The Role of Autistic Traits in the Perception of Emotion from Faces and Voices: a Behavioural and fMRI Investigation

Peipei Liu

Submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy

School of Education

College of Social Science

University of Glasgow

January 2018

Abstract

This thesis combined behavioural and fMRI approaches in the study of the role of autistic traits in the perception of emotion from faces and voices, addressing research questions concerning: behavioural recognition of a full range of six basic emotions across multiple domains (face, voice, and face-voice); neural correlates during the processing of a wide range of emotional expressions from the face, the voice and the combination of both; neural circuity in responding to an incongruence effect (incongruence vs. congruence).

The behavioural study investigated the effects of autistic traits as quantified by the Autism-Spectrum Quotient (AQ) on emotional processing in forms of unimodal (faces, voices) and crossmodal (emotionally congruent face-voice expressions) presentations. In addition, by taking into account the degree of anxiety, the role of co-morbid anxiety as measured by State-Trait Anxiety Inventory, Trait (STAI-T) on emotion recognition in autistic traits was also explored. Compared to an age and gender-matched group of individuals with low levels of autistic traits (LAQ), a trend of no general deficit was found in individuals with high levels of autistic traits (HAQ) in recognizing emotions presented in faces and voice, regardless of their co-morbid anxiety. However, co-morbid anxiety did moderate the relationship between autistic traits and the recognition of emotions (e.g., fear, surprise, and anger), and this effect tended to be different for the two groups. Specifically, with greater anxiety, individuals with HAQ were found to show less probility of correct response in recognizing the emotion of fear. In contrast, individuals with LAQ showed greater probability of correct response in recognizing fear expressions. For response time, anxiety symptoms tended to be significantly associated with greater response latency in the HAQ group but less response latency in the LAQ group in the recognition of emotional expressions, negative emotions in particular (e.g., anger, fear, and sadness); and this effect of anxiety was not restricted to specific modalities.

Despite the absence of finding a general emotion recognition deficit in individuals with considerable autistic traits compared to those with low levels of autistic traits, it did not necessarily mean that these two groups shared same neural network when processing emotions. Moreover, in the above study, anxiety was found to modulate emotion recognition performance among the participants. Based on these considerations, it was useful to explore the neural correlates engaged in processing of emotional expressions in individuals with high levels of autistic traits. Results of this investigation tended to suggest a hypo activation of brain areas dedicated to multimodal integration, particularly for displays showing happiness and disgust. However, both the HAQ group and LAQ group showed similar patterns of brain response (mainly in temporal regions) in response to face-voice combination. In response to emotional stimuli in single modality, the HAQ

group activated a number of frontal and temporal regions (e.g., STG, MFG, IFG); these differences may suggested a more effortful and less automatic processing in individual with HAQ.

In everyday life, emotional information is often conveyed by both the face and voice. Consequently, concurrently presented information by one source can alter the way that information from the other source is perceived and leads to emotional incongruence if information from the two sources was incongruent. Using fMRI, the present work also examined the neural circuity involved in responding to an incongruence effect (incongruence vs. congruence) from face-voice pairs in a group of individuals with considerable autistic traits. In addition, the differences in brain responses for emotional incongruity between explicit instructions to attend to facial expression and explicit instructions to attend to tone of voice in autistic traits was also explored. It was found that there was no significant incongruence effect between groups, given that individuals with a high level of autistic traits are able to recruit more normative neural networks for processing incongruence as individuals with a low level of autistic traits, regardless of instructions. Though no between group differences, individuals with HAQ showed negative activation in regions involved in the default-mode network. However, taken into account changes of instructions, a stronger incongruence effect was more likely to be occurred in the voice-attend condition for individuals with HAQ while in the face-attend condition for individuals with LAQ.

The present work is significant in providing novel evidence on the impact of comorbidities (e.g., anxiety) in emotion recognition in individuals with considerable autistic traits. These results highlighted the theme of anxiety in autistic traits and in turn suggest that participants' characteristics in those with ASD should not be ignored in either research or practice. The present work is also an attempt to provide a complete picture of the neural correlates dedicated for processing emotional information from different sources, and to provide complementary information for the results revealed in the behavioral study. In addition, the present work provides further insights into the strategies used to deal with incongruence in individuals with considerable autistic traits. These explorations contribute significantly to our understanding of the brain and behavioral phenotypes in autistic traits, and may carry important implications for practice. The final section of this thesis discussed the gender issue (e.g., female-dominated participant profile) and the issue of co-occurring anxiety with autistic traits. At the end of the thesis, potential practical and clinical implications were discussed. The limitations of this thesis and directions for future research were also presented.

Table of Contents

LIST OF TABLES

CHAPTER 2

CHAPTER 5

CHAPTER *6*

LIST OF FIGURES

Acknowledgements

During my PhD, I have received so much help from a number of people. I would like to take this opportunity to thank as many of them as possible.

First, I would like to give my heartfelt thanks to my supervisors, Margaret Sutherland and Frank Pollick, for their constant encouragement, enthusiasm and advice. This PhD would not exist without it, I could not have asked for better supervisors. Thank you, Margaret, who helped me constantly throughout my PhD. Thank you for taking time to meet with me, to discuss my research and find opportunity to share my research. Your support and mentorship is vital in completing this dissertation. Thank you, Frank, for supporting me in preparing databases, running the experiment, analysing the data and thanks for all the feedbacks, these shaped my thinking for doing research.

I also want to thank Jeffery Girard for allowing me to use the Binghamton–Pittsburgh 4D (BP4D) spontaneous facial expression database.

To all the members of the lab, I appreciate all the help I received throughout the process of setting up, piloting, testing and presenting the work. I especially want to thank Salim and Aso for helping me with the Presentation programming, and the PACO PRT creator. Another special thanks goes to Jing, thank you very much for your company and help. Also, I would like to thank Kelly, and Catherine, thank you very much for the company, it is really nice to be accompanied by you both during this period of time finishing my thesis.

I have wonderful friends during these years in Glasgow. Hongyi Wang, Fei Yi, Jiayu, Chong. Thank you very much for your companionship and help.

I would also like to express my deep thanks to the examination committee of the thesis, Dr Anthony Atkinson, Dr George Head and Dr Niamh Stack. Thank you very much for taking time to read the thesis so carefully and provide me with valuable comments and suggestions from which I greatly benefited for my future research.

Thanks also to the members of Autism Journal Club, especially David Simmons, Paula Regener, and Kirsty Ainsworth for organizing such lovely and helpful events, from which I learnt a lot.

Finally, I am very grateful to all the participants for their time and effort, as well as the schools and organisations that assisted me in recruiting participants.

Declaration

I declare that this thesis, submitted to the University of Glasgow for the degree of Doctor of Philosophy, is the result of my own research, except where otherwise acknowledged, and that this thesis has not been submitted for a higher degree to any other university or institution.

Signed: ………………………………………….

Date: ……………………………….

Definitions/abbreviations

ACC	Anterior Cingulate Cortex
AQ	Autism Spectrum Quotient
AC	Auditory Cortex
ACT	Attentional Control Theory
ADDM	Autism and Developmental Disabilities Monitoring
ADHD	Attention Deficit Hyperactivity Disorder
APA	American Psychiatric Association
AS	Asperger Syndrome
ASD	Autism Spectrum Disorder
AU	Action Units
BA	Brodmann Area
BAPQ	Broad Autism Phenotype Questionnaire
BOLD	Blood-Oxygen-Level Dependence
CBT	Cognitive-Behavioural Therapy
CC	Central Coherence
CCNI	Centre for Cognitive Neuroimaging
daCC	dosal anterior Cingulate Cortex
DASS	Depression Anxiety and Stress Scales
DCM	Dynamic Causal Modelling
dlPFC	dorsolateral Prefrontal Cortex
DMN	Default-Mode Network
dmPFC	dorso-medial PreFrontal Cortex
DSM III	Diagnostic and Statistical Manual of Disorders-III
DSM-5	Diagnostic and Statistical Manual of Mental Disorders 5th edition
DSM-IV	Diagnostic and Statistical Manual of Disorders-IV
DSM-V	Diagnostic and Statistical Manual-V
EEG	Electroencephalography
EPI	Echo planar Imaging
ERP	Event-related Potential
FFA	Fusiform Face Area

FG	Fusiform Gyrus
fMRI	functional Magnetic Resonance Imaging
GAS	Glasgow Anxiety Scale
GES	Goal Engagement System
GLM	General Linear Model
GLMM	Generalized Linear Mixed Model
HD	Huntington's Disease
HFA	High-Functioning Autism
ICD-10	International Classification of Diseases-10
ICD-9	International Classification of Diseases-9
IFG	Inferior Frontal Gyrus
IOG	Inferior Occipital Gyrus
IPL	Inferior Partial Lobule
LMM	Linear Mixed Model
MFG	Middle Frontal Gyrus
MNI	Montreal Neurological Institute
MNS	Mirror Neuron System
mPFC	middle PreFrontal Cortex
MTG	Middle Temporal Gyrus
MVPC	Multi-Voxel Pattern Classification
NBS	NeuroBehavioural Systerm
OCD	Obsessive-Compulsive Disorder
OFA	Occipital Face Area
OFC	Orbitalfrontal Cortex
OG	Occipital Gyrus
PATHS	Promoting Alternative Thinking Strategies
PCC	Posterior Cingulate Cortex
PDD	Pervasive Developmental Disorders
PET	Positron Emission Tomography
PTSD	Post-Traumatic Stress Disorders

Q-CHAT Quantitative Checklist for Autism in Toddlers

rs-fcMRI resting state- functional connectivity MRI

SEAL Social and Emotional Aspects of Learning

SFG Superior Frontal Gyrus

SNR Signal to Noise Ratio

SRS Social Responsiveness Scale

STAI State Trait Anxiety Inventory

STG Superior Temporal Gyrus

STS Superior Temporal Sulcus

TD Typical Developing individuals

TEACCH Treatment and Education of Autistic and related Communication-handicapped Children

TMS Transcranial Magnetic Stimulation

TOM Theory of Mind

VES Valence Evaluation System

vmPFC ventral-medial PreFrontal Cortex

WCC Weak Central Coherence

1. Overview

The purpose of this chapter is to give a brief synopsis of the overall nature and structure of this thesis. The chapter begins with a brief overview of the researcher's perspective, followed by the background to the research, its objectives, and the research questions that are investigated. The chapter then moves on to provide a brief outline of the organisation of the thesis.

1.1 The researcher's perspective

The opportunity to undertake research exploring features of emotion perception in individuals with profound autistic traits was particularly appealing to the researcher, who possessed a keen interest in the field of autism. In the early stages of this doctorate, a relative of the researcher was diagnosed as being autistic. This sparked the researcher's particular interest in this area. This interest has driven what the research has chosen to study, and has impacted on the researcher's chosen career. In the researcher's home country (Mainland in China), autism was not recognised by mental health professionals until after the second edition of the Chinese Category of Mental Disease (CCMD-2) was published in 1995. The general population in China exhibits poor understanding and inaccurate perceptions of the presentation of this disorder. The current work provided the researcher with a unique opportunity to investigate this area in detail, in order to develop a deeper understanding of the interaction between autistic traits and social and emotional communication. As such, this researcher was hoping to promote a greater understanding of this spectrum, and to make a positive contribution to autism research.

1.2 Background

Humans, as social beings, live in an environment, which incorporates many kinds of relationships. We constantly interact with other people; we see what they do and how they do things; we hear what they say and how they say things, and by these methods, we understand others' feelings, emotions and intentions. Likewise, learning is also a social enterprise, and learners must develop the skills to deal with the social communication and interaction that are necessary for learning. The content covered in a learning context is typically approached and processed as part of a social and emotional environment. In such an environment, learners need to work collaboratively with others and regulate their own emotions (Blair & Razza, 2007). In this sense, social and emotional skills are critical competencies for individuals, playing a significant role in facilitating life-long learning and global development.

It is well acknowledged that as humans, we use multiple channels to evaluate and determine emotions. In many cases, we are effective at interpreting daily social interaction through spoken language without much effort. However, social or interpersonal communication is much more than what is being said; it also includes what the person indicates by means of non-verbal cues such as facial expressions, gestures, physical states and tone of voice. We frequently interpret communicative information corresponding to these non-verbal sources. For example, living abroad, you might see two people talking to each other using a language that you are largely unfamiliar with, and whilst you might not be able to understand what is being said, you can still get an idea of the information being imparted, by reading the non-verbal signals. You could understand whether the interaction was tense or relaxed, and sense something about the relationship between the two people. As has been reported by Fabri (2006), more than 65% of information exchanged during a person-to-person conversation is conveyed non-verbally. Similarly, Knapp and Hall (2009) also emphasised that non-verbal information seems to be more important than verbal information for expressing people's emotional and mental states, especially in situations that involve changing moods. In non-verbal communication, many of the emotional signals are communicated through facial expressions or tone of voice. In real life, the evaluation of emotion is rarely based on just one source, but instead is processed simultaneously by multiple sensory channels. In this way, modality-specific information is combined and integrated together to create a unified emotion percept in certain contexts (De Gelder & Vroomen, 2000).

Individuals are constantly expected to cope with "the social demand in the social world which involves interactions with peers, understanding rules and codes of conduct" (Attwood, 1998). However, for some of them, this can be especially difficult, and this particularly applies to individuals with Autism Spectrum Disorder (ASD). In the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5; American Psychiatric Association, 2013) and 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10; World Health Organization, 1993), social deficit was indicated as a core deficiency for individuals with ASD. Despite the fact that individuals with Asperger Syndrome (AS) and High-Functioning Autism (HFA) (though these labels no longer exist in DSM-5) may have intelligence within the normal range, they tend to be affected by a life-long impairment in social communication and emotional behaviours (World Health Organization, 1993; Gillberg, 1998). A wealth of evidence suggests that a significant contributor to the social deficits in individuals with ASD is their impairment in understanding mental states; this is an ability that tends to be developed effortlessly in typically developing individuals (e.g.,Baron-Cohen et al., 2000; Klin, 2000). It is well acknowledged that one's communicative competence is critical for friendship development. In this sense, impaired emotional communication in individuals with ASD results in challenges in developing meaningful peer relationships (e.g., Bauminger, Solomon, & Rogers, 2010).

These difficulties can often result in anxiety, as part of a withdrawal system, and this may interfere with learning by causing students to avoid engaging in challenging school activities which may involve negative experiences or outcomes (e.g., Wigfield et al., 2006). It therefore impacts on educational outcomes, social participation, interpersonal relationships and friendships among students (Reaven, 2011). Although not a diagnostic criterion, it is well established that individuals with ASD tend to exhibit significantly higher levels of anxiety symptoms than typically developing individuals, demonstrated by increased physiological arousal, social anxiety, panic attacks, and separation anxiety (e.g., Bellini, 2004; Kim, Szatmari, Bryson, Streiner, & Wilson, 2000). As a matter of fact, in the original description of autism, Kanner (1943) noted the presence of substantial anxiety problems in a number of patients with autism. Studies examining the prevalence rates of comorbid symptomatology in individuals with ASD have suggested that anxiety or anxiety disorders are one of the most common comorbid disorders in individuals with ASD (van Steensel, Bögels, & Perrin, 2011; White & Roberson-Nay, 2009), especially for individuals who are higher functioning (e.g., Leyfer et al., 2006). It is estimated that 40%-50% of individuals with ASD meet the criteria for at least one anxiety disorder (Leyfer et al., 2006; Mattila et al., 2010; Simonoff et al., 2008). Sukhodolsky et al. (2008) examined the existence of anxiety in school-aged children with ASD, and suggested that an estimated 31% of children with ASD met the diagnostic criteria for specific phobia, 20% for social phobia, 11% for separation anxiety disorder, and 10% for generalised anxiety disorder. These rates make anxiety-related concerns amongst the most common presenting problems for school-aged children and adolescents with ASD. The long-term consequences of childhood anxiety were aslo emphasized in research with typically developing populations. For example, Pine et al. (2005) suggested that the presence of anxiety symptoms in young people was a significant predictor of the development of an anxiety disorder in adulthood. In addition, there are some symptoms that may be less pronounced in children but become more pronounced in adolescence and adulthood, such as difficulties with social-emotional behaviors (Bristol & Schopler, 1983).

The perception of emotions appears to be one of the fundamental cognitive abilities in humans, and has been reported to be closely related to socio-emotional skills and social competence (e.g., Stichter, O'Connor, Herzog, Lierheimer, & McGhee, 2012; Uljarevic & Hamilton, 2013; Williams & Gray, 2013). The experience of emotions in individuals represents their evaluation and judgements on the circumstances surrounding the environment, and these emotions often result in reactions to the environment (Baumeister & Bushman, 2007). Emotions contain motivational components, and tend to have an impact on cognition and adaptive functioning.

With the increase in diagnoses of autism over the past few decades, along with the increased application of inclusive education, it is highly likely that educators will have individuals who have been diagnosed with this spectrum disorder in the classroom. It is equally likely that there will be individuals who exhibit similar social and interpersonal challenges but do not have a diagnosis. In the general education/inclusive education settings, emotion perception abilities in individuals are important, especially with an increase in the use of collaborative learning (Bruffee, 1999), which calls for advanced interpersonal skills. Impaired recognition of others' emotions may lead to social dysfunctions in several areas, such as inappropriate social behaviour and poor interpersonal communication (e.g., Blair, 2005). If a person cannot recognise angry expressions, he/she may not learn to modify his/her behaviour, and may behave in ways that others see as disrespectful, and this, in turn, may affect how others behave towards him/her.

It is suggested that individuals' emotions and what they understand about the emotions of others might play a significant role in contexts of collaboration and collaborative learning (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). For example, during a problem solving activity, it is very important for the learners to think of the problem as a whole and to consider the solutions from their own perspective. In addition, one is expected to consider one another's perspective to solve the problem.

However, such abilities have been observed to be impared in a number of disorders, including Autism Spectrum Disorder (ASD). Autism is a complex and heterogeneous disorder; and there is increasing evidence that autistic traits lie along the continuum of social-communication disability that is also distributed across the general population (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Constantino & Todd, 2003). The goal of the present thesis was to characterise the effects of autistic traits on perceptual processing of emotions in individuals with substantial autistic traits. In addition, given that anxiety is associated with some features that are significantly correlated with ASD, such as social avoidance, poor social function, and social skills deficits (e.g., Bellini, 2006; Davis et al., 2011; Meyer & Turner, 2006), it is very likely that the co-existence of anxiety may confound the overall social impairments related to ASD. Therefore, the present work will also take into account the degree of anxiety, to examine whether the effect of autistic traits on emotion perception is mediated by the co-occuring anxiety. Understanding the ways in which people perceive emotions in others may contribute towards a better understanding of this population's deficits during social communication and interaction, and this also has potentially important practical and clinical implications.

1.3 Main questions

This thesis seeks to use mixed approaches (psychological approach and fMRI) to investigate emotion perception and associated neural mechanisms during the processing of emotional expressions in individuals with high levels of autistic traits, and how comorbid anxiety plays a role in this. This question was broken down into three specific questions, one for each study:

(1) Do individuals with substantial autistic traits recognise emotions across different multiple domains (face, voice, face-voice), and does comorbid anxiety modulate their emotion recognition?

(2) How does the brain process emotions conveyed in the face, the voice, and a combination of the both in individuals with high levels of autistic traits, and does the level of anxiety modulate brain activity in this?

(3) How does the brain respond to emotional incongruity, do different patterns of brain activation occur in the context of being instructed to either attend to a face, or attend to a voice in a group of individuals with high levels of autistic traits, and does comorbid anxiety mediate this phenomenon?

