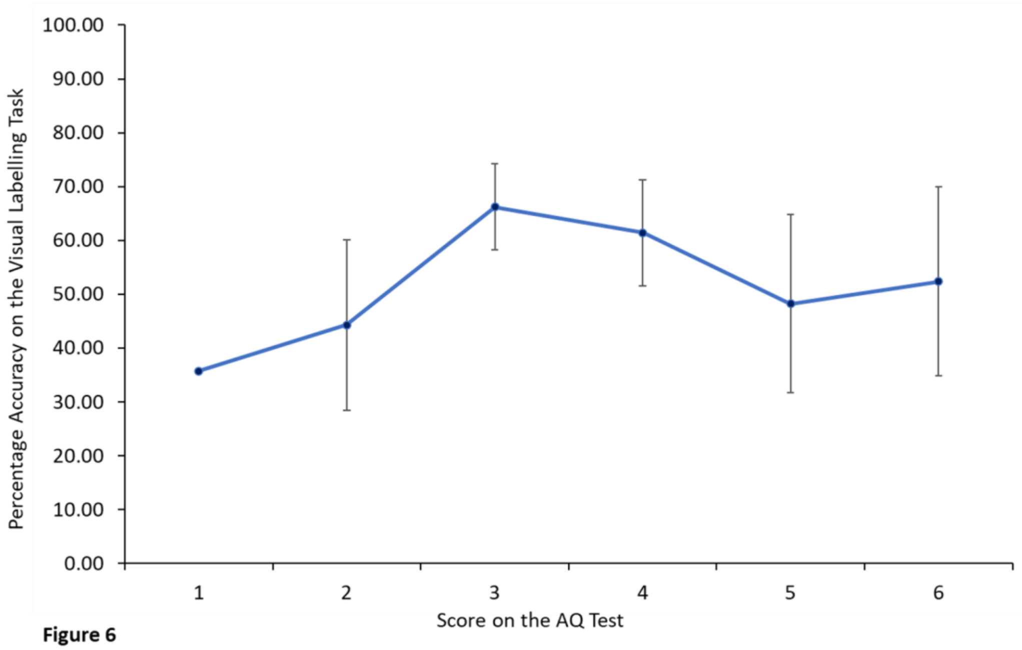

Figure 6

Mean Accuracy on the Visual Labelling Task for Typically Developing Participants Across AQ Scores. Error Bars: 95% confidence interval

The Effect of Gender

An independent t-test found that gender did not affect performance on either the matching task ($t(16) = -0.438$, $p = .0.73$), visual labelling task ($t(2.26) = --1.19$, $p = .26$), or auditory labelling tasks ($t(2.7) = -1.55$, $p = .95$) for the autistic group. Gender also had no effect on the matching ($t(16.07) = 0.377$, $p = .78$) and visual labelling task ($t(18.89) = -0.515$, $p = .290$) in the non-autistic group. These findings suggest that gender did not have an effect on the emotional recognition abilities of autistic and non-autistic participants.

Correlations Between Tasks

A Pearson test of correlation was used to evaluate the association between tasks. No significant correlations were found for the typically developing group. For the autistic group, a statistically significant correlation was found between the matching task and the visual labelling task ($r(17) = .66$, $p = .003$), the matching task and the auditory labelling task ($r(17) = .84$, $p < .001$), as well as the visual labelling task and auditory labelling task ($r(20) = .83$, $p < .001$). From this, it can be concluded that a single cross-modal factor or cluster of cross-modal factors influence performance across all tasks in the autistic group, and that this is not found in the typically developing group.

Discussion

Summary

The main aim of the present study was to investigate what aspect of emotion recognition processing is primarily responsible for the specific pattern of emotion recognition impairment frequently observed in autism. Secondly, the present study aimed to examine how age affected unimodal labelling tasks in auditory and visual domains, as well as a multimodal matching task. Finally, the effect of AQ score in typically developing participants was evaluated.

Many studies have observed that autistic people have an impairment to their ability to effectively recognise emotions (Uljarevic & Hamilton, 2013). No significant difference in emotion recognition accuracy was found between autistic and non-autistic groups for the matching task or the visual labelling task, counter to the first hypothesis.

When emotions were examined separately, distinct patterns emerged. For the matching task, a significant group difference was only found for fear and anger, whereas for the visual labelling task, an impairment in the autistic group was only present for disgust, supporting the second hypothesis.

Age has been shown to increase performance on an emotion recognition task, but this effect is lessened when autism is present (Rump et al., 2009; Lozier et al., 2014; Greimel, 2014; O'Connor et al., 2005). Age significantly correlated with performance for both groups in the matching task. No such correlations were found for the visual labelling task, challenging the third hypothesis.

It was predicted that a higher AQ score would correlate with an impaired emotion recognition ability (Sucksmith et al., 2011). For the typically developing group, a significant negative correlation was not found between performance on an AQ test, and the participants' ability to recognise emotions in the visual labelling task. On the surface, this challenges the fourth hypothesis, however, general performance was not significantly different between the two groups for either the matching or visual labelling task, so it is unlikely a correlation would be observed even if hypothesis 4 was accurate. additionally, a post-hoc analysis revealed a negative correlation between the ability to recognise happiness and score on an AQ test.

Gender has been shown to influence emotion recognition ability, however, despite prior research (Constantino & Todd, 2003; Kothari et al., 2013), the present study observed no differences between male and female participants.

Finally, Globerson et al. (2014) found evidence of a correlation between modalities in the autistic group only, suggesting a link unique to autism, which may be due to a difference in emotional recognition processing or due to a difference in a specific area involved in emotion recognition. This correlation was also found in the present study, further reinforcing this prior finding.

General Group Difference

Many studies have investigated the link between autism and a deficit to emotion recognition, but findings have been inconsistent. Overall, current research tends to conclude that there is a general emotion recognition deficit in autism, although this was not found by all studies (see Uljarevic & Hamilton, 2013 for a review) and does not seem to be universal to every autistic person (Nuske et al., 2012). Because of this, it was predicted that there would be an overall group difference in performance, with the autistic group performing significantly worse in both the matching task and the visual labelling task (Hypothesis 1).