1.4 Structure of the thesis

As shown in Figure 1.1, this thesis is set out in eight chapters. Chapter 1, *Overview,* begins by introducing the areas of investigation, discussing the study aims and providing a short overview of all the chapters included in the thesis. Chapter 2, *Introduction*, provides background information on Autism Spectrum Disorders, the connection between ASD and mental health with a focus on anxiety in ASD, and Emotions. Chapter 3, *Literature Review,* presents a review of the previous research concerning emotion perception from different sources in ASD and co-occurring anxiety. Chapter 4, *Methodology,* discusses the methodological issues that have shaped this project, including the reason for choosing a quantitative method, a description of the research design, participant selection process, and measures and materials used in the present thesis. In addition, a brief introduction to the fMRI technique, and data-analysis preparation for experimental data from both research approaches is also presented. Finally, I also discuss the ethical considerations for conducting the present research. Chapter 5 introduces a behavioral experiment in which the results of participants' (Study 1, n=50) recognition of a full range of six basic emotions across three emotion recognition tasks (face, voice, face-voice) are presented and discussed. Chapter 6 introduces an fMRI experiment examining the neural correlates during the processing of emotional expressions from faces and voices, and investigates how the brain combines information from the two sources (Study 2, n=29). The results from this study are presented and discussed. Chapter 7 introduces an fMRI experiment examining the neural correlates involved in responding to emotional incongruity (e.g., incongruent information vs. congruent information), and how changes in explicit instructions can modulate the brain's response to emotional incongruity (e.g., attend to face, attend to voice) (Study 3, n=30). In Chapter 8, the results of all the above studies are summarised, and these are accompanied by a discussion of the limitations and implications of the studies, and possible future directions for research.

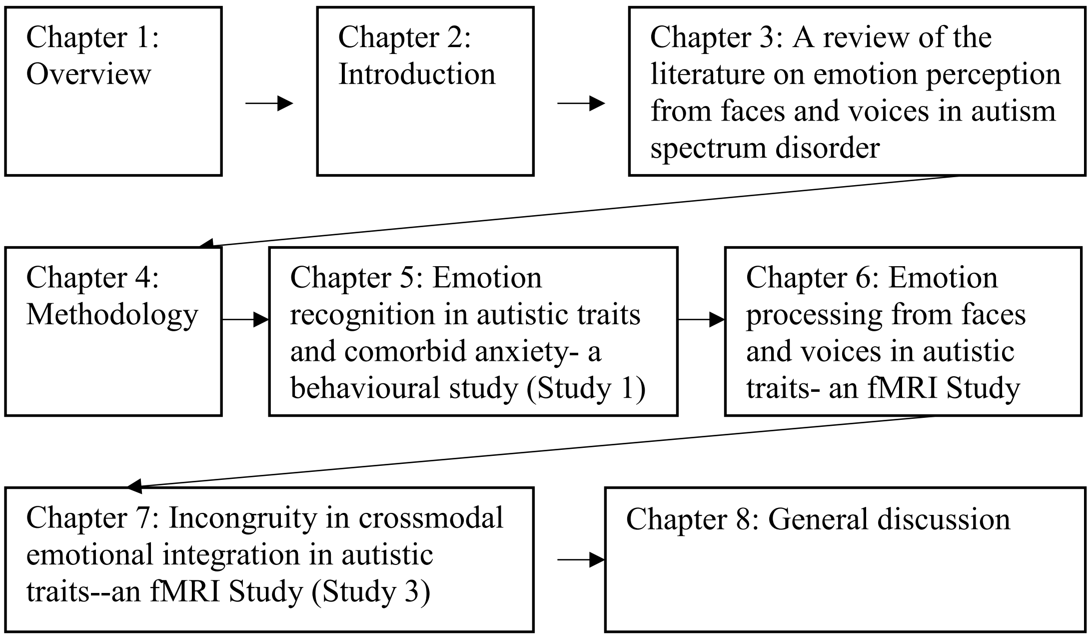
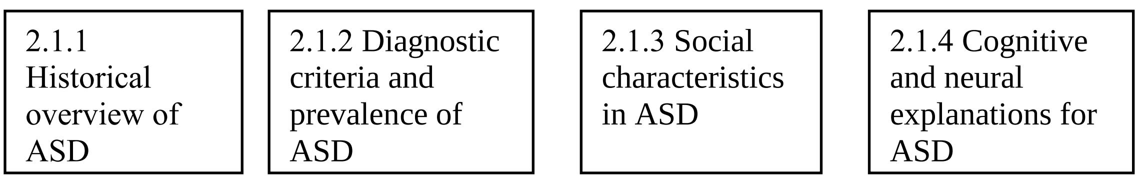


Figure 1.1-- Structure of the thesis

2. Introduction

2.1 Autism spectrum disorder

As illustrated in Figure 2.1, this section starts with the origin and development of the concept of autism. It introduces the original concept of "autism" as a Greek word, which provided the foundation for the later description of "Autism Spectrum Disorder" (ASD) which incorporates autism, Asperger's Syndrome and Pervasive Developmental Disorders (PDD). Following this, the diagnostic criteria, prevalence and the core characteristics of ASD are introduced. Theories from both cognitive and neural perspectives that are proposed to account for the behavioral phenotype in ASD are also introduced.



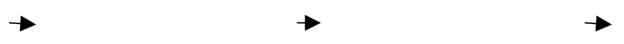


Figure 2.1-- Structure of the introduction to autism spectrum disorder

2.1.1 Historical overview of ASD

The word "AUTISM" stems from the Greek word “autos”, referring to the “self”. Historically, the term has been used to describe people who show a tendency to withdraw socially. The term “autism” was first used by Eugen Bleuler in 1911 to describe symptoms of self-centered thinking and withdrawal from society in a group of patients with schizophrenia (Frith, 2003). Similarly, the term “autistic” was also used by Ernst Kretschmer (1921) to describe adults with schizoid personality. In 1926, Sucharewa, a researcher in Moscow, Russia, described a small number of children with childhood-onset social isolation, repetitive behavior, phobias, eccentricities, peculiar thoughts and developmental delays, and also pointed out that they were “highly intelligent” (translated by Wolff, 1996). During this time, the term autism was used interchangeably with the label of childhood schizophrenia. It was not until the 1940s that Leo Kanner published ‘Autistic Disturbances of Affective Contact’, in which he clearly differentiated autism from schizophrenia. He used the term “autism” to describe children who show a preference for aloneness, intolerance of change, fascination with objects, impaired language abilities, and restricted interests. In this description, autism was considered to be a disorder that occurred only in children with learning disability. Almost at the same time, Hans Asperger, a scientist in Germany, independently published a paper “Diet autistischen Psychopathen im Kindesalter”, in which he described cases of “autistic psychopathy”, referring to children with average or above-average intelligence, impaired reciprocal social interactions, poor motor skills and limited interests. However, this paper did not receive much attention until 1981, when Lorna Wing referred to the work of Asperger in a clinical report describing similar cases, and used the term “Asperger’s Syndrome” to describe this condition.

2.1.2 Diagnostic criteria and prevalence of autism spectrum disorder

The diagnostic criteria for autism have been fairly consistent since they were introduced by Leo Kanner (Kanner, 1943). In 1956, Kanner and Eisenberg identified two core characteristics of autism: (1) considerable lack of affective contact with others, and (2) repetitive and restricted behaviors. In the same year, Kanner and Eisenberg added that these two essential characteristics needed to have manifested themselves by around the age of two years. Since these initial descriptions, the definition of autism spectrum disorder has become more refined. In the 1970s, Wing and Gould (1979) extended the existing criteria for identification of autism and developed the concept of a "spectrum of autistic disorders". This endeavour provided the foundation for the triad of deficits in autism spectrum disorders that we use nowadays, including difficulties in social interaction, dysfunctions in verbal and non-verbal abilities, and repetitive, stereotyped activities that emerge from birth or within the first few years of life. Wing and Potter (2002) also added the idea that each deficit can present with varying severity and manifestations in different individuals.

DSM-IV (American Psychiatric Association, 2012) and ICD-10 (WHO, 1993) made a substantial contribution to our current understanding of ASD. These two diagnostic frameworks shared similar criteria for the diagnosis of autistic spectrum disorders, and they were behaviorally based. In the diagnostic criteria of DSM-IV and ICD-10, Autism Spectrum Disorder was summarised as a collective term for a set of neurodevelopmental conditions characterised by persistent deficits in reciprocal social communication, social interaction, and restricted and repetitive interests, activities, and behaviors. These characteristics and behavioral patterns develop differently from person to person, with varying degrees of intensities ranging from relatively mild to extremely severe. To obtain a diagnosis of ASD, the onset of these core features must be present by the age of 3 years old, and in some cases can occur as early as 18 months (American Psychiatric Association, 2000). However, it is possible that for higher functioning individuals, these symptoms may not manifest themselves until social demands exceed the individual's limited capacities, and therefore impair everyday functioning. In 2013, the American Psychiatric Association (APA) revised the diagnostic manual of the fourth edition of the Diagnostic and Statistical Manual (DSM-IV), and produced the fifth edition (DSM-5). There were two main changes relating to ASD in the DSM-5. Firstly, the triad of impairments was reduced into two domains: deficits in social communication and social interaction; and restricted, repetitive behaviors, activities, and interests. Secondly, the sub-categories within ASD were removed. More specifically, in the DSM-IV (American Psychiatric Association, 2012) and ICD-10 (WHO, 1993), autistic disorder (A-D) and Asperger's Syndrome (AS) comprised the two major types of ASD. High-functioning autism (HFA) was diagnosed as a subcategory of A-D when intellectual functioning was intact. In the fifth version (DSM-5), terms like "autistic disorder", "Asperger's disorder", "childhood disintegrative disorder" and "PDD-NOS" were all encompassed by the term "autism spectrum disorder". There were also some other changes in DSM-5, such as specifying the needs that individuals have and how the condition affects their lives. It is worth pointing out that the new framework of DSM-5 includes sensory behaviors in diagnosis, although the overall description of impairments is the same. The diagnosis of autism, Asperger's syndrome and PDD-unspecified are still recognised in the ICD-10, although ICD-11 (expected release date 2018) may include revisions to this classification system.

The prevalence of ASD that is reported varies depending on methodological differences across studies, such as ascertainment method and diagnostic criteria. For a long time, autism was considered to be a rare condition. The prevalence of autism was first established by an epidemiological survey (Lotter, 1966). In this report, autism was thought to affect around 4 in 10,000 children. However, two decades later, in 2004, a national statistics survey in the UK reported that the prevalence of ASD was approximately 1 person in 100. Later, the National Adult Psychiatric Morbidity Survey (3rd) also reported the prevalence of Autism in the adult population as being 1 per 100 in England (Brugha et al., 2011). In 2012, another study estimated that 1 out of 88 in the general population had autism (Autism and Developmental Disabilities Monitoring, ADDM). In the United States, a prevalence of 14.67 out of 1000 children aged 8 years old was reported (Center for Disease Control and Prevention, 2014). In short, the reported prevalence of ASD has increased considerably over time. A few factors have been proposed to account for this increase, including improved diagnostic tools (Chakrabarti & Fombonne, 2001), the broadening of diagnostic criteria (Fombonne, 2002) and a growing awareness of autism in the general population. The increasing number of individuals identified with autism has also highlighted the large group of individuals who need appropriate services and support. Given the diversity within the spectrum (as discussed above), many diverse types of support are required. It is unclear how the DSM-5 will impact the estimated prevalence rates, but it has been suggested by researchers like Maenner et al. (2014) that there might be a potential reduction in reported ASD prevalence under the DSM-5 criteria.

2.1.3 Social characteristics in ASD

Social impairments typically affect the way in which individuals with ASD understand and react to the world surrounding them (Wing & Gould, 1979). Their use of social language is generally more resistant to change, and their abilities in understanding communicative information and their participation in reciprocal social interactions often continue to be areas of significant difficulty (Seltzer, Shattuck, Abbeduto, & Greenberg, 2004). Social difficulties tend to be more pronounced in unstructured natural situations, in which effective and efficient processing of, and responding to, social information is required (Crooke, Hendrix, & Rachman, 2008). Although for some high-functioning autistic individuals their challenges in social situations can be masked by good verbal skills in their early years, their limited play skills, interests, and their lack of awareness of social cues and norms inevitably become apparent when they grow up, and this will persist into adulthood (Koegel, Ashbaugh, Koegel, Detar, & Regester, 2013). These social deficits are suggested to impact adult outcomes and contribute to the unemployment and underemployment, paucity of friendships and romantic relationships, and low rates of independent living that have repeatedly been shown for adults with ASD (Farley et al., 2009).

There are several studies examining social functioning in adolescents and adults with ASD, through looking at friendships, peer relationships and social participation. Friendship studies have consistently demonstrated that in comparison with typically developing individuals, those with ASD are less likely to develop and maintain long-lasting, reciprocated and stable friendships. Orsmond, Krauss, and Seltzer (2004) reported that in their study, many individuals with ASD had difficulties in developing friendships. Few of them considered themselves to have even one true friendship, and even those who did often still reported feeling lonely. Even though many adults with ASD do report that they have friends, their relationships are often reported to contain lower levels of companionship, closeness, security, and intimacy, and to be less enjoyable than those of adults without ASD (Simon Baron-Cohen & Wheelwright, 2003; Bauminger et al., 2010).

In a further investigation of peer interaction and loneliness in adults with ASD, it was found that affected individuals tend to have few relationships with others (family members not included) and were reported to experience a high degree of loneliness (Jantz, 2011). Similarly, in studies investigating friendship amongst individuals with ASD, it is often reported that very few of them appear to develop and maintain quality friendships into adulthood (e.g., Orsmond et al., 2004), though they do possess certain levels of interpersonal awareness and desire. Therefore, lesser enjoyment of social interaction and lower levels of initiation in individuals with ASD may be interpreted as being a result of a lack of social skills rather than a lack of desire (e.g., Stokes, Newton, & Kaur, 2007). In a study examining social challenges and support among adults with ASD (Müller, Schuler, & Yates, 2008), a number of common experiences were revealed, including feelings of isolation, difficulties in initiating social interaction, communication challenges, efforts made to develop greater social/self-awareness, and desires to contribute to one's community. It is also important to note some participants in this study reported an association between feelings of isolation, awareness of differences and feelings of anxiety and depression.

2.1.4 Cognitive and neural explanations for ASD

Many attempts have been put forward to account for the profile of autistic impairments. However, no one universal deficit has been identified that could explain all of the characteristics of ASD that distinguish it from other conditions. Although it appears that the cognitive or neural atypicalities identified in individuals with ASD are linked to its behavioral features, the existing findings are mixed and require further exploration (Brunsdon et al., 2014). In this section, I will attempt to provide an overview of the cognitive/neural differences that appear to be relevant to information or emotion related processing in ASD. This section will therefore include descriptions of both cognitive theories (such as Theory of Mind and Weak Central Coherence theory) and neural theories (such as Temporal Binding Deficit, Enhanced Perceptual Functioning and Mirror-Neuron System dysfunction theory). In addition, a proposal entitled Social Motivation Theory has been put forward to explain the significance of motivational factors in social skills and social cognition (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012).Last but not least, the 'hypo-priors theory' of ASD, which has received increasing attention in recent years, will also be discussed.

Theory of Mind (ToM) The term "Theory of Mind" (ToM) was first used by Premack & Woodruff (1978), and described the ability to attribute a mental state to oneself and others. In 1983, Wimmer and Perner redefined ToM as the cognitive ability to construct a representation of the mental states of others, understanding their desires, beliefs, intentions, feelings and emotions, and to make inferences based on these mental states. As a cognitive ability, it is thought to develop by the age of 4 or 5 years (Wimmer & Perner, 1983). The ToM hypothesis has become one of most influential theories of ASD over the past few years (Simmons et al., 2009), and is also known as 'mentalising' (Frith, 2003), or 'perspective-taking' (Jameel, Vyas, Bellesi, Roberts, & Channon, 2014), positing that individuals with autism have difficulties in predicting and explaining the mental states of others (Simon Baron-Cohen, Leslie, & Frith, 1985). This theory was initially used to explain why children with autism perform poorly on False Belief tasks (Wimmer & Perner, 1983), in which the participants are required to infer the mental state of a person from another person's point of view (Baron-Cohen et al., 1985).

The ToM hypothesis was then transformed into the Extreme Male Brain (EMB) hypothesis (Baron-cohen, 2010), which argues that individuals with ASD are poor at "empathising" and good at "systemising". Empathising involves being able to perceive others' feelings and thoughts and respond appropriately (e.g. to feel upset when another person displays sadness). Systemising is the ability to analyse, understand and interact with rule-based systems, and is associated with technical professions (e.g. mathematics, engineering). The ToM theory, including the EMB, makes sense of the core social and communication deficits seen amongst individuals with ASD (Baron-Cohen, 2008). It is significant in its ability to make a connection between a person's impairment in understanding the mental status of others, and their difficulties in social interaction and communication. However, one criticism of this theory is that it fails to account for the non-social characteristics of ASD, such as obsessive behaviors or sensory problems.

(Weak) Central Coherence Theory Another theory that is important to ASD is the Central Coherence (CC) theory (originally known as Weak Central Coherence (WCC)). As a perceptual-cognitive theory, the Central Coherence (CC) theory proposes that individuals with ASD tend to have a specific cognitive style which causes them to think about and perceive inputs in discrete parts, rather than integrating discrete fragments or components of an object into a coherent whole (Happé & Frith, 2006). Support for this theory is derived from findings of superior performance in embedded figure tasks and block design tasks (Shah & Frith, 1983), and reduced sensitivity to visual illusions (Happé et al., 1996) in individuals with autism.

The original theory of CC (known as Weak Central Coherence (WCC) theory) suggested that it is an impairment in global processing that causes the superior local processing seen in ASD (Best, Moffat, Power, Owens, & Johnstone, 2008). However, follow-up research showed that individuals with ASD either exhibited superior local processing but were *not* impaired in global processing (e.g., Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Plaisted, Saksida, Alcántara, & Weisblatt, 2003), or were impaired in global processing (e.g., Behrmann et al., 2006), or had intact global processing but showed a local processing preference when given a choice (e.g., Plaisted, Swettenham, & Rees, 1999). In order to address these mixed findings, an updated version of this research was published (Happé & Frith, 2006). The updated version contained several revisions, as follows. First, the findings reported above are felt to be a result of superior local processing, rather than impaired global processing. Second, this is a cognitive style, rather than deficit. Third, it is considered to be one aspect of cognition in ASD, rather than representing the disorder as a whole. Fourth, this processing style can be overcome in certain circumstances.

This theory has been tested on a number of occasions using cognitive perceptual tests, such as the block design task and the embedded figures task (e.g., Shah & Frith, 1983;1993). In the block design task, participants are presented with several cubes that have either a white face, red face or a white and red face. Then, they are shown a simple geometric shape that can be made out of a combination of 9 or 16 such cubes, and are required to recreate the shape. Individuals with ASD were found to be quicker at completing this task compared to typically developing individuals. This (seeing the detail in an image) was taken as evidence of a local processing style in ASD. In the embedded figures task, participants are asked to identify independent shapes within a complete picture. In the experiment by Shah and Frith (1983), ASD participants were found to complete the tasks more quickly and with fewer errors than those without ASD, suggesting a preference for local processing.

The theory of WCC explains some of the non-social aspects of autism, particularly the information processing patterns observed in visual tasks. It takes into account not only the impairments in ASD but also the strengths that have frequently reported by researchers (e.g., Happé, 1994). The hypothesis of atypical patterns of information processing between the whole and the parts would not only explain the perceptual processing abnormalities that have been reported in ASD, but also speak to the different abilities in integrating sensory information from one sensory modality or from different sensory modalities.

Social Motivation Theory Instead of focusing on the cognitive impairments in ASD such as ToM deficits, the social motivation theory focuses on the impact of motivational factors on the development of social cognition and social skills in ASD (Chevallier et al., 2012). It posited that social motivation serves a significant role in guiding individuals' behaviors, and suggested that individuals with ASD have decreased social motivations. This is driven by biological differences in substrates such as the reward system, thus leading to diminished social interest and orienting, and less drive to maintain and engage in reciprocate social interactions, leaving the affected individuals with fewer social learning opportunities (Chevallier et al., 2012). In this sense, deficits in social communication can be construed as being an extreme result of diminished social motivation. The authors of this theory studied social orientation, social reward and social maintenance in ASD. They suggested that early deficits in the brain's reward circuitry (e.g., midbrain ventral tegmental area, nucleus accumbens of the basal ganglia, anterior cingulate cortex, vmPFC, and the OFC) in autism reduced the motivation for social experiences, leading to a decreased response to social rewards. This theory aids our understanding of individuals with ASD who demonstrate diminished motivation in social situations, and provides an explanation for the social deficits experienced by many individuals with ASD. Nevertheless, while diminished social motivation may explain a lack of social development in some individuals with ASD, it could not explain those who desire friendships yet demonstrate social development (e.g., Calder, Hill, & Pellicano, 2012).

Theory of Hypo-Priors The above accounts provide explanations for the social-emotional difficulties characterising this disorder. Pellicano and Burr (2012), however, concluded that theories such as the weak central coherence or enhanced perceptual function theory could not be fully compatible with findings from the existing literature. Instead, coming from a different perspective, they suggested that individuals with ASD were less affected by their prior experience, resulting in fewer internal constraints on perception, and therefore leading to altered perception. In the original paper, three possible predictions were put forward to clarify the effects of this 'hypo-prior' in autistic perception, namely more 'accurate perception', 'impeded performance' and 'sensory overwhelming' (Pellicano & Burr, 2012). Pellicano and Burr's hypo-priors theory was then extended by Friston, Lawson, and Frith (2013) and Lawson, Rees, and Friston (2014), resulting in the creation of Aberrant Precision Theory. In this account, the role of "prior" was linked to probabilistic predictive coding, and they suggested that autistic perception could be explained as a result of aberrant encoding of precision (e.g., an imbalance between sensory evidence and priors, with greater weight being ascribed to sensory evidence relative to prior beliefs).

The hypo-priors theory argues that it is not sensory processing itself that is different in autism, but the interpretation of sensory input to yield unique perceptual experiences in this population. If this is the case, it might be hypothesised that, in the context of emotion processing, due to the attenuated priors, individuals with ASD may fail to show "expected" behaviors, such as quickly and efficiently adjusting to a particular theme in a conversation conveyed by facial or vocal emotional information, thus leading to sensory differences (Charbonneau et al., 2013). The attenuated prior hypothesis seemed to be congruent with empirical findings in ASD, such as a reduced sensitivity to context (Frith & Happé, 1994), general difficulties with predictability (Gomot & Wicker, 2012), deficits in ToM (Baron-Cohen, Golan, & Ashwin, 2009)), reduced "top-down" control (Happé & Frith, 2006) and enhanced "bottom-up" functioning (Mottron, Dawson, & Soulieres, 2009).

In addition to the existing social-cognitive theories of ASD, attempts have been made to understand the neural basis of ASD by linking the symptoms to those of known functions of neuronal organisation in the brain. A number of brain regions are reported to be implicated in ASD, including the amygdala (Baron-Cohen et al., 2000), frontal cortex (Courchesne & Pierce, 2005), superior temporal sulcus, and the fusiform face area (Zilbovicius et al., 2006). The three theories that have received increasing attention are: Temporal binding deficit**,** Enhanced Perceptual Functioning and Mirror-Neuron System dysfunction, and these will be discussed below.

Temporal Binding Deficit The temporal binding deficit hypothesis was proposed to explain the neural underpinnings of both the core and non-core features of ASD (Brock, Brown, Boucher, & Rippon, 2002). This account is an expansion of the WCC, and suggests "whereas typical brain development involves the emergence of functionally specialized but nevertheless integrated regions, brain development in autism involves the emergence of functionally specialized brain regions that become increasingly isolated from each other over time" (Brock et al., 2002). Temporal binding is hypothesised to allow individuals to integrate incoming information and make sense of new information (Brock et al., 2002). The authors explain that the activity within networks of interconnected sensory regions are not as strongly correlated in ASD, resulting in impaired temporal binding in perceiving information, which would lead to the "weak coherence" of information in ASD. In sum, this theory accepts the WCC theory at the observable level but proposes that impaired integration of neural networks underlies the core features of ASD, as well as atypical perceptual processes necessitating integrative analysis.

Enhanced Perceptual Functioning Theory The enhanced perceptual functioning theory has been an influential account of perceptual processing differences in autism. It posits that individuals with ASD have enhanced detection of locally embedded targets (Shah & Frith, 1983) and show superior performance on tasks that require local-level processing (Siegel, Minshew, & Goldstein, 1996), at the expense of higher-order processes (Laurent Mottron, Burack, Dawson, Soulières, & Hubert, 2001). This theory may help to explain the superior low-level perception (or local processing) in ASD, such as the detection and discrimination of (visual) details. In addition, this local processing bias may lead to the ignoring of conceptual aspects, therefore making it difficult to detect more complex visual stimuli, such as facial expressions, thus leading to a relative lack of processing of emotional information. This may provide an explanation for why some individuals with ASD utilise emotional information in some tasks but not in others (e.g., Gaigg & Bowler, 2008; South et al., 2008).

In the updated version of this theory (Mottron et al., 2006), eight principles of autistic perception are proposed, which are:

1. The default setting of perception in individuals with autism is more locally oriented than that of typical individuals
2. An increased gradient of neural complexity is inversely related to level of performance in low-level tasks
3. Early atypical behaviours have regulatory functions towards perceptual development
4. Perceptual primary and associative brain regions are atypically activated during social and non-social tasks
5. Higher-order processing is optional in autism and mandatory in typical individuals
6. Perceptual expertise underlies savant syndrome
7. Savant syndrome provides a model for subtyping Pervasive Developmental Disorders
8. Enhanced functioning of primary perceptual brain regions may account for the perceptual atypicalities in autism.

One strength of the enhanced perceptual functioning theory is that it explains some of the non-social symptoms and atypical sensory processing patterns in ASD, in particular hypersensitivity, which is not covered by ToM. In addition, it accounts for enhanced local processing performance in certain perceptual tasks in ASD. However, it fails to fully account for all sensory problems reported in previous literature (such as hyposensitivity).

Mirror-Neuron System dysfunction (MNS) The mirror neuron system (MNS) was proposed as a neural mechanism that is fundamental to aspects of social cognition (Pfeifer, Iacoboni, & Mazziottaa, 2008). The MNS was first introduced by Gallese, Fadiga, Fogassi, and Rizzolatti (1996), following a study in which a group of neurons in region F5 of the monkey brain was selectively activated during imitation tasks. In humans, studies have been conducted using neuro-imaging technology, and the key MNS region has been identified as the inferior frontal cortex (IFC; involving central premotor cortex and the posterior inferior frontal gyrus), and parts of the inferior parietal lobule (IPL; involving rostral and posterior parts of the IPL, Casile et al., 2010; Iacoboni & Dapretto, 2006).

Behavioral evidence of poor imitation performance in autism (Ingersoll, 2008; Vivanti, Nadig, Ozonoff, & Rogers, 2008; Williams, Whiten, & Singh, 2004)) and neural evidence of hypoactivation within the MNS of the IFG during imitation tasks and theory of mind tasks (Mirella Dapretto et al., 2006; Hooker, Verosky, Germine, Knight, & D'Esposito, 2008; Pfeifer et al., 2008; Saarela et al., 2007), combined with the significant role of the MNS in social cognition (Buccino et al., 2004) have led to the idea that MNS dysfunction is the cause of poor social interaction in individuals with autism (Villalobos, Mizuno, Dahl, & Kemmotsu, 2005; J. H. G. Williams, Whiten, Suddendorf, & Perrett, 2001). However, there is also conflicting evidence suggesting good imitation performance in individuals with ASD (e.g., Bird, Leighton, Press, & Heyes, 2007; Hamilton, Brindley, & Frith, 2007). Further, although it is reported that autistic individuals demonstrate abnormal brain responses when viewing emotional stimuli (e.g., Dapretto et al., 2006), there is also evidence of normal-level brain responses when viewing goal-directed actions (e.g., Marsh & Hamilton, 2011).

Despite the considerable evidence of imitation impairment in ASD, other results seem to suggest that there might not be a global deficit in imitation, and that there may be typical responses of the MNS system in ASD, provided the stimuli are personally familiar to the observer. In summary, although the MNS dysfunction may be linked to some general or specific deficits in social abilities such as imitation, joint attention, or theory of mind, given the large number of other brain regions associated with the wide range of impairments seen in ASD, it seems unlikely that the MNS dysfunction is the sole cause of socialisation and communication deficits in ASD, or even the majority of them.

2.2 Anxiety and Anxiety Disorders

This section (as illustrated in Figure 2.2) provides a brief overview of anxiety and anxiety disorders: definition, components and assessment, with a focus on self-report measures. Following this, threat-related attentional bias in anxiety is introduced.

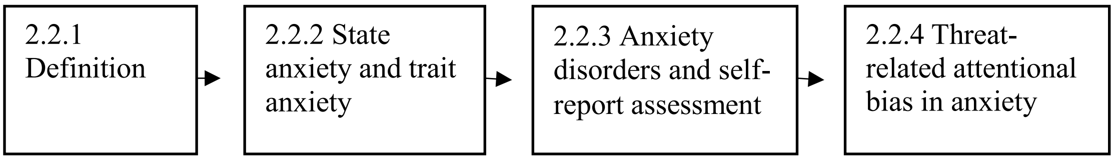


Figure 2.2 -- Structure of the introduction to anxiety and anxiety disorders

2.2.1 Definition

Anxiety is a universal phenomenon, and it is experienced by most people within the course of their lifetime (di Tomasso & Gosch, 2002). Barlow and Cerny (1988) defined anxiety as unpleasant feelings of nervousness, worry, and tension associated with an arousal of the autonomic nervous system. According to Raghunathan and Pham (1999) and Smith and Ellsworth (1985), anxiety is a specific emotion characterised by high arousal, negative valence, uncertainty, and a tendency towards feeling out of control.

Anxiety is a complicated phenomenon which involves many different aspects, including behavioural components, physiological components and cognitive components (e.g., Rachman, 2004; Albano, Chorpita, & Barlow, 2003). More specifically, the behavioural components include: avoiding specific situations, and fighting. The physiological components include: rapid pulse, muscle tension, palpitations, sweating and trembling, shallow breathing, shivering, and feeling nauseous. The cognitive components include: an attention bias towards threatening information, and negative thoughts or negative self-statements. Watson and Friend (1969) emphasised the effects of anxiety in a social context, suggesting that anxiety comprises the experience of distress, discomfort, fear in social situations and a fear of receiving negative evaluations from others.

2.2.2 State anxiety and trait anxiety

Spielberger (1966, 1972, 1983) proposed two dimensions of anxiety, namely, trait anxiety and state anxiety. State anxiety has been defined as "a transitory emotional state reflective of one's interpretation of a particular stressful situation at a particular period" (Vitasari, Wahab, Othman, Herawan, & Sinnadurai, 201:491). It can be evoked when an object or a situation is being considered as threatening at a particular moment, such as when giving a presentation, or during exams. The intensity of state anxiety may fluctuate over time. In contrast, trait anxiety is regarded as a stable predisposition to be anxious. It is a personality dimension that relates to relatively stable individual differences in anxiety proneness, and refers to a general tendency to respond with anxiety to perceived threats in the environment (Spielberger et al., 1983). To evaluate two dimensions of anxiety, Spielberger developed the State- Trait Anxiety Inventory (STAI). In this inventory, each form has 20 items using four-point Likert-scales, with total scale scores ranging from 20 to 80.

Spielberger (1972) suggested that these two types of anxiety comprise a conceptual framework of anxiety, but not a theory of anxiety, which means that the trait anxiety and state anxiety are highly correlated with each other and can be present concurrently. In other words, individuals with high trait anxiety are more likely to be anxious in a variety of situations and to experience more intensive state anxiety in such situations (Rachman, 2004). The intensity of anxiety experienced in certain circumstances is affected by the individuals' personality-related tendency towards trait anxiety. This proposal was echoed by William and colleagues (1988, 1997), who suggested that trait anxiety leads to a tendency to direct attention towards the potential threat, and this attentional bias increases as state anxiety increases.

2.2.3 Anxiety disorders and self-reported assessment

According to Beddington et al. (2008), anxiety disorders are major mental disorders which result in significant psychological, social, and economic costs worldwide. Prevalence estimates vary, but a study by Somers, Goldner, Waraich, and Hsu (2006) suggested the lifetime prevalence of anxiety disorders to be 16.6% for people in English speaking countries. A similar finding was reported by Brow and Barlow (1992), who suggested that approximately 15% of their studied population were affected by at least one anxiety disorder during their lifetime. Anxiety disorders can become chronic if left untreated (American Psychiatric Association, 2000). Standardised diagnostic systems, such as DSM-IV and ICD-10, classify types of anxiety based on their clinical features. For example, in DSM-IV-TR (American Psychiatric Association, 2000), anxiety disorders were divided into generalised anxiety disorder, panic disorder without agoraphobia, panic disorder with agoraphobia, specific phobias (SP), social anxiety disorder (SAD), acute and post-traumatic stress disorders (PTSD), obsessive-compulsive disorder (OCD), and acute stress disorder.

The assessment of anxiety level is crucial in order to find out the cause and appropriate treatment for the anxiety, and/or to explore the association between anxiety and performance. For research and clinical purposes, a variety of measures have been used to assess anxiety, such as clinical interviews, physiological recordings, rating scales, and behavioural observations (Wells, White, & Carter, 1997). Rating scales, such as self-report questionnaires, are frequently used in scientific settings due to their efficient administration, low cost, and good reliability and validity. A wide range of self-report rating scales are commonly used, such as the Spielberger State-Trait Anxiety Inventory (STAI; Spielberger, 1983), the Beck Depression Inventory (BDI; Beck, Steer, & Garbin, 1988); and the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983).

In the present thesis, the State-Trait Anxiety Inventory (STAI) was utilised for two reasons: Firstly, it is supported by existing literature, providing adequate evidence for measuring anxiety in research and clinical settings; Secondly, the STAI allows for differentiation between state anxiety and trait anxiety, providing a comprehensive picture of the anxiety status of individuals. Although the present studies took state anxiety into account, for the purposes of data analysis only the trait anxiety scores were reported. This is because trait anxiety, as a personality dimension, is more likely to have a significant effect on the executive system than state anxiety.

2.2.4 Threat-related attentional bias in anxiety

According to Wilt, Oehlberg and Revelle (2011), "Cognition is the process by which individuals make sense of the environment, it reflects one's thoughts, beliefs, modes of thinking and problem-solving". In a paper by Robinson, Vytal, Cornwell and Grillon (2013)**,** cognition was defined as "information processing", during which the information from the outside world is processed. In this sense, the underlying cognitive mechanisms of emotional state impact upon information processing in a specific way that contributes to adaptive behaviors. For example, a fearful state may facilitate detection of danger in a given situation and optimise response to the environment stimuli. Indeed, research into attentional responses in heightened anxiety states suggests that individuals who suffer from both clinical and sub clinical levels of anxiety process emotionally salient events in a quantifiably different way to individuals with low levels of anxiety, with faster performance in directing attention to threatening stimuli (e.g., Williams, Watts, MacLeod, & Mathews, 1997), with an impaired ability to disengage their attention from threats (Fox, Russo, Bowles, & Dutton, 2001). Such attentional bias towards threatening relevant information has been assigned a prominent role in the causation and maintenance of anxiety (e.g., Beck, 1976; Eysenck & Calvo, 1992; Mathews, 1990; Mathews & MacLeod, 2002; Williams, Watts, MacLeod, & Mathews, 1988).

In the past few years, a number of cognitive models have been put forward to account for the threat-related information processing bias in anxiety, including the Schema model (Beck, 1976; Bower, 1981); Williams, Watts, Macleod, and Matthews' (1988) Model ; Mogg and Bradley's, (1998) Cognitive-Motivational Model, and the attentional control theory (ACT) (Eysenck, Derakshan, Santos, & Calvo, 2007). According to the schema model (Bower, 1981), schemas affect all aspects of information processing. For individuals with heightened anxiety, schemas are sensitive to threat or danger. Consequently, threatening or danger-relevant information is favored at all stages of processing, including selective processes of attention, stimulus encoding, memory and interpretations (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007). Other theories, in contrast, have suggested that the processing bias in anxiety occurs at specific stages of information processing. For instance, Williams et al., (1988) suggested a pre-attentional level of processing bias in anxiety. That is, individuals' high level of anxiety orientates their attention towards threatening information at a very early stage of processing, automatically and without their awareness (e.g., Ohman, 1993). In the cognitive-motivational model of anxiety, Mogg and Bradley (1998) proposed that two different systems are utilised in mediating cognitive and behavioral responses to information, namely the valence evaluation system (VES) and the goal engagement system (GES). Reports from the VES will contribute to the GES, which determines the allocation of attention to the stimulus and therefore modulates the response. That is, if the stimulus is assessed as having a high subjective threat value during the valence evaluation process, current goals will be interrupted and attention will be allocated to the salient stimulus. However, if the stimulus input is evaluated as being of low threat, ongoing activities will not be interrupted and attention will be allocated to the present activities. It is suggested that individuals with high trait anxiety tend to have a more sensitive valence evaluation system than individuals with low levels of anxiety. According to this assumption, the threat-related biases in anxiety are confined to later stages of processing. The more recent models, such as attentional control theory (ACT) (Eysenck, 1997; Eysenck et al., 2007) reconcile the above views and suggest a potential time course of attentional allocation in maintaining anxiety. According to the ACT, anxiety impairs attentional control, affecting both the goal-driven system and the stimulus-driven system. Further, Eysenck et al. (2007) added that anxiety disrupted inhibition and the shifting of functions in the attentional control system, thus in turn affect performance. Indeed, a number of studies have explored the inhibition functioning using threaten stimuli (Cisler & Koster, 2010; Eysenck et al., 2007). It was found that individuals high in anxiety tend to be more distracted by task irrelevant threatening stimuli than individuals low in anxiety (e.g., Eysenck et al., 2007).

At the empirical level, a wide range of studies have tested the attentional bias. Amongst these studies, three main experimental paradigms have most commonly been used, including the emotional "Stroop" task, dot-probe task and emotional spatial cueing task (see the review by Cisler, Josh, Koster, & Ernst, 2011; Cialer & Koster, 2010). For the emotional stroop task (MacLeod, Mathews, & Tata, 1986), participants were asked to name the colour in which certain words were printed – either emotionally negative words or neutral words. Attentional biases are indicated by taking longer to name the colour of emotionally negative words, due to the difficulties in suppressing a response to emotionally relevant words while selectively maintaining attention to the colour of the words. The emotional stroop task was initially the most commonly used paradigm to explore threat-related attentional biases in anxiety. However, one criticism of this paradigm relates to the ambiguous interpretations of the latencies demonstrated. For example, delayed response latencies to threat-related stimuli may be due to effortful avoidance of processing a threat, or might possibly reflect competition at a later response-selection stage of information processing (e.g., MacLeod et al., 1986).

In order to overcome such problems, the dot-probe task was developed (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007b; Mogg & Bradley, 1998). In this task, participants are presented with two emotional stimuli (one neutral, one threat-relevant) simultaneously, followed by a dot probe which takes the place on the screen of one or other stimulus. Participants are instructed to detect the presence of the dot. In this task, attentional biases are indicated by shorter reaction latency to the dot when it is placed on the location of the previously presented threat stimulus. The dot-probe paradigm allowed researchers to manipulate the time interval between the presence of the stimuli and the probe, thus allowing them to investigate the time course of attention allocation. However, similarly to the stroop paradigm, it has been criticised with the argument that it is ambiguous whether the attentional bias to threat in anxiety as measured by the dot-probe tasks reflects faster engagement with a threat, or an inability to disengage from it.