Counter to this prediction, no group difference was found on either the visual labelling task or multimodal matching task (no group comparisons were possible for the auditory labelling task as only the autistic group completed it). This lack of difference could have a variety of possible causes, for instance, if this impairment is not universal to all autistic people (as suggested by Nuske et al., 2012) then it is a possible, if unlikely, that the collected autistic participants did not display this impairment.

Rump et al. (2009) asked 19 children with autism and 18 age matched controls to identify the emotion of a person in a video as their face shifted from the least intense version of an emotion to a more intense version of that emotion in order to assess how intense an emotion must be for participants to confidently recognise it. It was concluded that this deficit may only be present in low intensity stimuli (Rump et al., 2009). The stimuli used in the present study may have been too salient for this potential impairment in autism to be present. This may also explain the high performance in the matching task (Mean for the typically developing group: 80.95%, Mean for the autistic group: 80.56%) but not the visual labelling task (Mean for the typically developing group: 72.45%, Mean for the autistic group: 62.93%), although both tasks had participants with perfect accuracy in both groups, suggesting their performance was greater than can be measured by the tasks. Potentially, if the stimuli was too salient, this could have hidden any decreased sensitivity to emotional stimuli in autism, giving the appearance of no such deficit. Further research will need to be done to confirm this, however.

The recognition rates for emotions in the matching task were higher on average than those of the visual labelling task. This supports previous research which tends to find that participants are better able to recognise emotions in multimodal tasks compared to unimodal ones. However, counter to this research, the improvement in ability found in autism was greater than that found in typically developing populations. This appears to be due to a skill ceiling effect in the matching task as both groups performed highly accurately (autism group mean = 80.6, SD = 18.5, typically developing group mean = 81.0, SD 16.3). The skill ceiling effect occurs when performance on the task exceeds that which can be measured by the task itself. If some part of a population hit a skill ceiling in a group, then this would lower the overall mean performance from the actual value. If this potential effect is not universal (Nuske et al., 2012) the overall group difference would be reduced as some autistic participants would perform similarly to typically developing people, making the effect of a possible skill ceiling more of a factor to consider and potentially hiding differences between the two groups.

Specific Emotions in the Matching Task

Prior multimodal emotion recognition research tends to find an emotion recognition deficit for all emotions except happiness in autism, with some specific emotion differences (Doi et al., 2013; Golan et al., 2017). This pattern was also expected to appear in the present study (hypothesis 2).

Contrary to this, the autistic group displayed a deficit only in the recognition of fear and displayed a significant increase in performance for the recognition of anger. As most of the theories in this field attempt to explain the presence of a general deficit in autism, they are unequipped to explain this increase in performance for autism.

One current theory which attempts to explain this deficit is the amygdala theory, which suggests that this impairment is due to a difference in the structure of the amygdala in autistic people (Schultz, 2005). This theory predicts an impairment to fear specifically as well as a more general deficit for other negative emotions (Adolphs et al., 1999). The findings of the present study support this, as fear was found to be the only emotion impaired in autism in the matching task. However, this cannot explain the equally significant but opposite increase in performance for anger, found in the same task.

It would be expected that, if the amygdala theory were true, then the pattern associated with this theory would appear in both multimodal and unimodal tasks. This did not appear to be the case in the present study, which only found the predicted pattern in the matching task. This raises the possibility that this pattern was not the result of the amygdala but instead could be the result of the different task demands of the matching and visual labelling task. Most studies which have observed this pattern use a unimodal task, which makes it unlikely that multimodal specific task demands are responsible for the pattern suggested by the amygdala hypothesis.

Verbal ability was necessary for the visual labelling task but was not required for the matching task. Verbal IQ is frequently controlled for in similar literature (Kargas, López, Morris, & Reddy, 2016). While this may be able to potentially explain these task differences, the evidence that this could have influenced performance for the present study is inconclusive, as visual IQ could not be recorded.

Overall, autistic participants showed differences in performance on the emotional matching task, but this pattern does not effectively match the predictions of any one pre-existing theory which attempts to explain this potential impairment to emotional recognition in autism. It may be that the difference in emotion recognition found in autism has many possible causes, each affecting ability but leaving a different unique pattern of performance. A similar idea is suggested by Cuve et al. (2018) which concludes that some autistic people are hyposensitive to fixating on the eyes of another and some are hypersensitive, both cause an impairment but in different ways. If this is extrapolated to other modalities and processes it may be able to explain why the autistic population is so variable, especially in the recognition of different emotions.

Specific Emotions in the Visual Labelling Task

When previous research finds an impairment to emotion recognition in autism it tends to find that happiness is not impaired as well as finding other emotion specific deficits (Uljarevic & Hamilton, 2013; Lacroix et al., 2014; Tsang, 2018; O'Connor et al., 2005). Furthermore, some theories which seek to explain this deficit, such as the amygdala theory or the theory of altered gaze, predict that specific emotions will be harder for autistic people to recognise (such as fear for the amygdala theory or eye emotions for the theory of altered gaze). Because of this it was predicted that emotion specific deficits would be observed and that this was responsible for a more general deficit (hypothesis 2).

The present study found an impairment to emotional recognition in autism only for the recognition of disgust. This is counter to the predictions of altered gaze theory which posits that, for the emotion recognition of faces, every emotion should be impaired except for happiness and disgust. However, it is not unusual to find that the recognition of disgust is impaired in visual tasks (Lacroix et al., 2014; Tsang, 2018; O'Connor et al., 2005), although, when this specific emotional impairment is observed it is found as part of a general negative emotion impairment, which was not found in the present study.

However, a lack of support for altered gaze affecting visual emotion recognition for autism is not unheard of (Lacroix et al., 2014; Tsang, 2018; O'Connor et al., 2005; Kuusikko et al., 2009). There is a significant body of evidence to suggest altered gaze is occurring in autism, but the link between altered gaze and performance in emotional recognition tasks is less supported.

The amygdala theory would predict that all negative emotions would be impaired, but that fear recognition would be more impaired than others. While a deficit to disgust does not challenge the amygdala theory directly, a specific impairment to disgust alone does. If the amygdala plays a role in the emotion recognition differences in autism then it is not the sole factor influencing performance, as a difference in the amygdala is not predicted to cause the observed pattern. This does not appear to be due to differing task demands, as this decrease in the ability to recognise disgust was only observed in the autistic group and not in the typically developing group. Similarly, prior studies with similar methodologies and a similar age range did not find this pattern, raising questions as to the source of this disgust impairment (Rump et al., 2009; Evers et al., 2015). Like the present study, Evers et al. (2015), asked autistic children to recognise the emotions displayed by face stimuli and observed a particular difficulty in recognising disgust (alongside sadness and surprise) in the autistic group. After correcting for response bias (which was different for both groups), however, no specific emotion recognition deficits were found in the autistic group. Instead, a more general deficit to emotion recognition was observed. Potentially, this could explain the pattern observed by the present study. This finding also provides some evidence in support of the sensitivity theory, which predicts a more general decrease in performance. Future research should account for response bias in their analysis, as this may be key to understanding autism and its connection to emotion recognition.

While non-significant, autistic participants performed worse on average for every emotion except for happiness, sadness, and anger. These were the three emotions that were recognised the most accurately overall, barring disgust, which was accurately recognised in the typically developing group but not the autistic group. From this, it can be determined that high performance cannot explain why most emotions show no difference between groups and potentially implies the presence of a disgust specific deficit which was only visible in the verbal unimodal task.

Age in the Matching Task

Current research suggests that there is a developmental delay for the recognition of emotion (Lozier et al., 2014) in autism, though the exact trajectory of the development is not agreed upon. Typically, autistic people are found to improve less than typically developing people, with some finding no effect of age in autistic groups (see Lozier et al., 2014 for a review). Because of this, the third hypothesis predicted that the effect of age would be not significant in the autistic group but would be significant in the typically developing group for both tasks.

However, for the matching task no significant association between age and performance was found for either group. While this was predicted for the autistic group this finding is unexpected for the typically developing group.

While non-significant, the autistic group had a slightly stronger correlation between age and performance compared to the typically developing group, counter to predictions. This appears to be explained by the youngest group in the autistic group, which scored an average of 66% on the matching task, unlike all other groups. This itself may be evidence of a developmental delay, as it suggests that autistic participants are still developing at the ages of 5-6 whereas typically developing participants are not. This is difficult to confirm without further research, however.

Age and the Visual Labelling Task

For the visual labelling task, a significant correlation was found between age and performance for both the typically developing group and the autistic group. This finding is counter to hypothesis three, which predicted that the effect of age is altered in autism, and challenges the findings of Lozier et al. (2014), a meta-analysis of 43 studies on emotional face recognition in autistic people, which concluded that autistic people did not improve in their ability to recognise emotions from faces over time. Unlike the matching task, performance did not appear to hit a skill ceiling, as only the oldest typically developing group had a performance above 80% (mean for the oldest group: 80.36%) and there was a steady increase in the general ability to recognise emotions between the age groups.

When the effect of age was examined separately for each emotion a possible pattern emerges (figure 3, figure 4). Happiness, sadness and anger were the only emotions which do not appear to have non-significantly improved with age in either group, potentially suggesting that the development of the recognition of these emotions has fully developed, even in the youngest participants.

The autistic group performed worse on every emotion which had not plateaued. For disgust and fear, the typically developing group appear to reach a possible skill ceiling by the ages of 7-8 whereas the autistic group reach similar levels by the ages of 9-10. Together, these support the idea that a developmental delay could be a factor affecting the emotional recognition ability of autistic children. However, the high degree of variance and low sample size when participants are split into age groups weakens the foundation of this idea and suggests a need for further research into the nature of a possible developmental delay.

The Effect of Autism Quotient on the Typically Developing Group

It has been stated that the broader autism phenotype (BAP) represents a subclinical form of autism (Sucksmith et al., 2011). Because of this, the fourth hypothesis of the present study predicted that an increase in score on the AQ test would lead to a decrease in emotional recognition performance, as this impairment has been observed in autistic people (Uljarevic & Hamilton, 2013) and this negative association between score on an AQ test and emotion recognition performance has been commonly observed (Sucksmith et al., 2011; Poljac et al., 2012; McKenzie et al., 2018; Evers et al., 2015; Kadak, Demirel, Yavuz & Demir, 2014).

Counter to prior research, the present study observed no correlation between AQ score and emotion recognition ability in the visual labelling task or the matching task. This weakens the idea that there is a link between autistic traits and performance on an emotional recognition task, challenging the findings of previous studies (Sucksmith et al., 2011; Poljac et al., 2012; McKenzie et al., 2018; Evers et al., 2015; Kadak et al., 2014). Moreover, any potential link is further challenged by an absence of a negative correlation between AQ score and the ability to recognise disgust for the visual labelling task, as well as a lack of a correlation between AQ score and the ability to recognise fear or anger for the matching task, all of which were significantly different between the autistic group and the typically developing group for the respective tasks.

A slight decline in emotion recognition ability can be observed as AQ scores increase (as shown in figures 5 and 6) but was not significant. A similar non-significant trend was not observed in the visual labelling task. Together this might suggest that the link between AQ and performance only exists for multimodal tasks, but that does not appear to be the case (Palermo et al., 2006; Wallace et al., 2010). Furthermore, there were low participant numbers at the high and low end of the scale, making it difficult to conclude anything substantial about the relationship between score on an AQ test and the ability to recognise emotion, except that there was no observed link. Finally, any link between AQ score and autism would be difficult to determine using general performance on these tasks, as a significant general difference in performance was not observed between the autistic and typically developing group for either task. Without a difference in performance between autistic and non-autistic groups it is impossible to determine if participants with higher AQ scores were more like the autistic group than those with lower AQ scores.

Further research should seek to investigate if a larger range of AQ scores could influence performance on an emotion recognition task in children. It should also seek to compare the performance of autistic and typically developing people who display various levels of autistic traits, to see where, if anywhere, they diverge. It is important to confirm which elements of the BAP are contiguous with autism, to help elucidate what traits form the core of autism and to determine if these are different conditions or different expressions of the same condition. Due to the high degree of variation present in this study, it is critical that future research tests a higher number of participants, to increase the power of the study and increase the chances of detecting any possible effects of AQ score.