In order to determine the relative contribution of these two components of attention bias, a spatial cuing paradigm was developed (Fox, Russo, Bowles, & Dutton, 2001; Michael, Posner, & Petersen, 1990; Posner, 1980). In Posner's classical paradigm, participants focus on a fixation point orientated between two rectangles. A visual cue is presented at one of two locations, and this is followed by a target presented at either valid or invalid predictors of the spatial locations. Participants are instructed to press a key indicating the rectangle in which the target is located. Attentional biases are indicated either by shorter response latencies on valid threat-cued trials or longer response latencies on invalidly threat-cued trials, relative to neutral-cued trials. The results as measured by this paradigm (e.g., Bar-Haim et al., 2007; Fox et al., 2001)) supported the enhanced attentional bias theory for processing of threat-related information in anxiety.

Overall, the theoretical accounts of the underlying cognitive mechanisms for anxiety provide possible explanations for its development and maintenance anxiety. Despite disagreements regarding the specific underlying cognitive mechanisms, such as the stages of processing bias, the results from the above tasks have been interpreted as reflecting an anxiety-related bias in the allocation of attention towards a threat (Cisler, Josh, Koster, & Ernst, 2011; Schechner et al., 2012).

Moreover, beyond the traditional assumption of biased processing of threats in the development and maintenance of anxiety, Schechner et al. (2012) also indicated the likely existence of some form of reward-attention perturbation in anxiety. These results tend to have potential implications in the practice of training for alleviating anxiety.

2.3 Autism Spectrum Disorder and Mental Health

As the title suggests, this section introduces the co-morbidity of anxiety in autism spectrum disorder, and will be organised as follows (Figure 2.3):

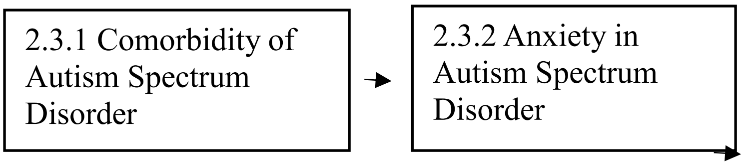


Figure 2.3 -- Structure of introduction to autism spectrum disorder and mental health

2.3.1 Comorbidity of autism spectrum disorder

As has been discussed, Autism Spectrum Disorders (ASD) are a range of neurodevelopmental conditions typically characterised by difficulties in social interactions and communication, as well as restricted interests and repetitive behaviors (American Psychiatric Association, 2000). In addition to the core impairments of ASD, affected individuals are reported to have other behavioural and emotional problems (Lainhart, 1999). In recent years, comorbidity, defined as the co-occurrent presence of two or even more disorders in the same person, has been found to be common than was previously believed in individuals with ASD (Brown & Barlow, 1992).

The core features of ASD have been investigated extensively, however it is only recently that the comorbid conditions experienced by individuals with ASD have started to receive attention from researchers (e.g., Frazier et al., 2001; Yoshida & Uchiyama, 2004; Lugnegård, Hallerbäck, & Gillberg, 2011). Previous research has suggested that the prevalence of comorbidity among individuals with autism ranges from approximately 40% (e.g., Moseley, Tonge, Brereton, & Einfeld, 2011) to 70% (e.g., Brereton, Tonge, & Einfeld, 2006), varying with age and severity. Anxiety disorders, obsessive-compulsive disorder (OCD), and attention-deficit/hyperactivity disorder (ADHD) are the most frequently reported comorbid disorders in young people with ASD (Simonoff et al., 2008).

2.3.2 Anxiety in Autism Spectrum Disorder

Anxiety symptoms in individuals with ASD have been reported for a long time. Indeed, Kanner (1943) described his patients' anxiety problems in his report - Autistic Disturbances of Affective Contact - in which he noted 6 out of 11 cases as having social fear, excessive worries, unusual obsessiveness, fixed routines, or phobias of both common and uncommon focus. More recently, anxiety disorders have been suggested to be one of the most common concomitant disorders occurring throughout the entire spectrum of ASD (Nadeau et al., 2011). Community and epidemiological studies using robust diagnostic criteria have suggested a prevalence rate of anxiety disorders in ASD ranging from 40%-50% (Leyfer et al., 2006; Mattila et al., 2010; Simonoff et al., 2008). More recently, Gobrial and Raghavan (2012) reported that more than 30% of individuals in their study suffered from anxiety symptoms, according to the Glasgow Anxiety Scale (GAS).

A number of factors have contributed to the variation in prevalence estimates of comorbid anxiety in ASD: (1) the significant heterogeneity in autism. It is not surprising that samples across studies may have a large diversity of function and impairment levels, (2) the inconsistency of assessment measures used across studies (i.e., semi-structured reviews vs. self-report questionnaires), (3) the potential overlap of symptoms between these two disorders, such as repetitive and restricted behaviours, impairments in social communication, and social avoidance may lead to confusion between anxiety and autism (Wood & Gadow, 2010),

Given the heterogeneity of ASD, it is not surprising that that there is not one anxiety disorder among individuals with ASD, but several types. Sukhodolsky et al. (2008) examined the existence of anxiety disorders in school-aged children with ASD. This study estimated that 31% of children with ASD met the diagnostic criteria for specific phobia, 20% for social phobia, 11% for separation anxiety disorder, and 10% for generalised anxiety disorder. Bellini (2004) and Muris et al. (1998), from their treatment settings, reported the prevalence rate of social anxiety disorders in ASD to range from 35%-55%. Simonoff et al. (2008) reported that at least 29% of individuals with ASD were reported to have a comorbid social anxiety disorder. Although anxiety symptoms tend to be present in individuals across the whole spectrum, they tend to be more pronounced in individuals with milder ASD, such as high functioning ASD, AS, or PDD-NOS (e.g., White et al., 2009). This can be due to, at least partially, less severe cognitive impairments, more awareness of themselves and also the differences between themselves and others and being more eager to be involved in social activities (Vickerstaff, Heriot, Wong, Lopes, & Dossetor, 2007). Despite a general consensus regarding the close relationship between anxiety and autism, diagnosing comorbid anxiety in autism is difficult. A number of factors may contribute to this difficulty, including: intellectual impairment in large groups of individuals, communication difficulties, diagnostic overshadowing, significant heterogeneity in ASD, and a lack of uniform measures in identifying concomitant disorders in ASD.

Even though in education settings all learners learn in different way and not all learners are rounded learners, there are certain markers that single out “at risk” individuals from others if the classroom educator knows what to be alert to. Take the classroom setting as an example, the classroom environment is complex and sometimes an overwhelming place for individuals with ASD. A number of factors (such as copying with changes, challenges in social interacting with others, and sensory overload) were suggested to be associated with an increase in anxiety. In this sense, the high rate of comorbidity argues for a comprehensive approach to react these comorbidities in different settings, providing support and resources as affected individuals needed.

2.4 Emotion

According to Salovey and Mayer (1990), emotions are "organised responses, crossing the boundaries of many subsystems, such as physiological, cognitive, motivational and experiential systems". They usually refer to both the inner feelings of oneself and the outer expression of these feelings, and can be positive or negative. According to Ekman and Davidson (1994), the concept of emotion is constructed by three elements. Firstly, emotions are expressions. They can be expressed through certain signs, such as facial or full-body movements. Secondly, emotions are caused by an internal drive and tend to be automatic. Thirdly, emotions have a significant impact on individuals' behaviours.

Emotions are inherently complex, and continuously develop and change over time. It is therefore not surprising that the different approaches proposed to differentiate between emotions. Generally speaking, there are two main theories that are proposed to deal with the conceptualization of emotion: categorical emotion-specific expressions (e.g., Ekman & Friesen, 1976), and dimensional accounts of emotions (e.g., Russell, 1980). The account of categorical emotion-specific expression suggested that emotions are universal and innate, though their numbers of emotions may vary from one theory to another. It is hypothesised that distinct emotions have different expressions, and that are implemented in different neural systems (e.g., Ekman et al., 1969, 1976, 1992). The most influential dimensional account is the circumplex model (Russell, 1980). According to Russell (1980), emotions are not distinct or separate, but continuous and vary along two dimensions: valence and arousal. This two dimensional account was then modified into three dimensions by Wundt (1896); those of pleasure -displeasure, arousal-calmness, and tension-relaxation. Although there is a long-standing debate between the discrete and dimensional models in accounting for emotions, the present work will not address this problem; instead, the present thesis was grounded in the discret account of emotions. In this section, only the work focusing or based on discrete categories will be discussed.

2.4.1 The primary emotions

Emotions are grounded in evolution. From an evolutionary point of view, emotions were shaped by natural selection that served adaptive needs (Nesse & Ellsworth, 2009). The evolutionary aspects of emotion can be traced back to Darwin's classic treatise, "The Expressions of Emotions in Man and Animals "(Darwin, 1872/1965). In this book, Darwin extended the evolution theory of natural selection and emphasised that natural selection shaped not only the physical structures of an organism, but also their minds and behaviours. William James (1884), another important figure in the field, proposed that emotion is a result of physiological reactions to the external environment. He suggested that some events in the environment are supposed to evoke a specific reaction, and that reaction is perceived as a specific emotion. However, he also pointed out that there is no single set of behavioural reactions that define an emotion. Instead, a wide range of behaviorial reactions are regarded to be associated with emotions.

On the basis of these contributions, Ekman and his colleagues developed a cross-culture investigation of facial expressions, and suggested that emotions were evolved via natural selection and are therefore biologically universal to all humans. This theory has become the most prominent proponent of the existence of basic emotions. The most popular example of this description is the classification of basic emotions into the most agreed-upon six categories: anger, happiness, fear, sadness, surprise, and disgust (Ekman, 1971, 1994). Most of the recent investigations into emotion perception, guided by the categorical emotions account, have focused on the processing of these basic emotions. Indeed, although the notion of basic emotions is ubiquitous, there are still arguments regarding how many basic emotions exist, what they are and how to evaluate them. Table 2.1 provides a brief summary of the proposals of a representative set of emotion theorists who support the basic emotion account. This table was modified from Ortony and Turner (1990) and Tracy and Randles (2011).

Table 2.1 -- A selection of lists of "Basic" emotions

Reference	Fundamental emotion
Ekman, Friesen, & Ellsworth (1982)	Anger, disgust, fear, joy, sadness, surprise
Ekman & Cordaro (2011)	Happiness, sadness, fear, anger, disgust, surprise, contempt
Frijda (1986)	Desire, happiness, interest, surprise, wonder, sorrow

Levenson (2011)	Enjoyment, sadness, fear, anger, disgust, interest, love, relief
Izard (1971)	Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
Oatley & Johnson-Laird (1987)	Anger, disgust, anxiety, happiness, sadness
Plutchik (1980)	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
Panksepp & Watt (2011)	Play, panic/grief, fear, rage, seeking, lust, care
Tomkins (1984)	Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise

Since the formulation of the basic emotion framework, efforts have been made to stipulate the criteria for evaluating an emotion as "basic". According to Ekman (1994, 1999), basic emotions are regarded to have the following characteristics: distinctive universal signals, presence in other primate species, distinctive physiology, rapid onset, emerge early in ontogeny, brief duration, automatic appraisal and unbidden occurrence, accompanied by distinctive thoughts, memories and images, and distinctive subjective experience. In addition to criteria proposed by Ekman, Plutchik (1980) suggested a set of criteria for evaluating an emotion as "basic": (1) presence in nonhuman animals (2) presence universally and across cultures (3) functions in adapting challenges for survival. Tracy and Randles (2011) also proposed the following criteria: being discrete, having a fixed set of neural and bodily expressed components, being a fixed feeling or motivational component that has been selected through longstanding interactions with ecologically valid stimuli, being psychologically primitive. In addition to the above characteristic, three different profiles for describing the basicness of emotions have been proposed on the basis of the work by Ortony and Turner (1990), and Scarantino and Griffiths (2011), namely conceptual basicness, biological basicness, and psychological basicness.

Specifically, from a conceptual perspective, the notion of basic emotions refers to logical-formal criteria that define the existence of some categories within taxonomies. In this sense, an emotion is considered to be basic if it contributes to create the most abstract category within a hierarchy where the elements share a certain number of common properties that are sufficient to determine whether a single element belongs to that category (Scarantino & Griffiths, 2011). From a psychological perspective, an emotion is basic only if it does not contain another emotion (Ortony & Turner, 1990). Emotions that are not regarded as basic if resulted from the integration of basic emotions, or from the integration of basic emotions and cognitive functions. From a biological perspective, it is assumed that there is an evolutionary origin and distinctive biological marks (Ortony & Turner, 1990). It needs to be noted that these notions of basic-ness of emotions are orthogonal to one another. That is, whether or not a certain emotion is designated by a basic-level category is independent of whether or not that emotion is basic according to other categories.

Likely, research into voices in auditory domain supports the idea that voices carry different emotional function. In general, vocal emotional expressions refers to the variation in a number of acoustic parameters, such as the pitch, rhythm, loudness, and voice quality (Banse & Scherer, 1996). Vocal correlates of emotions can be operationalized by both speech- embedded and non-linguistic emotional vocalizations. Speech embedded emotions, or emotional prosody were encoded by the suprasegmental characteristics, mainly representing an "index" (contingent to the emotional period) or "symbol" (conventional rules of vocal expression) of the emotional state of a speaker (Frühholz, Trost, & Grandjean, 2016). In contrast, non-linguistic vocalizations, such as laughter, cries, yawn, are encoded as "raw", "pure", or "primitive" forms of vocal expressions that are largely unconstrained by linguistic structure (Sauter & Eimer, 2009; Scott et al., 1997). Empirical studies examining the recognition process of vocal expressions confirmed that basic emotions could be identified in an accurate, differentiated manner from both speech prosody and non-linguistic vocalizations. For example, Scott et al. (1997) examined the emotion recognition of individuals using verbal and non-verbal vocalisations of basic emotions, and suggested the presence of distinct vocal signals for different emotions. Scherer, Banse, & Wallbott (2001) examined the recognition of anger, sadness, fear, joy and neutrality expressed by voice in the participants who came from different cultures, including Europe, Asia, and North America. A high consistency in emotion recognition across cultures was found, and this supports the universality of vocal signals of emotions.

The above account of "basic emotions" provides explanations for some routine observations in terms of emotions. In addition, it has made considerable contributions to the scientific research into emotions. More specifically, it has contributed to the development of techniques for the analysis of facial displays as guides to certain emotional states, and it has promoted our understanding of the neurobiology of emotions. However, it needs to note that it fails to fully account for the rich and diverse experience of emotions experienced by humans. In this sense, the data from the basic emotion account is only part of the data for emotion research; other data, such that provided by the dimensional theory of emotions, is also important.

2.4.2 Emotion perception and neural systems

Emotion perception is vital in social settings. Not only can emotional status be explicitly communicated, but it can also be inferred, allowing individuals to gather information regarding the intentions and behaviors of others, and facilitating appropriate responses (Bal et al., 2010;

Belin, Zatorre, Lafaille, Ahad, & Pike, 2000). For the past two decades, there has been a surge of interest in the study of emotion, especially on those aspects of emotion linked to cognitive processes. The collaboration between cognition and neuroscience has made this area of research increasingly popular, contributing to our better understanding of the interactions between emotion and cognitive processing, and their underlying neural bases.

2.4.2.1 Emotion perception from faces

Humans are regarded as being especially good at processing information from faces. The ability to process facial expressions emerges very early in childhood development. Using the habituation paradigm, Bornstein and Arterberry (2003) examined the abilities of 5 month old babies to recognise and discriminate between facial expressions. It was found that these babies showed sensitivity and preference to the changes of emotions in the faces, indicating that they may process key information about facial expression even at this young age. Event-related potential (ERP) studies (e.g., Batty & Taylor, 2003) suggested that emotionally salient information in faces could be recognised as early as 100ms after the onset of stimulus, and differentiation between specific emotion categories occurred as early as 140ms after stimulus onset. These findings were also consistent with a later study by Peltola, Leppänen, Palokangas, and Hietanen (2008) who examined the perception of facial expressions in 7 month old infants, and reported that the infants demonstrated different looking durations to faces which represented different emotional categories (e.g., fear and happy).

Although the perception of facial emotions emerges very early, the level of proficiency in typical developing individuals develops with age. For example, Bruce et al. (2000) found that children showed nearly perfect accuracy by 6 years of age when requested to select which face from a pair was happy, sad, angry, or surprised, while 10 years of age in the selecting the face pair that corresponded to the emotion in a third face. In addition, it is also suggested that the development course of emotion perception depends on the emotion to be recognized. For example, Gao and Maurer (2009) compared the emotion processing abilities of different emotions with different intensities amongst a variety of age groups: aged 5,7 and 10 years old, and adults. The results from this study showed that children as young as 5 years old are able to recognise happiness as well as adults can, even at low intensities. However, for the fearful face recognition task, only 10-year-old children showed same recognition accuracy levels as adults. In a similar study, Boyatzis, Chazan, and Ting (1993) examined facial emotion perception amongst preschool children. They found that children were better at recognising happiness and sadness than disgust and fear, suggesting that these emotions are more easily recognised at an earlier age.

Brain mechanisms for processing faces How is the richness of information from faces processed? In 1986, Bruce and Young proposed a face perception model that introduced functional pathways for expression analysis and speech-related analysis that are distinct from facial analysis. In this model, certain processes that are involved in face perception are functionally independent of each other. This idea of having separate routes for the recognition of facial features and facial expressions has been supported by studies in cognitive psychology and cognitive neuropsychology (e.g., Humphreys, Donnelly, & Riddoch, 1993; Parry et al., 1991; Pizzamiglio, Zoccolotti, Mammucari, & Cesaroni, 1983).

Although there is intensive debate about the amount of the face-processing neural networks, there is a great sense of agreement that there are numerous cortical regions activated for processing faces. The most influential model of face processing, corresponding to that of Bruce and Young (1986), was proposed by Haxby, Hoffman, and Gobbini (2000; 2002) who suggested a set of interconnected "core" and "extended" systems, as illustrated in Figure 2.4 (for a review, see Atkinson and Adolphs (2011)). According to this model, the core face-processing network consists of selective brain regions within the occipito-temporal cortex. More specifically, the superior temporal sulcus (STS), a region located in the lateral occipitotemporal cortex, is suggested to be involved in processing the changeable aspects of faces, such as emotional expression, eye-gaze and lip movement. These types of information are suggested to be significant in social interactions (Allison, Puce, & McCarthy, 2000). On the other hand, the fusiform face area (FFA), a region located in the medial occipitotemporal cortex, is preferentially involved in processing the invariant aspects of face structure, such as identity recognition. Additionally, the occipital face area (OFA), a region located on the lateral surface of the occipital lobe or in the vicinity of the inferior occipital gyrus (IOG), is suggested to receive input from early visual stages and feeds the output to both the FFA and STS.

Supporting evidence for the three principal cortical regions involved in the processing of faces comes from different sources: functional imaging investigations, single-cell recordings, and neuropsychological research. For example, greater activation of the fusiform region has been found when people are responding to faces than to non-faces, such as letter strings and textures (e.g., Puce, Allison, Asgari, Gore, & McCarthy, 1996), flowers (e.g., McCarthy, Puce, Gore, & Allison, 1997); houses, and hands (Kanwisher, McDermott, & Chun (1997). These results were taken as evidence for a face-selective region that is located at the lateral side of the mid-fusiform gyrus and is named as "fusiform face area" (FFA). Later, further experimental results, such as a higher FFA response on trials in which participants correctly identified a famous face than on trials in which they failed to recognise the same individual (Grill-Spector, Knouf, & Kanwisher, 2004), were suggested as evidence for supporting its role of extracting information about face identity. Other evidence on face processing comes from studies which have found that the FFA responds to a wide range of aspects spanning the whole face, such as the face parts, face configuration, spatial relations in faces, specific face parts (eyes, nose and mouth), and the bounding contour of a roughly oval shape (e.g., Rhodes et al., 2009; Yovel & Kanwisher, 2004). In addition to the evidence supporting FFA, the functional role of the OFA was evidenced using fMRI and transcranial magnetic stimulation (TMS). For example, Yovel, Paller, and Levy, (2005) examined the activation of both FFA and OFA in the processing of upright and inverted faces, and suggested that although the OFA showed a similar response to upright and inverted faces, the FFA showed a higher response to upright than inverted faces. Liu, Slotnick, Serences, and Yantis (2003) also found that although the FFA processes stimuli information about both face parts and face configuration, the OFA is sensitive only to face parts. These results can be regarded as evidence that OFA preferentially codes the physical aspects of a face and that it does so at an early stage of visual perception. Evidence regarding the specific role of STS in face processing was reported by Hoffman and Haxby (2000). In their study, a higher response in the STS was detected when participants performed a 1-back task on gaze information than face identify, and vice versa in the face-selective FFA. In addition, the STS was found to be involved in eye gaze and eye shift (Wicker, Michel, Henaff, & Decety, 1998; Pelphrey, Morris, & McCarthy, 2004).

Beyond this core perceptual system of face-processing, other brain regions were also proposed to be engaged in processing additional information in the face (e.g., mood, level of interest, attractiveness, or direction of attention). These brain regions, including the amygdala, insula, inferior frontal gyrus and orbitofrontal cortex, are regarded as the “extended” system.

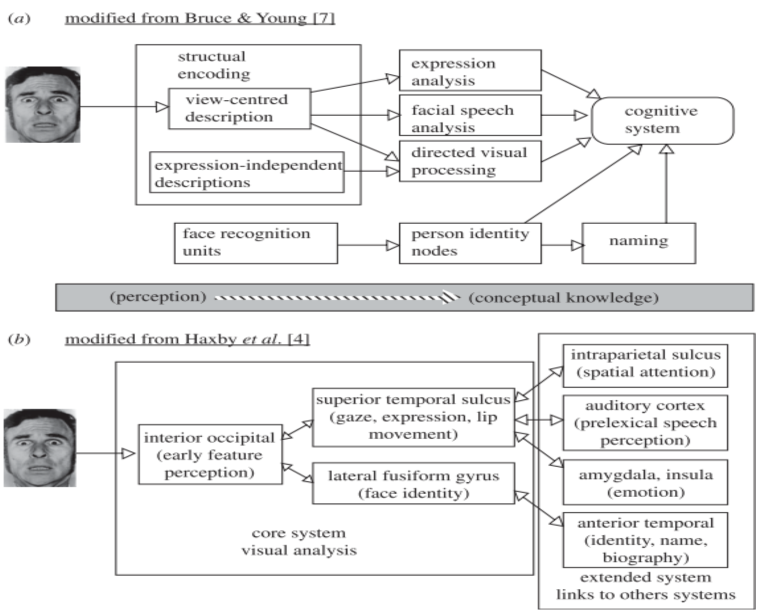


Figure 2.4-- A copy of the face-processing model of (a) Bruce & Young (1986) and (b) Haxby et al., (2000; 2002), from Atkinson and Adolphs (2011)

In addition to the functions of specific brain regions, attempts have also been made to investigate how these regions interact in face processing. Dynamic causal modeling (DCM), which is based on fMRI activity (Friston, Harrison, & Penny, 2003), is commonly used to examine the effective connectivity among brain regions. For example, employing a functional connectivity analysis, Ishai (2008) reported the existence of a distributed network for face-processing: the lateral FG, connected to lower-order areas of the OG as well as to the STS, amygdala and frontal area. In addition, using realistic dynamic facial stimuli, Foley, Rippon, Thai, Longe, and Senior (2012) confirmed the role of the IOG, STS, and FG areas, and also reported that the connection strength between aspects of the core network (OFA and STS) and of the extended system (amygdala) is increased for processing affect-laden gestures.

The neural basis for emotion perception in faces In the existing literature, findings from lesion and imaging studies (e.g., fMRI) contributed to our understanding of brain structures and functions during the processing of emotions. Specifically, imaging studies have great advantages to provide evidence of neural structures involved in the processing of basic emotions (for a review, see Calder, Lawrence, & Young, 2001). From another perspective, lesion studies seem to provide evidence of causal attributions between brain structure and functions that complement the findings of neuroimaging studies.

The role of the amygdala in processing fearful faces has been highlighted in functional imaging studies, and this is in fact the most widely replicated neuroimaging finding in this area (Breiter et al., 1996; Edwards, Jackson, & Pattison, 2002; Morris et al., 1996; Phillips et al., 1998). There is a wealth evidence showing that amygdala damage can affect some aspects of emotion perception, and the most consistent results are seen in the realm of fear (Adolphs et al., 1999; Adolphs, Tranel, Damasio, & Damasio, 1994; Calder, 1996; Montaldi et al., 1998; Young, Hellawell, Van de Wal, & Johnson, 1996). Moreover, it is suggested that the deficits in the recognition of fear in patients with bilateral amygdala damage is not related with the intact ability of identity recognition (Adolphs, Tranel, Damasio, & Damasio, 1995), age and gender (Anderson & Phelps, 2000).

It is well acknowledged that fear provides a critical survival-related function in face of threat by activating a range of adaptive, protective or defensive behaviors, being significant to individuals' well-beings. Due to the proximity relationship between amygdala and hippocampus, a main structure for memory, it is not surprising that the amygdala may also be involved in some form of memory functions, such as conditioned learning. In this view, amygdala damage interferes with memory processes for emotional events (Phelps et al., 1998). In addition, as just discussed, lesion of amygdala also causes the individual to have impaired ability to interpret threating information, such as fearful expressions. Given these considerations, it might be possible that individuals who have difficulties in responding to threatening information will have difficulties functioning in the learning context where emotions were embedded in its daily contexts, resulting in aberrant social behaviors. Individuals with amygdala damage or were shown atypical amygdala activity may also have difficulties in functioning during threatening situations.

Despite of the evidence supporting the amygdala' s role in processing fearful faces, research by Sprengelmeyer, Rausch, Eysel, and Przuntek (1998) failed to find amygdala activation for recognition of fearful facial expressions. The absence of amygdala activation in this study is suggested as a consequence of the rapid habituation of the amygdala in response to fearful faces, an effect already reported by Breiter et al., (1996). In addition, meta-analyses of functional neuroimaging studies (e.g., Sergerie, Chochol, & Armony, 2008; Vytal & Hamann, 2010) have suggested that differences in the use of control stimuli (pictures of houses, neutral face stimuli, emotional face stimuli) might result in different patterns of findings across studies. For example, the face vs. non-face contrast does not rule out the possibility that the activation is to faces per se, rather than specifically to facial expressions. In order to investigate this question, a block design fMRI study by Mattavelli et al., (2014) compared the neural responses to facial images posing emotional expressions with three different control conditions (non-face condition, mildly happy faces and neutral faces). The results of this study suggested that compared to neutral faces or mildly happy faces, higher amygdala activation was found when processing expressions indicating threatening or aversive stimuli (e.g., fearful faces), rather than in the processing of facial expressions of happy, disgust, or sad. However, the authors also reported that disgusted and happy expressions also activated some voxels in the anatomically defined amygdala, and showed a change in percentage signal for the functionally defined region.

Using brain imaging techniques, Phillips et al. (1997,1998) reported the activations of the anterior insular cortex, caudate nucleus and the putamen in response to disgusted facial expressions. Similarly, Sprengelmeyer, Rausch, Eysel, and Przuntek (1998) suggested that disgusted facial expressions activated the right basal ganglia and left anterior insula. In line with findings from imaging studies, patients with a selective lesion to the insula and basal ganglia are suggested to be impaired in recognizing and experiencing disgust. Indeed, patients with Huntington's Disease (HD) which initially affects the basal ganglia and caudate nucleus, were found to have particular difficulties in recognizing disgusted expressions in faces, but were not so impaired in recognizing other facial expressions, including fear and anger (Sprengelmeyer et al., 1997). Support for this view also comes from two additional studies (Gray, Young, Barker, Curtis, & Gibson, 1997; Sprengelmeyer et al., 1998) with Huntington's disease (HD) gene carriers. Mitchell et al. (2005) reported that patients with HD showed reduced ability to identify the distaste for bad smells. The converging evidence from both lesion and neuroimaging studies thus supports the view that the processing of disgust in faces incorporates the basal ganglia and insula.

Blair, Morris, Frith, Perrett, and Dolan (1999) found that increased intensity of angry facial expressions was associated with enhanced activity in the orbitofrontal and anterior cingulate cortex during a gender discrimination task. In a study by Sprengelmeyer et al., (1998), angry facial expression processing was correlated with activation in the posterior part of the right gyrus cingulate and the left media temporal gyrus. In addition, in a case of the patient Phineas Gage (Damasio, 1994), orbitofrontal cortex lesion was found to be linked to inappropriate emotional and behavioral response, such as pathological manifestations of anger and lack of self-control. Functions of orbitofrontal cortex for processing emotions was confirmed in a study by Grafman et al. (1996) reporting that patients with orbitofrontal cortex lesions become irritable more easily and use verbal aggression more frequently compared to health participants. In addition, there is evidence of the relationships between altered orbitofrontal cortex function and increase in aggression in individuals with personality disorders, such as antisocial disorders and borderline personality disorder (Glenn, Raine, & Schug, 2009; Harenski, Antonenko, Shane, & Kiehl, 2010; Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000; Yang, Raine, Colletti, Toga, & Narr, 2009).

Results examining the neural responses to sad facial expressions are less consistent. In the study by Blair et al. (1999), increasing intensity of sad facial expressions was associated with increased activation in the left amygdala and right temporal pole. However, this involvement of the left amygdala in response to sad expressions seem to contradict with Adolphs et al.(1994), in which (as discussed previously), patients with amygdala damage were unimpaired in recognising sad facial expressions. Blair et al. (1999) explained that these inconsistent results might be due to the left amygdala activation being part of a neural response for processing sad expressions, but not being a prerequisite for naming sad expressions. Another study examining the perception of sad facial expressions was conducted by Killgore and Yurgelun-Todd (2004). In this study, using a backward masking paradigm, the authors found increased activation in the left anterior cingulate gyrus when the masked emotion was sadness.

In an fMRI study, Breiter et al., (1996) unexpectedly found amygdala activation when participants were perceiving happy emotions. Winston, O'Doherty, and Dolan (2003) examined the neural responses occurring during the processing of multiple facial emotions at both high and low intensities (disgust, fear, happiness, and sadness) and reported activation of the amygdala and fusiform cortex for processing all high-intensity emotions in both direct and incidental processing tasks, including happiness. In the study mentioned previously by Killgore and Yurgelun-Todd (2004), using a backward masking paradigm, it was found that non-consciously perceived happiness was associated with activation in the anterior cingulate gyrus and amygdala.

2.4.2.2 Emotion perception from auditory modality

As one of the primary sources of social and communicative information, the human voice contains a rich source of information about the gender, age, affective state of the speaker (Karpf, 2006). Emotional states in human vocalizations could be expressed through varying acoustic features (Banse & Scherer, 1996). The accurate and efficient processing of emotional content form the combined acoustic profiles and discriminative voice features has a major impact on behaviours in certain contexts and social interactions (Belin, Fecteau, & Bédard, 2004), and therefore being significant for adaptive contextual behaviour. Atypical patterns of emotion recognition in voices, as observed in some neurological and psychiatric disorders, tend to predict emotion-behavioural problems, which would be detrimental for social functioning and the quality of life.

From the earliest stage of development, infants tend to respond to emotion-laden vocal information from their mothers and other people (Fernald & Morikawa, 1993), and this ability continues to develop with age (e.g., Mumme, Fernald, & Herrera 1996; Parise, Cleveland, Costabile, & Striano, 2007). A study by Sauter, Panattoni, and Happ (2013) found that children as young as 5 years old can reliably perceive emotions in vocalisations, and the accuracy rate among participants increased to 83.9% for 10 year old participants, suggesting that the ability to recognise emotions from voices continues to develop with age.

Neural processing of emotional voices The neural network for affective vocal processing is suggested to be comprised with a number of cortical and subcortical structures with differential and complementary functionality (Frühholz, Trost, & Grandjean, 2014; Pannese, Grandjean, & Frühholz, 2015). It is well evidenced that cortical regions encompassing primary and secondary auditory cortex (AC) and the superior temporal cortex (STC) are central in processing emotional expressions in auditory modality (Frühholz & Grandjean, 2013; Szameitat et al., 2010). Ethofer et al. (2012) reported that regions in left and right temporal lobes in the superior temporal sulcus adjacent to the left and right primary auditory cortices were strongly responsive to voices expressing anger, sadness, joy, and relief compared to voices with neural emotion. Complementary to the STC, the IFC is thought to integrate emotional relevant sound features provided by the STC via doral and ventral connections and being important in vocal monitoring during the production of emotional voices (Ethofer et al., 2012; Frühholz & Grandjean, 2012; Frühholz, Gschwind, &

Grandjean, 2015; Frühholz et al., 2014). These data tend to suggest the significance of fronto-temporal network during decoding of emotional voice. Similarly, Alba-Ferrara, Hausmann, Mitchell, and Weis (2011) examined the neural activity engaged in the processing of emotional vocal sounds and found that emotional vocal cues (emotion vs. neutral) elicited brain activity in regions around the temporo-frontal network, involving the middle and superior temporal gyri, left temporal pole, right insula, Broca's area and its right hemisphere homologue, as well as the left motor cortex. In addition, complex emotions (e.g., proud, guilty, bored) activated extended brain networks in the mPFC, premotor cortex, frontal operculum and left insula, compared to simple emotions (happy, sad, angry).

There is also evidence suggesting the involvement of the amygdala in processing emotional vocalisations (e.g., Fecteau, Belin, Joanette, & Armony, 2007; Wiethoff, Wildgruber, Grodd, & Ethofer, 2009; Fruhholz & Grandjean, 2013). Evidence from these studies highlight the role of amygdala for not only the emotional analysis on of the acoustic features, which is overall affective value based on acoustic features that are pre-processed in other brain regions, especially in the auditory cortex (Kumar, von Kriegstein, Friston, & Griffiths, 2012), but also for affective discrimination of the vocalizations (Frühholz et al., 2014). For example, using event-related fMRI, Fecteau et al., (2007) found increased activation in the amygdala when processing emotional vocalisations involving both positive (happiness and sexual pleasure) and negative (sadness and fear) ones, compared to neutral vocalisations. Pannese, Grandjean, and Fru¨hholz, (2016) indicated that auditory cortex (e.g., temporal voice area) is sensitive to spectral high-frequency voice cues when discriminating vocal anger from vocal fear and joy, whereas the amygdala is sensitive to vocal pitch when discriminating between negative vocal emotions (i.e., anger and fear). These results together provide evidence that, besides the auditory cortex, the amygdala too processes acoustic information, when this is relevant to the discrimination of auditory emotions. Other support for the involvement of the amygdala was also reported in processing emotion of fear (both facial and auditory channel) when compared to the mild happy stimuli (Phillips et al., 1998). Additionally, Phillips et al. (1998) found that different neural systems were involved in processing disgust and fear, suggesting the possibility of distinct neural substrates underlying specific emotional vocalisations.

However, some studies have failed to replicate the above effect on vocal expressions of fear (e.g., Anderson & Phelps, 1998; Morris, Scott, & Dolan, 1999). For example, Morris, Scott, and Dolan (1999) reported decreased amygdala responses to fearful vocalisations when compared with a combination of sad, happy and neutral vocalisations. In the same study, the results demonstrating increased anterior insula activation were proposed to be suggestive of functional interactions between the amygdala and insula. However, in Anderson and Phelps's (1998) study, participants with amygdala damage did show poorer recognition of the non-verbal aspects of fearful vocalisations than of other emotions. Given the inconsistency, more investigation into the role of the amygdala in fear processing is expected.

Some studies indicated the neural network for processing anger vocal expressions by involving anger voices as stimuli. Frühholz and Grandjean (2012) examined the brain correlates within the fronto-temporal pathways for decoding angry expressions explicitly and implicitly and found anger also considerably drives brain network responses and dynamic. Specifically, explicit processing activated a specific right-left STG networking connecting higher-level AC while implicit processing elicited low-level left auditory cortex (AC) and left-right STG network. Moreover, a widespread interconnectivity between bilateral IFG and bilateral STG was found during implicit processing but not in explicit processing. Similarly, Korb, Frühholz, and Grandjean (2015) found the brain activity in a number of regions including the superior temporal gyrus, the superior temporal sulcus and the inferior frontal gyrus in the right hemisphere in response to anger (anger vs. neutral) in the auditory modality. This brain network has also been found in prior fMRI studies (e.g., Frühholz, Ceravolo, & Grandjean, 2012; Grandjean et al., 2005) and was regarded as fundamental for the processing of emotional vocal expressions. Using the same stimuli as used in prior studies (Frühholz & Grandjean, 2012) Frühholz et al. (2015) explored the while matter fiber connectivity between regions of STC and IFC using probabilistic diffusion tensor based tractography and reported strong structural connectivity for the right dorsal and ventral temporo-frontal pathway during processing of emotional voices (anger).

As for other emotions, the aforementioned study by Johnstone et al. (2006) also reported increased activation in a number of regions involving the MTG (right anterior, right posterior, and left region specifically) and inferior frontal gyrus when perceiving happy vocal information, compared to angry vocal information. Blasi et al. (2011) studied brain activation during voice and emotion processing in infants during natural sleep. In this study, infants listened to human non-verbal vocalisations in positive, negative and neutral emotional states, as well as a set of non-verbal environmental sounds. This study found increased activation in the insula and orbitofrontal cortex when the infant was being played sad vocalisations, compared to neutral vocalisations.

Although functional imaging studies is significant in providing evidence of neural circuits involved in the processing emotional information in voices, our understanding of brain functions for emotion processing also benefited by the results from neurophysiological studies, such as lesion studies, in which brain regions that are necessary to recognize or express such emotions could be mapped. For example, in a study by Scott et al. (1997), patients with amygdala damage who had normal hearing ability were found to be impaired in recognising non-verbal emotional vocalisations of fear and anger, compared to those without amygdala damage. Apart from the reported significant link between amygdala damage and the recognition of fear expression, there is evidence of atypical emotion recognition of disgust in patients with insula and basal ganglia damage. For example, Calder, Keane, Manes, Antoun, and Young (2000) examined the perception of emotions across modalities (facial expressions, non-verbal emotional vocalisations, and emotional prosody) in a patient with anterior insula and the putamen lesions and found a highly selective difficulties with the recognition and experience of disgust, rather than other emotions, such as fear or anger. Similarly, Sprengelmeyer et al. (1996) also observed impairments in the perception of disgust from both faces and emotional speech in patients with Huntington's disease (HD). In addition, studies of patients with frontal lesions report specific in processing non-verbal emotional vocalisations of sadness can arise following damage to the ventromedial frontal lobe (Hornak et al., 2003).

2.4.2.3 Emotional perception from face-voices

In social interaction, emotional information is largely multimodal and can be expressed via different sources such as facial expressions, vocal prosody, gestures and body postures (Rothman & Nowicki, 2004). In real life, the evaluation of emotions rarely relies on one cue in isolation but on the integration of multiple cues. Thus, successful social interaction depends on the integration of emotional information from multiple sensory organs into a coherent percept, most notably through the interactions between our auditory and visual systems (Koelewijn, Bronkhorst, & Theeuwes, 2010). In recent years, the topic of multisensory emotion processing has received considerable attention. An increased understanding of this area will provide us with a fuller picture of how integrated perception of emotion in the face and the voice occurs, and how the brain integrates information from multiple modalities.