The Effect of Gender

Gender differences appear to be present equally, in both typically developing and autistic children, though male autistic children have some unique impairments to visual emotion recognition. (Constantino & Todd, 2003; Kothari et al., 2013). The present study observed no gender difference for either the visual labelling task or the matching task in either group. The findings of the present study challenges the observed gender differences of prior studies which investigated typically developing and autistic children. However, due to a low sample size for autistic girls, it was not possible to compare performance between autistic boys and girls or to conclude whether autistic girls displayed an impairment.

Task Correlation

Globerson et al. (2014), a previous study investigating emotion recognition in autism across modalities found a correlation for verbal emotion recognition ability and facial emotion recognition ability, but only in the autistic group. This implies autistic participants are relying more on general emotion processing areas rather than modality specific processes, perhaps because they are using a different processing method, which relies more on these general areas. Because of the findings of that study, it was predicted that a similar autism exclusive correlation would be found between the emotion matching task and visual labelling task in the present study.

Supporting the conclusions of Globerson et al. (2014), the present study found a correlation between the visual labelling task, auditory labelling task and the matching task only in the autistic group, whereas no link between the matching task and visual labelling task was observed in the typically developing group (the typically developing group could not complete the auditory labelling task). The source of this correlation is likely linked to a higher level, multimodal process that both auditory and visual modalities use when recognising emotion, as current research suggests emotion recognition across modalities is impaired.

In the autistic group, a stronger correlation was found between the auditory labelling task and the matching task, compared to the correlation between the visual labelling task and matching task. This suggests that the recognition of auditory stimuli in the matching task was more of an influence on performance than the ability to recognise visual stimuli. However, without data on the performance of the typically developing group in this auditory recognition task, it is unknown if this increased link was unique to autism.

This correlation is not present in non-emotion recognition in Globerson et al. (2014), making it likely that an area involved in high level emotion processing is linked to the difference in emotion recognition found in autism. While there is evidence to suggest a decrease in sensitivity to emotional stimuli is present in autism (Song & Hakoda, 2018; Charbonneau et al., 2013; Kennedy & Adolphs, 2010) and could theoretically be due to an difference in a high-level emotion recognition area, this would predict a flat decrease in performance across emotions, when current research, including the present study, suggests a much more uneven pattern.

The correlation found in the present study and Globerson et al. (2014) could be linked to a difference in the amygdala, which is posited to be in part responsible for the emotion recognition differences in autism. An alteration to the amygdala could act as a bottleneck, decreasing performance across all modalities and creating a stronger correlation of performance, or it could necessitate the formation of a workaround for the emotion recognition process which relies more on cross-modal processes, potentially explaining the increased correlation.

The theory of altered gaze cannot solely explain this correlation as it is specific to the visual modality. However, Kliemann et al., (2012) found a correlation between altered gaze and activation in the amygdala which suggests that altered gaze is linked to a difference in the amygdala, and hints at a possible similar behaviour change in other modalities caused by the amygdala which needs to be explored.

This theory of altered gaze also suggests that there are two different causes for the impairment to emotion recognition in autism, hyposensitivity and hypersensitivity (Cuve et al., 2018).

Hyposensitivity is predicted to cause participants to orient to the face less than typically developing people and when they do fixate on the face, it is not in the typical pattern (Cuve et al., 2018), whereas, hypersensitivity is believed to cause participants to actively avoid the eyes (Kliemann et al., 2012). This is possibly due to increased emotional content as autistic participants show increased activation in the amygdala when looking at the eyes (Kliemann et al., 2012).

This raises the question as to whether hyposensitivity and hypersensitivity can also be detected in the amygdala, as this has been linked to the differing gaze patterns. Future studies should attempt to investigate if hyposensitivity and hypersensitivity (as found in altered gaze) are present across modalities in emotion recognition and whether they are mutually exclusive.

Limitations

The present study does have some limitations which need to be addressed. Firstly, performance in the matching task was high in both groups, this appears to have created a skill ceiling effect, meaning that the present study was unable to measure the true performance of some participants. This makes it difficult to determine if there was no difference in performance between the two groups, or if the lack of a difference is due to this skill ceiling.

Secondly, typically developing participants were unable to complete the auditory task due to time constraints. This means the typically developing group could not be used as a baseline and prevented the comparison of group effects across unimodal tasks. This would have been valuable as it would have enabled the present study to investigate if those two modalities have a different pattern of deficit, which would imply multiple lower-level deficits are responsible for the emotion recognition difficulties in autism.

Finally, the conclusions that could be made from the present study on the matter of autistic traits were limited due to a lack of participants which had an especially high or low AQ score, which was exacerbated by the autistic group not being able to complete the AQ test. Because of this, the present study was not able to determine if broader autism phenotype (BAP) is contiguous with autism.

Directions for Future Research

Current research in this area tends to be focused on unimodal visual emotion recognition tasks to the detriment of other modalities. This makes it more difficult to determine if the observed effects are caused by low-level visual specific processes or if they are caused by higher-level multimodal processes. Future research should try to include similar tasks for multiple modalities to help elucidate if the pattern of deficit is different or similar across modalities. This research should also test for a correlation between the emotion recognition ability of different modalities as this will help reinforce if a single area is responsible for much of the difference.

Future research should also include lower intensity stimuli if possible. The present study elicited no group effect, however, previous research with similar age ranges found a group difference in lower intensity stimuli. This observation, combined with the high-performance rate of all participants suggests that a skill ceiling effect occurred, at least in the matching task. Using stimuli of various intensity could increase the range of ability which the task can effectively measure and allow for a more accurate view of participants' ability at this age.

Cuve et al., (2018) found that autistic participants can be split into hypersensitive and hyposensitive groups based on how they react to seeing eyes in particular. This could also be occurring in the amygdala, which would explain some inconsistencies in the research, with

Baron-Cohen et al. (1999) finding a decrease in activation in the amygdala for autism and Kliemann et al., (2012) finding an increase. Future research should seek to determine if this difference in sensitivity is present in the amygdala, and if so, how this difference influences the ability to recognise emotions.

Finally, the influence of autism on the development of emotion recognition needs to be further considered. Many studies find a lack of development in age (see Lozier et al., 2014 for a review). The present study found a non-significant increase in performance with age for both groups in the visual labelling task and found some evidence of a developmental delay in the matching task. This suggests different developmental trajectories for unimodal and multimodal recognition. Most research focuses on unimodal visual emotion recognition but in the real world, emotion recognition is typically multimodal. Because of this, it is vital that more research investigates the effect of age on multimodal tasks. It is also important to determine how the developmental trajectory is influenced in autism and to what extent it varies in the autistic population as this could potentially explain some of the heterogeneity found in the autistic population.