Amongst investigations into audiovisual interactions in the form of multisensory integration, many studies have used facial expressions and emotional voices as bimodal stimuli (Dolan, Morris, & de Gelder, 2001; Klasen, Kenworthy, Mathiak, Kircher, & Mathiak, 2011; Kreifelts, Ethofer, Huberle, Grodd, & Wildgruber, 2010; Park et al., 2010; Pourtois, de Gelder, Bol, & Crommelinck, 2005; Robins, Hunyadi, & Schultz, 2009).

Early research has suggested that even young infants are sensitive to multimodal information (e.g., Haith, Bergman, & Moore, 1977; Walker-Andrews & Lennon, 1991). For example, infants (5-7 month olds) were found to look longer at a face that demonstrates the same expression as the heard voice than at a face which demonstrates a different expression, implying that emotion perception may be inherently multimodal (Walker-Andrews, 1997)..

A great deal of evidence from behavioral and perceptual studies indicates that multi-modal integration (e.g., combined face-voice stimuli) has significant behavioral advantages in facilitating perception, even beyond the effects of each source in isolation (e.g., De Gelder & Vroomen, 2000; Collignon et al., 2008; Dalton, Doolittle, Nagata, & Breslin, 2000; Dematte, 2006), or the sum of their parts (e.g., Iarocci & McDonald, 2006; Stein, Wallace, & Stanford, 1999). For example, congruent bimodal emotional conditions lead to shorter response latencies compared to single-modality conditions (de Gelder & Vroomen, 2000; Dolan et al., 2001; Massaro & Egan, 1996). A study by Forster, Cavina-Pratesi, Aglioti, and Berlucchi (2002) instructed observers to press a response key as soon as they perceived a visual and/or a tactile stimulus. It was found that reaction times were significantly shorter for simultaneous visual-tactile stimuli than for two visual stimuli or two tactile stimuli.

In addition to the congruency effect, modality dominance in crossmodal integration processing has been researched in recent years, with a focus on emotion perception paradigms. Evidence of visual dominance in perceiving emotions from audio-visual integration has been reported in a few studies (e.g., Collignon et al., 2008; Klasen et al., 2011). For example, Collignon et al. (2008) requested participants to identify emotions in an audio-visual emotionally incongruent condition, and found that participants performed better in the visual (face) to-be-attended condition, compared to the auditory to-be-attended condition, suggesting enhanced salience for the visual domain in perceiving emotions from audio-visual integration. However, Petrini, McAleer, and Pollick (2010) reported the dominance of the auditory signal over the visual signal in the perception of emotional expression from music improvisation. However, there is a possibility that inconsistency between these studies may be explained by their unimodal differences rather than differences in the nature of audio-visual integration. For example, the emotion perception was mainly based on auditory signal might be due to the fact that auditory signals play a particularly salient role when listening to music than the corresponding visual signals. In addition, Collignon and colleages added that participants were more likely to base their response on the less ambiguous domain. Therefore, the variable nature of modality dominance during audio-visual integration tend to be in line with the view that modality dominance is flexibly context dependent and can be affected by different factors, such as differences in whether visual information is temporally unfolding or not, in attention induced by the task or in the reliability of each modality (Collignon et al., 2008; Petrini et al., 2010; Takagi et al., 2015). .

At a neural level, it has been revealed that our brain has the extraordinary ability to integrate rather complicated multisensory information into a unique and coherent percept. There is compelling evidence suggesting multisensory convergence in the superior temporal cortex, most notably in the posterior region (for a review, see Beauchamp, 2005). For example, in a series of studies by Beauchamp, Lee, Argall, and Martin (2004), the pSTS/MTG were found to not only respond to objects presented in auditory and visual conditions, but to show greater activity for combined auditory-visual objects than to the unimodal information (39% greater), suggesting the role of pSTS/MTG in integrating different types of information across modalities. In addition to object perception, the STS was also found to demonstrate multisensory responses to cross-modal linguistic stimuli (Van Atteveldt, Formisano, Goebel, & Blomert, 2004; Wright, Pelphrey, Allison, McKeown, & McCarthy, 2003). In addition, other regions showing multisensory convergence in some studies include the the insula/claustrum (Calvert, 2001; Mesulam & Mufson, 1982; Pearson, Brodal, Gatter, & Powell, 1982) , the orbitalfrontal cortex (Jones & Powell, 1970) and sub-cortical areas such as the thalamus (Mufson & Mesulam, 1984), intraparietal sulcus (Calvert, 2001; Stein & Stanford, 2008), superior colliculus (Stin & Meredith, 1990; Wallace, Meredith, & Stein, 1998) and fusiform gyrus (Kassuba et al., 2011).

Beyond face-voice integration, only a small number of studies have attempted to explore the neural correlations to emotion perception using neuroimaging techniques (Dolan et al., 2001; Ethofer et al., 2006; Pourtois, de Gelder, Bol, & Crommelinck, 2005). It is noteworthy that these studies tend to use stimuli consisting of a static photograph of faces paired with a short audio clip. In a study that contrasted congruent audio-visual fear expressions with incongruent audio-visual expressions, the left amygdala was found to be significantly activated (Dolan et al., 2001), suggesting the involvement of amygdala in multimodal emotional processing, especially for fear. Pourtois et al. (2005) investigated the cerebral activation of participants performing gender discrimination tasks on emotions of fear and happiness conveyed by visual (face), auditory (voice) and a combination of both modalities (face-voice). After conjunction analysis, it was found that the middle temporal gyrus (MTG) was more activated in response to audio-visual stimuli than either face only or voice only stimuli, regardless of the emotion category. A separate conjunction analysis of emotions revealed different activations in brain substrates for the processing of happy or fearful audio-visual information. Specifically, regions of the superior frontal gyrus, the middle frontal gyrus, and the inferior parietal lobule in the left hemisphere were involved in the happy audio-visual integration, while a posterior region of the MTG was found to be highly involved in fear audio-visual integration. In another study by Park et al., (2010), a number of regions involving the superior temporal gyrus (STG), inferior frontal gyrus (IFG), and parahippocampal gyrus including the amygdala were more activated for processing bimodal stimuli than unimodal stimuli, irrespective of emotion content. In addition, analysis of specific emotions suggested that anger (anger vs. neutral) activated regions of the posterior cingulate, fusiform gyrus, and cerebellum, while happiness (happiness vs. neutral) activated regions of the MTG, parahippocampal gyrus, hippocampus, claustrum, inferior parietal lobule, cuneus, middle frontal gyrus (MFG), IFG, and anterior cingulate. Along with this, the study reported an increased functional connectivity between the audio-visual integration regions and primary auditory and visual regions, suggesting the existence of parallel processing pathways for multisensory integration.

In order to maximally represent real-world social contexts, dynamic events have also been used in a few studies. For example, Kreifelts et al. (2007) used dynamic video paired with a single spoken word, and found increased activation in the posterior superior temporal gyrus (pSTG) and right thalamus when contrasting the audiovisual condition to unimodal conditions. Using continuous carryover design, Watson et al. (2014) examined the brain correlates of the integration of emotional information (angry, happy) from the face and voice. It was firstly found the crossmodal adaptation in the pSTS and confirmed the presence of pSTS as "convergence" areas to combine inputs from visual and auditory cortices. Similarly, Robins, Hunyadi, and Schultz (2009) involved dynamic emotional cues (anger, fearful, happy) and also reported increased activation in the posterior superior temporal sulcus (pSTS) during the audiovisual conditions. Separate analyses also indicated audio-visual integration in regions of the bilateral anterior superior temporal gyrus (aSTG) and fusiform gyrus (FG) for emotional information, and only in the right aSTG and left FG for neutral stimuli. In addition, separate analysis of the emotions (emotion vs. neutral) found that the bilateral aSTG activation detected in the emotional audio-visual display was highly driven by angry stimuli, with the left aSTG being driven by fearful audio-visual stimuli. In a more recent study, Kim, Wang, Wedell, and Shinkareva, (2016) extended past research and examined how the valence and arousal information in naturalistic dynamic multimodal stimuli are represented in the brain. Using multivariate pattern analysis
(MVPA) approach, the study confirmed a number of regions to be responsive to valence information (PCC, MFG, STG, MTG, mPFC) and arousal information (PC and OFC), and many of these regions were consistent with the brain regions previously linked to modality-general representations of emotions (e.g., MFG, STG).

Altogether, the above section attempted to provide an overview of what we currently know about the development of emotion recognition in humans and the neural representations of emotional expressions in the brain. It needs to note that even though there is considerable evidence, as discussed above, supporting for different neutral systems of emotion processing, it does not necessary refer to one-to-one relationship between the brain structure and functions. Indeed, Lindquist, Wager, Kober, Bliss-Moreau, and Barrett (2012) suggested that it is not possible to isolate unique and specific neural correlates for each basic emotion as the brain area activated by one emotion was also activated by at least another basic emotion. Using a hierarchical Bayesian approach, Wager et al. (2015) conducted a multivariate meta-analysis to identify patterns of brain activity engaged in processing five emotion categories. Even though a unique and prototypical pattern of brain activity for each emotion category, Wanger and colleagues emphasized that these activation patterns partly overlap one another, and are linked to other basic process. These results seem to indicate that emotion categories are not constrained within any one single region or system, but are represented by multiple brain networks or a one-to-many relationship (e.g., Anderson, 2016; Kirby & Robinson, 2015; Vytal & Hamann, 2010).

There are studies to consider the representation and processing of emotional states in the brain from a different point of view. In a study by Baucom, Wedell, Wang, Blitzer, and Shinkareva, (2012) used MVPC to classify dimensional affective properties of pictures based on distributed whole brain activity and to identify patterns of brain activity that predict affective responses but are not necessarily constrained to anatomical regions implicated by univariate analysis. Results of this study suggested that two emotional dimensions (valence and arousal levels) were linked to neural patterns of activity. These results seem to be consistent with a circumplex model of emotional states. Using peak coordinates derived from a meta-analysis of task-evoked emotion fMRI studies, Touroutoglou, Lindquist, Dickerson, and Barrett (2015) generated a set whole-brain rs-fcMRI discovery maps for each emotion category and examined the spatial overlap in their conjunction. Data of this experiment deny patterns of brain activity constitute legitimate neural bases for basic emotions, as they do not correspond to intrinsic patterns of neural co-activation (e.g., to the networks found during resting state). Instead, the variance in the discovery maps was accounted for the domain-general network, supporting the conceptual act theory of emotion.

However, it needs to note that the choice of statistical methods in meta-analysis (e.g., standard pairwise comparison, or density analysis, or co- activation approach) is crucial and can lead to different results. So far, it appears to us that a wealth of evidence supports the existence of relatively specialized neural networks for the processing of different basic emotions. Despite of evidence supporting different view (e.g., Baucom et al., 2012; Touroutoglou et al., 2015), neuroimaging data and recent meta-analyses does not seem to provide sufficiently solid ground to disconfirm the concept of basic emotions. It is still important and good to retain the value of basic emotions. At the same time, it would be beneficial to reconsider the plausible approach to the study of basic emotions. It is thus suggested that the absence of strict one-to-one mapping between structures and functions does not necessary require the abandon basic emotions themselves; And the focus of neuroscientific research are suggested to move from individual brain regions to networks, and from the simplistic region-based one-to- one localizations to more sophisticated network-based one-to- many relationship between neural structure and function (Celeghin, Diano, Bagnis, Viola, & Tamietto, 2017).

2.4.3 Emotion perception ability and performance

The classroom context is a social entity containing various aspects, including student-teacher interactions, student-student interactions, pedagogical strategies, classroom management, and motivational climate (Brown, Kanny, & Johnson, 2013). Individuals' emotional knowledge sets the basis for effective emotion utilization and social adjustment, playing a significant role in social and behavioural outcomes (Izard, 1971; 2002). A great deal of research has attempted to uncover the associations between emotion and performance, confirming the significant role of emotion understanding in numerous outcomes.

2.4.3.1 Emotion perception ability and language competence

The associations between emotion understanding and language competence have been explored in a number of studies in children. For example, Colwell and Hart (2006) examined children's recognition of emotions (happiness, anger, sadness and fear) displayed by an adult female, and found that children's emotion perception ability was positively associated with their language competence. Similarly, Trentacosta, Izard, Mostow, and Fine (2006) reported positive associations between verbal ability (as assessed by the Stanford-Binet vocabulary subtest) and children's knowledge of facial expressions and their understanding of prototypical situations related to happiness, sadness, anger, and fear. In addition, evidence for an association between emotion understanding and vocabulary scores (as assessed by the vocabulary subtest of the Weschler Intelligence Scale) was reported by Bajgar, Ciarrochi, Lane, and Deane (2005) in which children were asked to answer two types of questions: "How would you feel?" and "How would the other person feel?" in response to evocative interpersonal scenarios that were developed to elicit feelings of anger, fear, happiness, or sadness. Some researchers suggested that the associations between emotion knowledge and language competence might due to the fact that completing most of the tasks require verbal abilities in participants (Shields et al., 2001)

2.4.3.2 Emotion perception ability and attentional competence

In addition to language competence, emotion perception ability has also been found to interact with attentional competence. Eisenberg et al., (2001) suggested that attention is an indicator of regulation ability. In this sense, students use attention to regulate emotions, and their experience of emotions impacts the attention toward or away from the stimulus, which in turn affects the type and intensity of a child's emotional experience (Greenberg & Snell, 1997). For these reasons, attentional competence is a potential correlate of emotional competence.

According to Nelson, Martin, Havill, and Kamphaus (1999), children with high emotion perception ability are more likely to perform better in focusing and maintaining attention in the classroom. In a study examining the associations between emotion knowledge and attentional competence (Trentacosta et al., 2006), participants were asked to identify those of their peers who expressed the highest level of happiness, sadness, and anger. Results of this study suggested that children who show more happiness nominations and fewer sadness and anger nominations are more likely to be rated by teachers as being more attentionally competent. In contrast, those children who show more sadness and anger nominations tend to be rated as less attentionally competent. Findings of this study provide support to the assertion that attentional competence is correlated with positive peer perceptions (Ruff & Rothbart, 1996; Bellanti et al., 2000). These results tend to suggest that students who perform better in emotion recognition task tend to be equipped with appropriate emotion display rules and tend to show attentional competence (e.g., sustaining their attention on academic tasks). The ability of sustaining their attention and inhibiting the tendency of being distracted from tasks in the school environment is significant for their successful learning (Entwisle & Alexander, 1998).

2.4.3.3 Emotion perception ability and motivational outcomes

Emotion perception ability is directly linked to the input and output of the emotional states of individuals and have an impact on motivational processes (Carver, 2004), which in turn is thought to influence motivational outcomes either independently (Efklides & Petkaki, 2005) or in concert with achievement goals (Linnenbrink & Pintrich, 2002). Research has shown that good emotional understanding may facilitate the sensitivity of students to teachers' feedback about their performance and behaviours (e.g., Cutting & Dunn, 2002). This may be related to motivational processes, such as putting in more effort and engaging in self-regulation which in turn facilitates cognitive engagement and thus increases the adoption of achievement goals (e.g., Estrada, Isen, & Young, 1994; Pekrun, Goetz, Titz, & Perry, 2002). In a reciprocal pattern, outcomes such as academic performance may feedback and influence the interest and attention that children devote to an academic task, thus impacting upon emotions and emotion perception ability (Pekrun, 1990).

2.4.3.4 Emotion perception ability and school outcomes

A number of studies have examined the associations between emotion perception ability and performance in students. One study suggested that children high in emotion perception ability tend to participate in more advanced forms of cognitive activities at school (Rivers, Brackett, Salovey, & Mayer, 2007). In a study by Collins and Nowicki (2001), children's ability to express emotions and understand others' emotions displayed in faces, postures, gestures, and tone of voice was found to be positively related to their academic achievement. Similarly, there is research suggesting that students' emotion perception ability moderates associations between achievement goals and outcomes (e.g., Vassiou, Mouratidis, Andreou, & Kafetsios, 2014). Indeed, Izard et al. (2001) suggest that the emotion understanding mediated the relation between early school readiness, verbal ability, and teacher ratings of academic competence in middle childhood.

In addition, individuals' emotion perception abilities impact the dynamics between students and teachers, which in turn influence their school performance. There is evidence suggesting that students with high emotion perception ability can better regulate their negative emotions (Bandura, Caprara, Barbaranelli, Gerbino, & Pastorelli, 2003) and tend to experience more positive emotions as they exhibit more pro-social behaviour (Bandura et al., 2003) than students with low emotion perception ability. Thus, high emotion perception ability tends to facilitate emotional exchanges amongst students and between students and instructors in the learning/classroom context (Linnenbrink & Pintrich, 2002). This transmission of emotions between students and teachers will facilitate teachers' gathering of information regarding the learning comprehension and understanding of students. However, students with low emotion perception ability may have poorer relationships and may experience more disruptive encounters (e.g., stress or conflict) with teachers and peers, and as a result, leading to inability in concentrating on academic tasks (Izard, et al. 2001).

Taken together, these findings suggest that individuals' emotion understanding is not only important for their social skills and social relationships, but also for other outcomes through mediating the relation between emotional understanding, motivational competence, language competence, attentional competence, and academic performance. For example, emotion understanding skills of individuals may provide them with more positive peer and teacher relationships that facilitate achievement motivation and attention towards academic tasks, leading to good learning outcomes (Trentacosta et al., 2006). In this sense, the ability in emotion perception is an important facet of emotional intelligence and has profound effects on one's global ability (e.g. Qualter, Whiteley, Hutchinson, & Pope, 2007). Results of these studies also provide evidence for informing educators, practitioners and school psychologists the needs to consider students' emotional understanding, language competence, attentional competence, motivational competence, learning outcomes as relatively intertwined aspects in their development. In this sense, it is possible that in classroom settings, students who have emotional understanding problems are more likely to have problems in other aspects, such as motivation, attention, and school adjustment.

3. A review of the literature on emotion perception from faces and voices in Autism Spectrum Disorder

As discussed previously, since Kanner's (1943) first description of autism, impairments related to emotion processing have been seen as a hallmark symptom of Autistic Spectrum Disorder. Indeed, the current ICD-10 and DSM-IV criteria for diagnosis of ASD have listed marked difficulties in understanding expressions in faces, gestures, and body postures within their symptomology. In the revised diagnostic criteria for autism spectrum disorders (DMS-5), reduced sharing of emotions and affect was mentioned under the core deficits of social-emotional reciprocity. Those with autistic traits were reported to share their emotions less, and to gain less enjoyment from social interactions. In recent decades, sophisticated neuropsychological techniques have been developed which have allowed us to measure the social-emotional aspects of neural-cognition in individuals. This has provided us with greater understanding of the atypical functions present in a variety of psychological and neurological disorders. The current section of this thesis will describe empirical studies that focus on emotion perception from faces, affect prosody and multichannel communication in individuals with ASD. Both behavioral and fMRI studies will be discussed to provide a full picture of the current status on this topic. Suggestions for future research are made, paying particular attention to methodology and validation.

3.1 Emotion perception from faces

Given that social deficits are a core feature of ASD, along with the fact that much of the social information we perceive during daily communication is conveyed by means of facial expressions, it is not surprising that face processing has dominated the research in ASD literature, more so than the processing of other channels such as voice or body language. The following section will present a review of behavioral and neurological research in face perception and facial emotion processing.