Conclusion

The current study presents an attempt to determine where autistic people differ in the emotion recognition process, and whether there is a single primary cause, or many distinct causes which each modulate performance. It also aimed to unpack what other elements could influence performance, such as age and gender. The autistic group showed no general impairment for either task, but had unique, significant emotion specific differences for each, these cannot be fully explained by any single theory currently, suggesting multiple factors play a role in the effect of autism on emotional recognition. Despite this, the amygdala theory seems to most accurately explain the results of the present study and other studies in this area.

The autistic group demonstrated a strong, significant correlation for task performance which was not found in the typically developing group. This suggests that either a single primary location is responsible (possibly the amygdala) for a large amount of the change of performance in autism, or that autistic people use a fundamentally different processing style which is more similar across modalities than typically developing people. Finding the source of this potential deficit is important as it will allow for a greater understanding of how the deficit manifests, what compensatory strategies are used and what steps are necessary to help reduce the effect of the impairment.

Furthermore, a non-significant developmental delay trend was observed only in the multimodal task. This difference in development between the multimodal and unimodal tasks highlights a key difference between real world emotion recognition, which tends to be multimodal, and current research, which tends to be unimodal and especially visual. This type of methodology has its benefits but can make it difficult to determine what results were due to differences in visual perception and what were due to more general emotion recognition processes. Potentially, this difference in development for unimodal and multimodal tasks highlights a limitation in current research that needs to be addressed by future studies. This could possibly be done by designing tasks more reflective of real-world emotion recognition, or by using multiple tasks which focus on different modalities, which would allow future studies to better elucidate the influence each process has on emotion recognition.

This study also found supporting evidence for a task correlation which was only present in the autistic group, supporting the findings of Globerson et al. (2014). Without multimodal research, this correlation would not have been as visible, and this potentially powerful insight may have been missed. This reinforces the need for research where the same participants are given multiple tasks across modalities, rather than only visual.

Finally, this study suggests that prior research which find a smaller volume of the amygdala do not conflict with those that find a larger volume, and instead, both may exist simultaneously in the autistic population. This could explain the differences in the findings of studies which examine the effect of autism in gaze behaviour and may offer a path to understanding the large heterogeneity in autism itself, though this remains to be seen.

If these behavioural and neurological differences in autism can be better identified then it will be easier to model how emotion recognition is different in autism, what it's strengths and weaknesses are, and how tools could be developed to help minimise the weaknesses and emphasise the strengths.

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Appendices

Appendix A – Information Sheet to Parents of Potential Participants

Information about the research

UNIVERSITY OF LINCOLN

Title of Study: Comparing autistic and non-autistic children across visual and auditory modalities
Name of Researcher(s): James Baggott, Niko Kargas

We'd like to invite your child to take part in our research study. Before you decide whether your child will participate, we would like you to understand why the research is being done and what it would involve for your child. Contact information has been provided at the bottom of this sheet if you have any questions. The study should take a total of 20 minutes to complete.

What is the purpose of the study?

It is commonly found in autism research that autistic people perform worse at recognising emotions. This has been found for emotional recognition involving either voices or faces, however, very few studies have tested both at the same time. By testing with the same people, a direct comparison can be made between emotional recognition ability involving faces and involving voices. If performance in these areas are linked, then it suggests the worse performance in autism is caused by something hearing voices and seeing faces both need, such as emotional processing. We are also collecting the participants' age, which should help clear up how that and autism effect emotional recognition. This could be a big step in our understanding of this key part of autism and how it affects the participants. A better understand of this area could also provide teachers with the tools needed to help autistic children be understood and help them understand others. The study will take place in Gosberton House Academy.

This study will also go towards the completion of a MSc in Psychology for the researcher (James Baggott).

Why have I been invited?

You are being invited to take part because your child has a diagnosis of autism. Children without autism will not be invited to take part in the study.

Do I have to take part?

It is up to you to decide whether to let your child take part.

If you do decide to let them take part, please sign the consent form provided. they are free to withdraw at any time without giving a reason. This would not affect the legal rights of your or your child. If you do not agree to let them take part, then this will not affect their education.

The data collected up to this point may still be kept.

What will happen to my child if they take part?

Your child will only be needed for the 20 minutes to complete the study. This study has three different trials. The first trial is a matching task. In this task, the child will see a cartoon face showing an emotion (examples included at the end of the document), they will also hear two vocal sounds representing one of six emotions. They will then be asked to match the emotion displayed by the image with the sound that fits that emotion. For the second task the children are presented with the same emotional images again, this time however, they are asked if they can identify the displayed emotion. The final task is similar to the second task, but the child is asked to identify the emotional sounds instead. The data from this will be compared with the data of typically developing children who completed the same tasks at the summer scientist event at Lincoln university.

Expenses and payments

Participants will not be paid to participate in the study

What are the possible disadvantages and risks of taking part?

There are no significant health risks due to the study only using sounds and images. However, if your child is especially sensitive to sound, they may not wish to take part, as some sounds may be distressing.

What are the possible benefits of taking part?

While we do not know what the outcome of this study will be the data will be highly useful in determining what part of emotional recognition autistic children tend to struggle with. Knowing where the difference lies can be valuable when developing training or therapy for autistic kids to aid in this area.

Will my child's taking part in the study be kept confidential?

Only anonymised data will be kept from the study. This includes how they answered in the labelling task, their performance in the matching task, their age, gender and information about their diagnosis.
We will follow ethical and legal practice and all information about you will be handled in confidence.

Privacy notice

The University of Lincoln is the lead organisation for this study. The university's Research Participant Privacy notice https://ethics.lincoln.ac.uk/research-privacy-notice/ will explain how we will be using information from your child in order to complete this study and will be the data controller for this study. This means that we are responsible for looking after their information and using it properly.

We will keep identifiable information about your child for 7 years after the study has finished.

What will happen if they don't want to carry on with the study?

Your child's participation is voluntary, and they are free to withdraw at any time, without giving any reason, and without their legal rights being affected. If they withdraw from the study, we will keep the information about them that we have already obtained. To safeguard their rights, we will use the least amount of identifying information possible.

What will happen to the results of the research study?

No information that could identify you or your child will be included in the final publication or in the thesis. These results will also go towards the completion of a MSc by research at the University of Lincoln.

Who is organising research?

This research is being organised by the University of Lincoln.

Who has reviewed the study?

All research in the NHS is looked at by independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given approval by the University of Lincoln Research Ethics Committee.

What if there is a problem?

If you have an issue with any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions. The researchers contact details are given at the end of this information sheet. If you remain unhappy and wish to complain formally, you can do this by contacting ethics@lincoln.ac.uk.

If you feel that we have let you down in relation to your information rights then please contact the Information Compliance team by email on compliance@lincoln.ac.uk or by post at Information Compliance, Secretariat, University of Lincoln, Brayford Pool, Lincoln, LN6 7TS.

You can also make complaints directly to the Information Commissioner's Office (ICO). The ICO is the independent authority upholding information rights for the UK. Their website is ico.org.uk and their telephone helpline number is 0303 123 1113.

Appendix B – Consent Form to Parents of Children with Autism

Project ID: 0247

Participant Identification Number for this study:

UNIVERSITY OF LINCOLN

CONSENT FORM

Title of Project: Comparing autistic and non-autistic children across visual and auditory modalities

Name of Researcher: James Baggott

Name of Participant:

Please initial box

1. I confirm that I have read the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my child's participation is voluntary and that they are free to withdraw at any time without giving any reason, without their legal rights being affected. I understand that should they withdraw then the information collected so far may not be erased and that this information may still be used in the project analysis. ☐

3. I understand that relevant sections of data collected during the study, may be looked at by individuals from the University of Lincoln, from regulatory authorities, where it is relevant to my child's taking part in this research. I give permission for these individuals to have access to their records, I understand that my child's personal details will be kept confidential. ☐

4. (If appropriate) I understand that the information collected about my child will be used to support other research in the future and may be shared anonymously with other researchers. ☐

5. I would like to receive a summary of the results of the study Yes ☐ No ☐

6. I would like to receive the full report of the study Yes ☐ No ☐

7. I agree to take part in the above study. ☐

______________	______________	______________
Name of Participant	Date	Signature
______________	______________	______________
Name of Person taking consent	Date	Signature

____

Email to send summary of the results/full report to

Appendix C – Auditory Labelling Response Sheet

Auditory Labelling Response Sheet
(Final version 1.0: 11/02/2019)

UNIVERSITY OF LINCOLN

Title of Study: Comparing autistic and non-autistic children across visual and auditory modalities
Name of Researcher(s): James Baggott, Niko Kargas

Participant number: **Participant gender:** **Participant age:**

	Label	Participant's label
1	Amused Female	
2	Amused Male	
3	Disgust Female	
4	Disgust Male	
5	Angry Female	
6	Angry Male	
7	Fear Female	
8	Fear Male	
9	Neutral Female	
10	Neutral Male	
11	Sad Female	
12	Sad Male	
13	Surprise Female	
14	Surprise Male	

Further information and contact details

Researcher

James Baggott

JBaggott@lincoln.ac.uk

Supervisor

Dr Niko Kargas

nkargas@lincoln.ac.uk

T: 01522 886861

Room: SSB3210

Appendix D – Visual Labelling Response Sheet

Visual Labelling Response Sheet
(Final version 1.0: 11/02/2019)

UNIVERSITY OF LINCOLN

Title of Study: Comparing autistic and non-autistic children across visual and auditory modalities
Name of Researcher(s): James Baggott, Niko Kargas

Participant number: **Participant gender:** **Participant age:**

	Label	Participant's label
1	Amused Panther	
2	Amused Candle	
3	Disgusted Girl	
4	Disgusted Round Face	
5	Angry Car	
6	Angry Lion	
7	Fear Teapot	
8	Fear Spongebob	
9	Neutral Car	
10	Neutral Horse	
11	Sad Cat	
12	Sad Robot	
13	Surprise Car	
14	Surprise Hyena	

Further information and contact details

Researcher

James Baggott

JBaggott@lincoln.ac.uk

Supervisor

Dr Niko Kargas

nkargas@lincoln.ac.uk

T: 01522 886861

Room: SSB3210

Appendix E – Participant Debrief Sheet

Participant Debrief Sheet

UNIVERSITY OF LINCOLN

Title of Study: Matching emotions across visual and auditory modalities in children with autism
Name of Researcher(s): James Baggott, Niko Kargas

We'd like to thank you for taking part in our research study. This research will provide crucial information and broaden our understanding of emotional recognition in autism

What was the aim of the study?
Autistic children appear to have a deficit in areas of emotional recognition, including affective prosody, which is the ability to discern emotion from spoken words sperate to the words meaning. In the general population, as well as to inspire further research into the acquisition of Theory of Mind.

Little research has been done on affective prosody recognition in autism. What has been done is contradictory. however there does seem to be a deficit in emotional processing. There also appears to be some differences in ability which are emotion specific. This appears to be the case with visual recognition as well. If performance in the two modalities correlate, then this could suggest a shared deficit in emotional processing overall rather than a specific deficit in each modality.

The aim of this study is to compare visual and auditory modalities through the matching and labelling tasks and to see if these differences are consistent across autism diagnoses.

Questions and withdrawing
If you have any further questions about the study, please feel free to ask the researcher before you finish or alternatively contact the researcher (**jbaggott@lincoln.ac.uk**) or their supervisor (**nkargas.lincoln.ac.uk**) at any time. If you wish to withdraw your data, please also contact the researcher or supervisor with your unique participant number. In cases where your participation was anonymous please contact ethics@lincoln.ac.uk with your unique participant number. Please note you will only be able to withdraw up until the point of data analysis.

Further help and support
If you have any ethical concerns regarding the current research, your treatment as a participant or your involvement in the study please feel free to contact ethics@lincoln.ac.uk.

Appendix F – Ethical Approval

Human Ethics Committee

27 March 2019

Dear James Baggott

Your application Matching emotions across visual and auditory modalities in children with autism Review ref: 2019-Mar-0247 has been given a favourable ethical opinion

Please see attached letter for confirmation of favourable ethical opinion and any conditions of approval - please retain a copy with your research data. You may also need to provide a copy of the attached letter, when submitting any journal publications.