3.1.1 Face processing

Given the significant role of visual processing in social functions (e.g., Baron-Cohen, Wheelwright, & Jolliffe, 1997; Dalton et al., 2005; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002), the development and the use of salient facial features (e.g., eye gaze, mouth movements, face processing) in communication has been widely researched in ASD. Behavioral evidence exists to suggest that individuals with ASD demonstrate atypical patterns of face processing. For example, individuals with ASD were frequently reported to show different scan path and preferential attention for face processing (diminished attention to the eye region, heightened attention around the mouth region: (Baron-Cohen, 1997; Boraston, Corden, Miles, Skuse, & Blakemore, 2008; Gross, 2004; Klin et al., 2002), this type of face processing appears from a very young age (6 months old), continuing into adulthood. In addition, there is also evidence of poor facial identity recognition (e.g., Kirchner, Hatri, Heekeren, & Dziobek, 2011), poor face discrimination (e.g., Rutherford, Clements, & Sekuler, 2007), and poor face memory (e.g., Wilson, Brock, & Palermo, 2010) in individuals with ASD.

One possibility that has been suggested for atypical face processing in ASD stems from a lack of expertise in processing information from faces. Schultz et al. (2000) investigated this phenomenon. They hypothesized that individuals with ASD may process faces in a manner similar to object processing in TDs. This hypothesis was confirmed by their fMRI results, which demonstrated that for processing faces, individuals with ASD tend to recruit neural networks which are more often used for object processing (e.g., inferior temporal gyrus) while typical developing individuals recruited the right fusiform gyrus. In addition, individuals with ASD were found to show atypical patterns of brain activation for face processing, including reduced activation in the fusiform face area (FFA-Haxby, Hoffman, & Gobbini, 2002), and the occipital face area (OFC) (2011, Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Bookheimer, Wang, Scott, Sigman, & Dapretto, 2008; Humphreys, Hasson, Avidan, Minshew, & Behrmann, 2008). Aberrant activation of the amygdala has been reported in a number of studies of face processing in ASD (Bookheimer et al., 2008; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2007).

3.1.2 Emotion perception from faces

The main body of face-emotion processing research in ASD concentrated on the use of children or younger adolescents as participants and measuring the accuracy of recognizing emotions from static, prototypical facial expressions as stimuli (e.g., Hobson, 1986; Lindner & Rosén, 2006). A number of studies have involved older adolescents and adults as participants, in which, a range of stimuli, such as static facial expressions, complex/subtle expressions, blended, or morphed expressions, dynamic expressions have been used, on the basis that these individuals are more likely to have the cognitive ability to accurately identify them (e.g., Baron-cohen, Baldwin, & Crowson, 1997; Howard et al., 2000; Humphreys, Minshew, Leonard, & Behrmann, 2007; Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008; Rump, Giovannelli, Minshew, & Strauss, 2009). These studies tend to use high-functioning individuals or individuals with AS and measure both accuracy and reaction times. However, they have produced mixed results. While many of them have reported decreased recognition accuracy in identifying emotions in adults with ASD, especially for negative emotions, such as disgust, fear, anger, sadness (Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007; Bal et al., 2010; Howard et al., 2000; Sucksmith, Allison, Baron-Cohen, Chakrabarti, & Hoekstra, 2013), some of them have failed to find impaired emotion recognition in adults with ASD (Adolphs, Sears, & Piven, 2001; Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008; Ogai et al., 2003; Rutherford & Towns, 2008) or more subtle emotions (Baron-cohen et al., 1997; Teunisse & de Gelder, 2001). A number of factors might have contributed to the heterogeneity of results, including demographic factors (e.g., age, language/verbal abilities), nature of task demands, and which dependent variables were measured (Harms, Martin, & Wallace, 2010).

When the task demands are taken into account, the results of a number of studies do not seem to support a general emotion recognition deficit in ASD. Despite a deficit in emotion recognition being found in some studies (Dalton et al., 2005; Macdonald et al., 1989; Sucksmith et al., 2013; Tantam, Monaghan, Nicholson, & Stirling, 1989; Wallace et al., 2008), there is evidence of no impaired ability in recognizing emotions from faces, especially for the processing of basic emotions (Baron-Cohen et al., 1997; Capps, Yirmiyat, & Sigmant, 1992; Homer & Rutherford, 2008). There are also studies reporting recognition deficits with only specific negative emotions, such as fear, anger and disgust (Ashwin, Chapman, Colle, & Baron-Cohen, 2006), fear and disgust (Humphreys et al., 2007), and fear and sadness (Corden et al., 2008). In addition, there are studies examined the performance of emotion recognition in more complex and subtle emotions and reported that individuals with ASD were less well in recognizing emotions, such as shame, envy, and guilt (e.g., Baron-Cohen et al., 1997) and surprise (e.g., Baron-Cohen, Spitz, & Cross, 1993).

Even if some individuals with ASD appear to show comparable performance to recognise emotions as TDs, this does not rule out the possibility that they are using compensatory mechanisms to do so. It is possible that some individuals with ASD use explicit cognitive or verbally mediated processes to recognise emotions, in contrast to the use of more automatic emotion processing, which occurs in TD individuals. In this sense, higher functional individuals on the spectrum might be able to capitalise on their cognitive and/or language abilities, especially their emotional-word vocabulary, to correctly identify emotions. Consistent with this assumption, there is evidence suggesting that there is an association between mental age (Hobson, 1986) or verbal mental age (Dyck, Piek, Hay, Smith, & Hallmayer, 2006; Ozonoff, Pennington, & Rogers, 1990) and emotion recognition ability in individuals with ASD, at least in terms of recognising basic emotions. A meta-analysis by Trevisan and Birmingham (2016) has also supported a positive correlation between verbal intelligence and face emotion recognition in individuals with ASD. In addition, in some cases, the local/featural processing style in ASD may compensate for a less efficient processing style, especially for those who have learnt skills in using salient features to analyse emotions.

Recently, an increasing number of studies have used dynamic facial expressions as stimuli to examine the ability of emotion recognition in ASD due to their higher ecological validity compared to static images of faces. Some of these studies reported impaired ability in recognizing emotional faces, in which, children and young adolescents with ASD were involved (e.g., Bal et al., 2010; Evers, Steyaert, Noens, & Wagemans, 2015; Golan, Baron-cohen, & Golan Yael, 2008). In another study, which involved older adolescents and adults, Charbonneau et al., (2013) reported impaired emotion recognition in faces in individuals with ASD. Conversely, there are studies to suggest no recognition impairments in individuals with ASD (Gepner, Deruelle, & Grynfeltt, 2001; Jones et al., 2011; Kätsyri, Saalasti, Tiippana, von Wendt, & Sams, 2008; Lacroix, Guidetti, Rogé, & Reilly, 2009; Loveland et al., 1997).

In everyday social interactions, individuals frequently encounter more subtle facial expressions. A number of studies have used morphing techniques (Leopold, Toole, Vetter, & Blanz, 2001) to produce emotions to best represent these type of emotional expressions in experimental settings, Individuals with ASD have shown difficulty on tasks that using mixed facial expressions (e.g., Teunisse & de Gelder, 2001), emotion blends (e.g., Humphreys et al., 2007; Kuusikko et al., 2009), and sequences of low- to high-intensity emotional faces (e.g., Bal et al., 2010), although there have been some exceptions (e.g., Castelli, 2005; Homer & Rutherford, 2008).

Despite of the well-researched behavioral studies, their underlying brain functions have only recently been examined, and this is mostly thanks to advances in imaging techniques, such as functional magnetic resonance imaging (fMRI). To date, imaging studies has reported atypical patterns of brain activation in ASD for processing emotional expressions in faces, regardless of whether their behavioral performance was preserved (e.g., Homer & Rutherford, 2008) or impaired

(Philip et al., 2010; Rump et al., 2009). Some studies have reported fusiform hypo responsiveness to facial expressions of emotions individuals with ASD (e.g., Bölte et al., 2006; Critchley et al., 2000; Deeley et al., 2007; Hall, Szechtman, & Nahmias, 2003; Piggot et al., 2004; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004). In addition to the FG, the amygdala is also a region that has been examined extensively in ASD research. Decreased amygdala activity has frequently been reported in people with ASD in response to emotional faces (e.g., Ashwin et al., 2007; Corbett et al., 2009; Dapretto et al., 2006; Pelphrey, Morris, McCarthy, & LaBar, 2007; Weng et al., 2011), although some studies have failed to find decreased amygdala activity (Piggot et al., 2004), and one study have found increased amygdala activity (Monk et al., 2010).

In addition to the amygdala, FG and related structures, abnormalities in other brain regions have also been detected in ASD. Some have reported hypoactivity in brain regions such as the left orbito-frontal cortex (OFC) (Ashwin et al., 2007), cerebellum (Critchley et al., 2000), extrastriate cortices (Deeley et al., 2007), medial-frontal and orbito-frontal cortices (Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008; Ogai et al., 2003), and inferior frontal gyrus (IFG) (Mirella Dapretto et al., 2006; Greimel et al., 2010; Hall et al., 2003; Ogai et al., 2003) compared to TD controls while other studies have reported increased activation in the superior parietal lobule (Hubl et al., 2003), precuneus (Wang et al., 2004), occipital and anterior parietal regions (Dapretto et al., 2006), anterior cingulate gyrus and superior temporal cortex (Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007), and vPFC and striatum (Weng et al., 2011).

As in behavioral studies, the task format may also impact upon results in fMRI studies. For example, there may be significant differences in the relative pattern of brain activation for the task demands requiring explicit or implicit processing. Consistent with this assumption, Critchley et al., (2000) compared brain activity in two separate tasks between individuals with and without ASD, one requiring explicit processing (emotion labeling) and the other requiring implicit (gender labeling) processing. They found that autistic individuals showed decreased activation than TDs in the left cerebellum and left amygdala-hippocampal region in gender identification task. In explicit processing task, the left middle temporal gyrus was activated in TDs but not in ASDs. In addition, Piggot et al., (2004) and Wang et al., (2004) found reduced FG activity in face-emotion matching tasks, but not in labeling tasks.

There is evidence of atypical neural activation during the processing of dynamic facial expressions in several brain regions of individuals with ASD (Pelphrey et al., 2007; Sato, Toichi, Uono, & Kochiyama, 2012). For example, Pelphrey et al. (2007) found decreased activation in regions of amygdala and fusiform gyrus in individuals with ASD compared to TDs during the viewing of dynamic facial expressions (anger and fear). It was also reported that only the TDs demonstrated activity that differentiated dynamic and static facial expressions of emotions. Using the emotions of happiness and fear, Sato et al. (2012) found decreased activity in the regions described above and also in the inferior frontal gyrus (IFG) in individuals with ASD, compared to TDs.

Altogether, the overview of these studies reveals that individuals with ASD show a tendency to employ an object-processing strategy for face processing, which is perhaps due to a lack of motivation to attend to, or a preference for not attending to, the social salient features of faces. As for the processing of emotional expressions, alteration in the ability to recognize emotions in ASD has been found in most of the studies in this area, which is often suggested as a possible source for certain atypical social and communicative behaviours that characterize this population, despite a few exceptions. A number of factors, including demographic characteristics of participants, stimulus type, task demands, variables measured, methodological features (e.g., labelling versus matching paradigms) could all account for the heterogeneity of findings regarding emotion processing (behavioral and neural) in ASD. Therefore, It is important to be cautious when interpreting the results from previous studies. As for the results of the imaging data, along with the above factors, the selection of baseline conditions, the use of different statistical thresholds including those that were uncorrected for multiple comparisons, makes it difficult to directly compare and contrast findings between studies. Despite of this, results from functional neuroimaging studies have implicated a range of cortical lobes that demonstrated atypical activity in ASD (involving both hypo-responsiveness and hyper-responsiveness). Factors contribute to atypical brain activity in ASD might vary across participants, but one possibility is that ASD individuals tend to use different patterns of processing strategy in processing social information, such as pay increased attention to specific features of faces and employing conscious self-monitoring of their responses (Ashwin et al., 2007), more local processing strategy (Hubl et al., 2003), increased attentional load (Wang et al., 2004) or increased visual and motor attention (Dapretto et al., 2006). These suggestions, if they are accurate, may be indicative of more effortful and less automatic processing of emotions in individuals with ASD than in TD controls.

3.2 Emotion perception from voice

The auditory modality (such as the tone of voice), like the visual modality, constitutes an important part of social-communicative interaction. Behavioural research examining the perceptual aspects of voice expressions were typically preceded to present participants with emotional expressive semantically neutral sentences/word and asked them to match the presented stimulus to expressive faces or descriptor words in a forced or multi-choice response task. Most empirical research in this area suggests the presence of deficits in comprehending emotional expressions in voice when individuals are asked to label those emotions (e.g., Jones et al., 2011; Lindner & Rosén, 2006; Mazefsky & Oswald, 2007; Philip et al., 2010; Rutherford, Baron-Cohen, & Wheelwright, 2002), or to detect the emotions in irony and sarcasm (e.g., Wang, Lee, Sigman, & Dapretto, 2006; Wang, Lee, Sigman, & Dapretto, 2007), or to match them to facial expressions of emotions (Hobson, Ouston, & Lee, 1988; Loveland et al., 1995). However, there is also evidence of comparative performance between groups (ASD vs. TD) in vocal affect naming tasks (e.g., Baker, Montgomery, & Abramson, 2010; Jones et al., 2011; O'Connor, 2007) or face-voice emotion matching tasks (e.g., Loveland et al., 1997). Similarly to emotion recognition in faces, a number of factors are proposed to contribute to the heterogeneous results in the existing literature, including types of tasks/task procedures, task demands, and demographic features (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007).

The processing of emotional information in voices appears to be related to task manipulation. There is evidence suggesting that individuals with ASD are more likely to be impaired in tasks which involve higher order cognitive loads, such as complex emotions (Golan, Baron-Cohen, Hill, & Rutherford, 2007; Rutherford et al., 2002), abstract emotions (Golan et al., 2007), social emotions and attitude recognition (Chevallier, Noveck, Happé, & Wilson, 2011). There is also evidence of impaired recognition perception in individuals with ASD in understanding irony, one of the types of stimuli that require higher-order mindreading skills (e.g., Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2001; Wang, Lee, Sigman, & Dapretto, 2006; Wang et al., 2007). Aside from the task demands, task procedures might also help explain the conflicting findings regarding emotion recognition in voice. For example, in a series of emotion recognition tasks involving faces, voices, and faces and voices, individuals with ASD have been found to show comparable performances to TDs in auditory conditions (O'Connor, 2007). However, in response, Philip et al.,(2010) argued that the same emotional cues were used more than once in tasks (e.g., auditory cues were used in both the auditory perception task and the face-voice task), which may have had an impact in modulating the participants' performance. Then, in the study of Philip et al. (2010), by using different stimuli across tasks (face, body movements, and vocalisations), individuals with ASD were found to be impaired in their performance, suggesting a broad-ranging deficit in emotion perception including in the auditory domain.

It has also been suggested that demographic characteristics may impact upon the results regarding emotion perception from voices, such as sample size, diagnostic distinct across participants. As mentioned above, impaired recognition of basic vocal expressions were reported in a few studies involving children (Lindner & Rosén, 2006); and adults (Philip et al., 2010). However, it needs be aware that these differences may be limited due to the relative small sample size. In a study involving a relatively large sample size (99 adolescents with ASD and 57 age- and IQ-matched controls), Jones et al., (2011) found comparative performances between groups when they were required to identify emotional expressions in voices. In addition, there is also evidence of different performance in performance among autistic individuals with different diagnoses. Mazefsky and Oswald (2007) examined emotion perception from facial expressions and vocal/linguistic expressions across three groups: children with HFA, AS and TDs. Impaired emotion perception was found in the children with HFA but not AS and TDs.

Compared to the increasing neural evidence for the processing of emotional expressions from faces by individuals with ASD, the neural processing of emotions from voices is still largely unexplored. Current research in this area tends to report differences within the temporal and/or frontal regions amongst individuals with and without ASD, especially for the research using speech stimuli (Blasi et al., 2015; Gervais et al., 2004; Hesling et al., 2010; Lai, Schneider, Schwarzenberger, & Hirsch, 2011). Hesling et al., (2010) found hypoactivation in regions of the left middle temporal gyrus, left media prefrontal cortex and left precuneus in adults with ASD than TDs in response to speech stimuli. Gervais et al. (2004) reported that adults with ASD failed to elicit significant activation in the STS in response to vocal sounds, and no brain region was more activated by vocal sounds than non-vocal sounds in this sample. Indeed, the critical role in the perception and processing of social information within the STS have been reported across modalities (Materna, Dicke, & Thier, 2008; Redcay, 2008).

There is evidence of differing neural activation for the processing of emotional expressions among individuals with and without ASD. Eigsti, Schuh, Mencl, Schultz, and Paul (2012) directly explored the neural processing of emotional (anger) prosody in individuals with HF-ASD. During an implicit task (no emotion labelling required), TD adolescents showed increased activation relative to ASD individuals in the left IFG, whilst the ASD group activated more widespread brain regions, involving bilateral parahippocampal gyrus, which may be related to the memory demanding or the visualization of stimuli. Eigsti et al. (2012) discussed the results and suggested that the widespread brain activation may be due to a more effortful processing of social information as well as a higher reliance on cognitive control in ASD. Despite this evidence for the processing of anger in voices, the brain correlates involved in the processing of other emotions are still to be investigated. A recent fMRI study by Gebauer, Skewes, Westphael, Heaton, and Vuust (2014) examined the processing of affective prosody (happy, sad and neutral) in adults with and without ASD, and the authors reported that a number of regions in the fronto-temporal and subcortical brain regions were activated in both groups when processing affective prosody. When a less conservative statistical significance level ($p<0.001$ uncorrected) was applied, the ASD group were found to show increased activation in the right caudate in response to affective prosody, and they tended to rate the emotional intensity as lower than TDs, which may suggest increased attentional demands experienced by this group. In addition, Wang et al. (2006) reported enhanced activation in the right inferior frontal gyrus and bilateral temporal regions in adolescents with ASD than typical developing individuals in response to ironic sentences. In addition, correlations between enhanced right temporal activation and communicative functions and increased activity in right inferior frontal and bilateral temporal regions and verbal IQ were also reported in the ASD group. Blasi et al. (2015) found that infants who were at low risk for ASD elicited more activation than high-risk infants in the right fusiform gyrus and left hippocampus in response to sad vs. neutral vocal sounds. Neutral voices caused less activation than sad voices in the caudate and the right superior frontal gyrus among infants with high-risk of ASD than they did in low-risk infants.

As has been discussed above, similar discrepancies have been observed in studies that have investigated perception of emotions from voices in ASD. These inconsistencies are likely due to a combination of differences in task design, demographic features across studies and inter-individual differences amongst participants (Järvinen-pasley, Wallace, Ramus, Happé, & Heaton, 2008). Imaging studies tend to provide evidence of neuroanatomical differences in temporal and/or frontal regions to emotional vocal information processing. These limited results tend to suggest the excessive cognitive control or greater resources elicited for processing communicative cues in ASD. These assumptions might also be interpreted to suggest a less automatic processing strategy in ASD. However, the research in voice processing, especially non-verbal affective vocalizations in ASD is still scarce. To further progress our understanding of this field, more research aimed at determining the neural activity for both general emotional information and for specific emotions are warrant.

3.3 Emotion perception from face-voice

Previous research into emotion processing has mostly focused on uni-modal systems, such as only focussing on facial expressions or only vocal sounds. In natural settings, most of our social interactions involve combining information from both the face and the voice. The ability to combine such information accurately, resulting in a unified percept, is a requisite skill for adaptive social functioning. As previously demonstrated, in typically developing individuals, audio-visual integration is usually reported to be advantageous in enhancing performance in emotion recognition (de Gelder & Vroomen, 2000; Dolan et al., 2001; Kreifelts et al., 2007). A number of studies have been conducted on face-voice integration in ASD. Amongst these studies there is evidence suggesting that individuals with ASD cannot integrate multisensory information appropriately in emotion perception (e.g., Charbonneau et al., 2013; O'Connor, 2007; Xavier et al., 2015). For example, O'Connor (2007) reported that adults with ASD were less accurate in identifying whether faces and voices were emotionally congruent or emotionally incongruent, though they showed comparative performances in unimodal conditions in the context of emotion recognition. Similarly, decreased multisensory gain during audio-visual processing (differentiating fear and disgust) was found in individuals with ASD, as compared to typically developing individuals (Charbonneau et al., 2013). However, there are studies reporting no impairments of individuals with ASD in matching photographed facial expressions with emotional gestures and voices (Prior, Dahlstrom, & Squires, 1990), or in distinguishing between emotional congruent and incongruent faces and voices.