If you have any queries please contact ethics@lincoln.ac.uk

Kind Regards

Samantha

Appendix G – Correlation across Task Perfromance for each Group

Correlations

Group			Accuracy_Overall	Visual_Label_Accuracy_Overall	Auditory_Label_Accuracy_Overall
Typically Developing	Accuracy_Overall	Pearson Correlation	1	.285	.[a]
		Sig. (2-tailed)		.211	.
		N	21	21	0
	Visual_Label_Accuracy_Overall	Pearson Correlation	.285	1	.[a]
		Sig. (2-tailed)	.211		.
		N	21	21	0
	Auditory_Label_Accuracy_Overall	Pearson Correlation	.[a]	.[a]	.[a]
		Sig. (2-tailed)	.	.	
		N	0	0	0
ASD (Autism/Aspergers)	Accuracy_Overall	Pearson Correlation	1	.662**	.841**
		Sig. (2-tailed)		.003	.000
		N	18	18	18
	Visual_Label_Accuracy_Overall	Pearson Correlation	.662**	1	.830**
		Sig. (2-tailed)	.003		.000
		N	18	21	21
	Auditory_Label_Accuracy_Overall	Pearson Correlation	.841**	.830**	1
		Sig. (2-tailed)	.000	.000	
		N	18	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Appendix H – Independent T-Test for the Matching Task, for each Emotion across Groups

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy_Anger	Typically Developing	21	76.1905	37.48015	8.17884
	ASD (Autism/Aspergers)	18	91.6667	19.17412	4.51938
Accuracy_Disgust	Typically Developing	21	92.8571	23.90457	5.21641
	ASD (Autism/Aspergers)	18	88.8889	27.41594	6.46200
Accuracy_Fear	Typically Developing	21	92.8571	17.92843	3.91230
	ASD (Autism/Aspergers)	18	77.7778	35.23961	8.30606
Accuracy_Happiness	Typically Developing	21	80.9524	29.47961	6.43298
	ASD (Autism/Aspergers)	18	72.2222	39.19117	9.23745
Accuracy_Sadness	Typically Developing	21	76.1905	30.07926	6.56383
	ASD (Autism/Aspergers)	18	77.7778	35.23961	8.30606
Accuracy_Surprise	Typically Developing	21	76.1905	30.07926	6.56383
	ASD (Autism/Aspergers)	18	75.0000	25.72479	6.06339
Accuracy_Neutral	Typically Developing	21	71.4286	37.32100	8.14411
	ASD (Autism/Aspergers)	18	80.5556	30.38425	7.16164

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Accuracy_Anger	Equal variances assumed	11.778	.001	-1.581	37	.122	-15.47619	9.78631	-35.30513	4.35275
	Equal variances not assumed			-1.656	30.710	.108	-15.47619	9.34442	-34.54157	3.58919
Accuracy_Disgust	Equal variances assumed	.772	.385	.483	37	.632	3.96825	8.21581	-12.67855	20.61506
	Equal variances not assumed			.478	34.075	.636	3.96825	8.30472	-12.90759	20.84409
Accuracy_Fear	Equal variances assumed	12.620	.001	1.721	37	.094	15.07937	8.76325	-2.67666	32.83539
	Equal variances not assumed			1.642	24.361	.113	15.07937	9.18132	-3.85511	34.01385
Accuracy_Happiness	Equal variances assumed	2.852	.100	.793	37	.433	8.73016	11.01262	-13.58352	31.04384
	Equal variances not assumed			.776	31.242	.444	8.73016	11.25672	-14.22087	31.68118
Accuracy_Sadness	Equal variances assumed	.267	.608	-.152	37	.880	-1.58730	10.45596	-22.77308	19.59848
	Equal variances not assumed			-.150	33.693	.882	-1.58730	10.58652	-23.10892	19.93431
Accuracy_Surprise	Equal variances assumed	.688	.412	.132	37	.896	1.19048	9.04595	-17.13837	19.51932
	Equal variances not assumed			.133	37.000	.895	1.19048	8.93580	-16.91519	19.29614
Accuracy_Neutral	Equal variances assumed	1.791	.189	-.828	37	.413	-9.12698	11.02015	-31.45593	13.20196
	Equal variances not assumed			-.842	36.919	.405	-9.12698	10.84507	-31.10282	12.84885

Appendix I – Independant T-Test for the Visual Labelling Task, for each Emotion across Groups

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Visual_Label_Accuracy_Anger	Typically Developing	21	85.7143	23.14550	5.05076
	ASD (Autism/Aspergers)	21	83.3333	32.91403	7.18243
Visual_Label_Accuracy_Disgust	Typically Developing	21	83.3333	36.51484	7.96819
	ASD (Autism/Aspergers)	21	64.2857	47.80914	10.43281
Visual_Label_Accuracy_Fear	Typically Developing	21	71.4286	33.80617	7.37711
	ASD (Autism/Aspergers)	21	52.3810	43.23248	9.43410
Visual_Label_Accuracy_Happiness	Typically Developing	21	95.2381	15.03963	3.28192
	ASD (Autism/Aspergers)	21	92.8571	23.90457	5.21641
Visual_Label_Accuracy_Neutral	Typically Developing	21	42.8571	42.67820	9.31315
	ASD (Autism/Aspergers)	21	26.1905	37.48015	8.17884
Visual_Label_Accuracy_Sadness	Typically Developing	21	76.1905	33.98179	7.41543
	ASD (Autism/Aspergers)	21	78.5714	33.80617	7.37711
Visual_Label_Accuracy_Surprise	Typically Developing	21	52.3810	40.23739	8.78052
	ASD (Autism/Aspergers)	21	42.8571	45.51295	9.93174

									Confidence Interval of the Difference	
									wer	Upper
Overall	assumed								4.27646	23.32408
	Equal variances not assumed			1.395	38.387	.171	9.52381	6.82818	-4.29455	23.34217
Visual_Label_Accuracy_Anger	Equal variances assumed	1.036	.315	.271	40	.788	2.38095	8.78052	-15.36514	20.12704
	Equal variances not assumed			.271	35.894	.788	2.38095	8.78052	-15.42860	20.19050
Visual_Label_Accuracy_Disgust	Equal variances assumed	7.781	.008	1.451	40	.155	19.04762	13.12767	-7.48438	45.57962
	Equal variances not assumed			1.451	37.409	.155	19.04762	13.12767	-7.54174	45.63698
Visual_Label_Accuracy_Fear	Equal variances assumed	1.229	.274	1.590	40	.120	19.04762	11.97598	-5.15673	43.25197
	Equal variances not assumed			1.590	37.802	.120	19.04762	11.97598	-5.20064	43.29588
Visual_Label_Accuracy_Happiness	Equal variances assumed	.716	.402	.386	40	.701	2.38095	6.16294	-10.07482	14.83672
	Equal variances not assumed			.386	33.689	.702	2.38095	6.16294	-10.14792	14.90982
Visual_Label_Accuracy_Neutral	Equal variances assumed	.553	.462	1.345	40	.186	16.66667	12.39468	-8.38392	41.71725
	Equal variances not assumed			1.345	39.344	.186	16.66667	12.39468	-8.39694	41.73027
Visual_Label_Accuracy_Sadness	Equal variances assumed	.033	.857	-.228	40	.821	-2.38095	10.45994	-23.52129	18.75938
	Equal variances not assumed			-.228	39.999	.821	-2.38095	10.45994	-23.52131	18.75940
Visual_Label_Accuracy_Surprise	Equal variances assumed	1.957	.170	.718	40	.477	9.52381	13.25658	-17.26874	36.31636
	Equal variances not assumed			.718	39.408	.477	9.52381	13.25658	-17.28129	36.32891

Appendix J – Spearman's Test of Correlation between Age and Performance

Correlations

	Group			Age in years	Accuracy_Overall	Visual_Label_Accuracy_Overall
Spearman's rho	Typically Developing	Age in years	Correlation Coefficient	1.000	.185	.481*
			Sig. (2-tailed)	.	.422	.027
			N	21	21	21
		Accuracy_Overall	Correlation Coefficient	.185	1.000	.414
			Sig. (2-tailed)	.422	.	.062
			N	21	21	21
		Visual_Label_Accuracy_Overall	Correlation Coefficient	.481*	.414	1.000
			Sig. (2-tailed)	.027	.062	.
			N	21	21	21
	ASD (Autism/Aspergers)	Age in years	Correlation Coefficient	1.000	.296	.486*
			Sig. (2-tailed)	.	.233	.026
			N	21	18	21
		Accuracy_Overall	Correlation Coefficient	.296	1.000	.654**
			Sig. (2-tailed)	.233	.	.003
			N	18	18	18
		Visual_Label_Accuracy_Overall	Correlation Coefficient	.486*	.654**	1.000
			Sig. (2-tailed)	.026	.003	.
			N	21	18	21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix K – Correlations between Tasks and AQ in the Typically Developing Group

Correlations

		AQ_Overall_Score	Accuracy_Overall	Label_Accuracy_Overall
AQ_Overall_Score	Pearson Correlation	1	-.168	-.102
	Sig. (2-tailed)		.181	.415
	N	66	65	66
Accuracy_Overall	Pearson Correlation	-.168	1	.506**
	Sig. (2-tailed)	.181		.000
	N	65	71	71
Label_Accuracy_Overall	Pearson Correlation	-.102	.506**	1
	Sig. (2-tailed)	.415	.000	
	N	66	71	72

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix L – Indepentant T-Test for the Effect of Gender, across all Tasks and Groups

Independent Samples Test

			Levene's Test for Equality of Variances		t-test for Equality of Means						
										95% Confidence Interval of the Difference	
Group			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Typically Developing	Accuracy_Overall	Equal variances assumed	.083	.776	.377	19	.710	2.77833	7.36501	-12.63682	18.19348
		Equal variances not assumed			.370	16.073	.716	2.77833	7.50532	-13.12637	18.68303
	Visual_Label_Accuracy_Overall	Equal variances assumed	1.182	.290	-.515	19	.613	-4.56349	8.86382	-23.11569	13.98870
		Equal variances not assumed			-.532	18.891	.601	-4.56349	8.57192	-22.51176	13.38478
ASD (Autism/Aspergers)	Accuracy_Overall	Equal variances assumed	.119	.734	-.438	16	.667	-5.23810	11.96651	-30.60596	20.12977
		Equal variances not assumed			-.456	2.978	.680	-5.23810	11.48512	-41.94127	31.46508
	Visual_Label_Accuracy_Overall	Equal variances assumed	1.354	.259	-1.191	19	.248	-17.85714	14.98979	-49.23113	13.51684
		Equal variances not assumed			-.850	2.276	.475	-17.85714	21.01412	-98.53452	62.82023
	Auditory_Label_Accuracy_Overall	Equal variances assumed	.004	.950	-1.546	19	.139	-22.22222	14.37132	-52.30174	7.85730
		Equal variances not assumed			-1.551	2.720	.228	-22.22222	14.32715	-70.59613	26.15169

Appendix M – Correlation across Task Perfromance for each Group

Correlations

Group			Accuracy_Overall	Visual_Label_Accuracy_Overall	Auditory_Label_Accuracy_Overall
Typically Developing	Accuracy_Overall	Pearson Correlation	1	.285	.[a]
		Sig. (2-tailed)		.211	.
		N	21	21	0
	Visual_Label_Accuracy_Overall	Pearson Correlation	.285	1	.[a]
		Sig. (2-tailed)	.211		.
		N	21	21	0
	Auditory_Label_Accuracy_Overall	Pearson Correlation	.[a]	.[a]	.[a]
		Sig. (2-tailed)	.	.	
		N	0	0	0
ASD (Autism/Aspergers)	Accuracy_Overall	Pearson Correlation	1	.662**	.841**
		Sig. (2-tailed)		.003	.000
		N	18	18	18
	Visual_Label_Accuracy_Overall	Pearson Correlation	.662**	1	.830**
		Sig. (2-tailed)	.003		.000
		N	18	21	21
	Auditory_Label_Accuracy_Overall	Pearson Correlation	.841**	.830**	1
		Sig. (2-tailed)	.000	.000	
		N	18	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.