Despite of the comparative performance (as reported in a few studies) at the behavioural level, it does not necessarily mean that they use typical neural mechanism in the process of multisensory integration as individuals without ASD as it is difficult to rule out compensation strategies. A few studies have examined the neural correlates in multisensory processing in ASD and reported atypical patterns of brain activation in ASD. In a pilot study by Loveland, Steinberg, Pearson, Mansour, and Reddoch (2008), no clusters were reported to show greater activation in the ASD group in response to emotionally congruent face-voice pairs vs. emotionally incongruent face-voice pairs, compared to a TD group, which showed more activation in a number of brain regions including the bilateral lingual gyrus, bilateral cuneus, right middle frontal gyrus, and left parahippocampal gyrus and left fusiform. These results provide evidence of the brain regions responsible for processing face-voice stimuli in ASD. However, the small sample size in this pilot study limits the conclusions that can be drawn. Later, Doyle-Thomas, Goldberg, Szatmari, and Hall, (2013) reported that individuals with ASD activated different brain areas in the frontal-parietal network - regions that were reported to be involved in attention modulation and semantic processing (Silk et al., 2005), compared to TDs, who activated a number of frontal and temporal regions. The authors discussed these results and suggested that the teenagers with ASD in their sample may have recruited the parietal-frontal network as a compensatory system.

Altogether, the evidence for intact ability of multisensory integration in ASD appears mixed at first glance, but the neural abnormities reported from functional imaging studies tend to suggest the use of compensatory mechanism of individuals with ASD in facilitating emotional information processing from multiple modalities. Given the limited evidence and very little comparative work that has been done in the area of multisensory perception, there is certainly need for further exploration of the determinants of MSI in autism. Future research in this area will hopefully further elucidate the specific processes underlying multisensory integration and clarify the emotion specific processing.

3.4 Emotion perception in ASD with comorbid anxiety

Anxiety disorders have been suggested to be one of the most common disorders to occur concurrently with the entire spectrum of ASDs (Nadeau et al., 2011). Despite the frequently reported presence of comorbid anxiety in ASD, to the researcher's knowledge, there is no behavioral study has examined the relationship between comorbid anxiety and autistic traits in the context of emotion perception. Only a few studies have examined the relationship between symptoms of autism and anxiety in modulating the neural activity during the processing of emotional information. An early study by Amaral, Bauman, and Schumann (2003) reported an abnormal amygdala structure and function in social behaviors in the adult and infant macaque monkey, which the authors suggested to be related to higher rates of fear and increased anxiety. In an aforementioned study by Corbett et al. (2009), the authors reported a negative correlation between social anxiety symptoms and the size of the right amygdala in children with ASD (in comparison with the size of the left amygdala, and the total cerebral volume). In responding to emotional faces (angry and fearful) in a matching task, Kleinhans et al. (2010) indicated that as anxiety scores increase, hyperactivation in the right amygdala and left middle temporal lobe, and hypoactivation in the fusiform face area occurred for the ASD group, while no relationship was found between anxiety and brain responses in the TDs.

The above studies suggest that anxiety has an impact on brain activation (mainly in the amygdala) during emotion processing in individuals with ASD. These results suggest that anxious individuals with ASD tend to have an increased sensitivity to emotional information, which may hinder their interpretation of and responses to emotional information from the face, and result in greater levels of avoidance. However, no absolute conclusions can be drawn from the existing literature, due to the limited number of studies in this area.

3.5 Summary

Generally speaking, the results of the existing literature suggest that there are differences in emotion perception and brain processing of emotional expressions in individuals with ASD in comparison with TDs. This might explain some of the difficulties this group have with detecting emotions in others. These atypical patterns of communicative information processing may have a substantial effect on social development and interpersonal interactions, and may be considered as a contributing factor to the social and communicative impairments that are evident in ASD. The findings from these studies add a valuable contribution to the understanding of autistic neurophysiology.

Overall, behavioral studies suggest that individuals with ASD tend to decode emotional expressions from different channels differently to TD individuals. However, in some cases, they perform similarly to controls in labelling/matching emotions. This comparative performance between individuals with ASD and TDs is possibly due to the use of compensatory mechanisms, such as feature-based learning, language/verbal mediated processes, or other analytic strategies, in order to compensate for a lack of intuitive emotion recognition capability. These assumptions are also complemented by the results revealed from neurological studies in ASD. Take facial emotion processing as an example: individuals with ASD are reported to show a tendency towards hypo-activation in the amygdala-fusiform areas, along with hyper-activation in widespread brain regions such as the ACC and precunues, which are thought to be related to self-monitoring and attentional load (e.g., Ashwin et al., 2007; Wang et al., 2004). These results may suggest more effortful and cognitively based mechanisms for processing emotional expressions in individuals with ASD than in TDs. This processing strategy tends to be attention-demanding, which may have direct implications for decoding intentions and reciprocating social exchanges, and may contribute to the broader social impairments and interpersonal abnormalities that are characteristic of ASD.

3.5.1 Demographic characteristics of participants

In autism research field, participants across studies tend to be unrepresentative of the ASD population as a whole, as it is disproportionately male (male: female in ASD are 4:1 and in AS are 8:1) (for a review see Philip et al., 2012). These results might be partially due to the fact that researchers tended to exclude female participants in order to reduce additional variation in their sample, as well as the relatively small sample sizes in these studies, which have been often reported in many of the investigations in the literature.

Due to practical considerations, such as task demands, ethical issues, and finding an appropriate comparison group, it is not surprising that the participant profile in the literature is biased towards HFA or AS without learning disabilities. The results from these studies do add a valuable contribution to our understanding of this condition. However, we should remain aware that many of the individuals on this spectrum may also have other conditions along with ASD, such as OCD or anxiety disorders. In this sense, in order to generalise the results from the existing studies to the larger population of individuals with ASD, the recruitment of larger sample sizes that are more representative of the ASD population would be beneficial in future investigations. To maximise the power of studies to identify significant differences between groups, future studies could examine dividing samples into subgroups based on certain demographic features. In addition, in order to answer when and how the emotion process becomes abnormal in ASD, both behavioral and brain-based longitudinal studies are also needed. Longitudinal studies will allow tracking of the developmental changes in brain function, and should also shed light on whether the differences identified in adult populations with ASD are related to the specific expression of ASD, or represent mechanisms developed over time to compensate for impairment.

3.5.2 Stimuli types in studies

It is well acknowledged that during the investigations of behavioural performance and brain function in ASD, there has been a general bias towards the processing of unimodal stimuli, in particular of facial expressions. Whilst this is not surprising given the crucial role of faces in social functions and social communication, emotion perception in our daily life is not limited to uni-modal face processing or to the visual domain. Neural response of individuals with ASD when processing other kinds of social information, such as tone of voice, or multimodal stimuli tends to be under-investigated to date. Moreover, the use of full, apex emotions (e.g., static faces displaying prototypical emotional expressions) may also limit the sensitivity of certain types of behavioral measures, which may have an impact on the mixed findings throughout the literature. In this sense, future research would be benefit from greater investigation by the use of other modalities (e.g., tone of voice), or involving more ecologically valid stimuli (e.g., dynamic and natural facial expressions), or involving cross modal stimuli (e.g., face-voice integration) to investigate emotion processing in ASD. As has been previously discussed, it is increasingly acknowledge that ASD are commonly presented with other conditions, such as anxiety and it is not surprising that the co-morbid anxiety would also impact emotion processing in the behavioral and neuroimaging literature. To reduce this, future studies could take their levels of anxiety into account; and this would maximize the power of studies to identify the specific role of anxiety in modulating their performance.

4. Methodology

All research is based on underlying philosophic assumptions about what constitutes a valid research and what research approaches are appropriate for promoting knowledge within a given research. In order to conduct and evaluate any research, it is therefore important to know what these assumptions are. This chapter discussed the philosophic assumptions and the research methodologies underlying the research. A total of nine sections constructed this chapter (Figure 4.1). Section 1: *The choice of quantitative method* reviewed common philosophical assumptions; the positivism paradigm was identified for the present research. Section 2: *Research design* discusses the specific design used in this research (Study 1, Study 2, and Study 3). In these three studies, data was collected and analysed through qualitative methods. Section 3: *Participant selection* introduces two screening processes, which were included in the project in order to meet the inclusive criteria for determining appropriate participants. Section 4: *Measures* and *Materials* presents the measures used for assessing traits of autism and anxiety in a general population, and describes the two expression databases used for creating experimental stimuli in the present research. Section 5: *An introduction to fMRI* introduces MRI technique, with a focus on fMRI. Section 6: *Data analysis* discusses the preparations made for analysing data from both the behavioural experiment and the fMRI experiments. Section 7: *Ethical considerations* discusses how ethical considerations contributed to the experimental design and the running of the experiments.

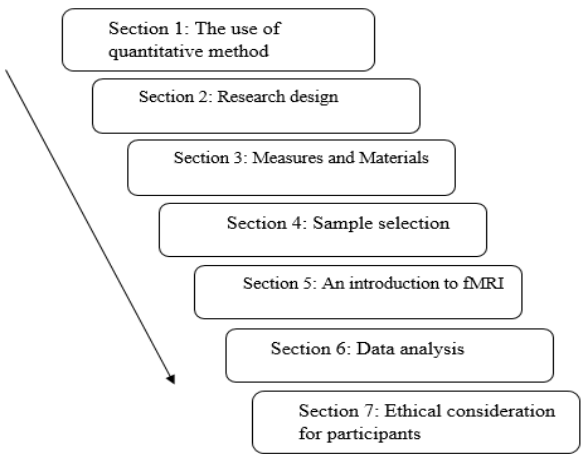


Figure 4.1--The stucture of the methodology chapter

4.1 The use of quantitative method

According to Kuhn (1962), a research paradigm is “the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed”, which can be characterized through ontology, epistemology and methodology (Admiraal & Wubbels, 2005, p.315). Ontology is the study of being and is regarded as the nature of existence and the nature of reality. Epistemology indicates ways of knowing and is regarded as the nature of knowledge. Together, these aspects help to determine the assumptions and beliefs that construct the researchers' view of a research question, how to investigate the research question, and the methods used to achieve the research goals. Methodology refers to the investigative approaches, such as tools or techniques of the research (Guba & Lincoln, 2004, p.21-22; Bryman, 2004; Denscombe, 2002).

It is suggested that particular paradigms is be associated with certain methodologies. In general, the positivism paradigm usually assumes a quantitative methodology while an interpretative or constructivist paradigm usually assumes a qualitative methodology. Which research paradigm should be used? The answer to this question is rather difficult, and to some extent is pragmatic. Generally speaking, any research paradigms contain weaknesses and strengths. It is very important for the researcher to think critically about the specific challenges and strengths of using certain research approaches, and to design the research in such a way that it attempts to eliminate the challenges, resulting in the collection of reliable and valid data. In the following section, a brief review of research paradigms will be presented.

Positivism/Post-positivism The paradigm of positivism/post-positivism of exploring the reality is based on the assumptions that observation and reason are the best ways of understanding human behaviors; true knowledge is based on experience of senses and can be obtained by observations and experiments. At the ontological level, positivists/post-positivists believe that the reality of the world is objective and independent of the researcher's interest in it. The positivists believe that reality is quantifiable, measureable and can be broken into variables. Post-positivists supported this understanding of reality but suggested that research could uncover the reality within a certain realm of probability (Ponterotto, 2005). At the epistemological level, the paradigm of positivism/ post-positivism assumes that knowledge of humans can be tested empirically (e.g., Eichelberger, 1989). The research approaches are quantitative and involve the data collection and analysis from questionnaires, observations, tests and experiments. The research data is objective and independent of the researcher's interest and values. At the methodological level, the research goal of positivism/ post-positivism design is most commonly related with uncovering the facts and to predict behaviors (Bogdan & Biklen, 2003). Specifically, purposes of research may involve predicting results, testing theories or examining correlational or causual relationships between variables. Variables in the positivism/post-positivism paradigm are defined as it is used or measured or observed. Research results can replicable if following the same procedure and methods.

Interpretivism/Constructivism The interpretivism/constructivism paradigm serves as an alternative to positivism/post-positivism. At the ontological level, the interpretivism/constructivism paradigm assumes that the nature of the reality is socially constructed (Mertens, 2009) and consists of individuals' subjective experiences and interpretations of the external world (Walsham, 1993). In this view, multiple realties exist due to the varying human experience (e.g., varying knowledge, experience, and interpretations). At the epistemological level, the interpretivism/constructivism paradigm believes that knowledge and meaning are understood through interpretations and observations, and there is no objective knowledge and meaning that is independent of human mental processes (Deetz, 1996). At the methodological level, the interpretivism/constructivism paradigm focuses on individuals' experiences. It is usually based on qualitative research methods that were taken place in a natural setting. The interpretivism/constructivism research does not predefine the variables (e.g., dependent and independent variables). The research questions tend to be open-ended, descriptive and non-directional (Creswell, 2003) and pay attention to detail and context. Techniques of data collection are varied depending on the research questions, the use of research design, and the nature of participants. They include interviews, focus groups, personal and official documents, observations, etc.

The research questions and goals of my present work dictated the methodology used. As discussed above, a quantitative research approach is usually used to examine the cause of events, or correlations between events, under specific conditions, and uses a deductive approach to problem solving (Tashakkori & Teddlie, 1998). It is very useful for research questions, which require us to draw meaningful summaries from numerical or probabilistic values. The purpose of the current research was to determine whether anxiety symptoms and traits of autism impact individuals' performance in emotion perception. More specifically, the researcher wished to compare whether there were group differences in emotion processing between individuals who are high in autistic traits and individuals who are low in autistic traits, and how levels of anxiety confound their performance. This type of research is positivistic and tends to use hypothetic–deductive method. In this sense, the present work (1) required a highly structured research design, and (2) required a highly objective approach, not only for the research design, but also for the researcher and participants. For example, the research should not be part of what the researcher observes, so that he/she does not bring his or her own interests, values and biases towards the research. Similarly, the research should not be part of what the participants think and believe. It is also important that (3) the results of the work should be determined numerically or statistically, and should be replicable using the same research paradigm, and (4) the variables (dependent and indecent variables) should be pre-defined. Given these considerations, a quantitative approach was very appropriate for the present work, since it provides an exact measurement of the efficacy of such designs and research questions.

The aim of the present work was to promote understanding of emotion perception in people with autistic traits, and this main goal was divided into several research questions. First, a behavioural experiment was conducted to determine any differences in emotion recognition between groups of participants. In this experiment, both the probability of success and response time in the emotion recognition were examined. To provide a complete picture of emotion perception in people autistic traits, an assessment of behavioural performance would not have been enough. Moreover, even comparable performance does not rule out the possibility of different neural systems being recruited for the processing of emotional expressions. Therefore, fMRI experiments were conducted to examine the underlying neural correlates during these processes.

4.2 Research design

The current research used a quantitative approach, which incorporated multiple research strands (Figure 2). A behavioural investigation, based on a laboratory experiment, was used to address the first study aim (Study 1). This experiment comprised three emotion recognition tasks, namely the face emotion recognition task, voice emotion recognition task, and face-voice emotion recognition task Participants' response times and accuracies for the recognition of emotional expressions were recorded for all tasks. The performances were compared between two experimental groups: individuals high in autistic traits and individuals low in autistic traits. In addition, participants' scores on the State Trait Anxiety Inventory-Trait scale (STAI-T; Spielberger, 1983) were used as an index of their level of anxiety, to examine its impact in emotion recognition. Due to the repeated measure design and the potential variability of the data sets across different levels (e.g., a range of emotions), multi-level modelling was used for data analysis (details of this will be provided in the following section).

During the last few decades, the availability of more sophisticated techniques, such as functional Magnetic Resonance Imaging (fMRI; Wicker et al., 2008), and electrophysiological (event-related potentials; ERPs) (Wong, Fung, Chua, & McAlonan, 2008) has allowed for the mapping of associations between brain functions and behaviours across a wide range of research topics. In the field of autism, an ability to explore the neural correlates underlying emotion perception is significant in terms of allowing us to understand behaviours and the theoretical basis of information processing in such a population, and is of potential use in developing therapies. Therefore, in addition to measuring behaviours, I also examined the cerebral representations, which occurred during the processing of emotional expressions, using functional MRI (fMRI) (study 2 and study 3). In Study 2, patterns of brain activation were recorded while participants passively perceived emotional expressions from faces and voices, and this demonstrated how emotional expressions from different sources were combined in the brain. Study 3 was conducted to examine the neural representations for processing emotional incongruence (incongruence vs. congruence). In this study, whole brain fMRI data were collected while participants were instructed to attend one modality (e.g., face or voice) while concurrently being exposed to the other, either emotion-congruent or emotion-incongruent, modality (e.g., voice or face). It should be noted that in both fMRI experiments, an implicit processing task was used, in which participants passively viewed and/or listened to stimuli presentation. The decision to use a passive viewing and/or listening paradigm rather than an explicit emotion labelling task (as in the behavioural experiment) was made for the following reasons: first, a passive viewing and/or listening paradigm has the advantage that it allows for the automatic and implicit processing of input information, which may be helpful in reducing potential confounding differences across different groups. Second, using an implicit emotion processing task in the present study has pragmatic advantages. For example, the use of an implicit emotion processing task tends to make the block design easier to implement, and also significantly reduces the burden on participants (e.g., prolonging the time for completing tasks in the scanner, or reducing any anxiety caused by task demands in the scanner). Similarly to Study 1, participants' scores in STAI-T were used as an index of anxiety in Study 2 and Study 3, to assess whether the degrees of anxiety modulated the pattern of brain activation during the processing of emotional information. The data in Study 2 and Study 3 were analysed using the General Linear Model (GLM) in Brainvoyager QX 2.8. An introduction to fMRI technique and GLM data analysis is presented in the following section.

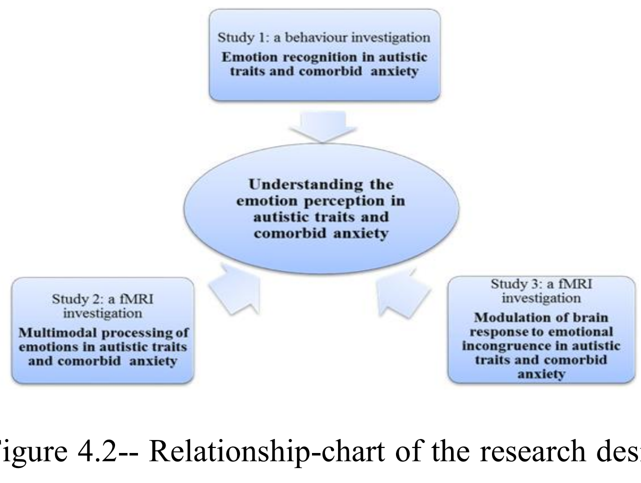


Figure 4.2-- Relationship-chart of the research design, including the behavioural (Study 1) and fMRI investigations (Studies 2&3).

4.3 Participants

4.3.1 Screening

The research participants were grouped by their levels of autistic traits. In order to determine whom the potential participants would be, and balance the participant numbers across different groups, a web-based online screening test was conducted prior to the experiment (http://experiments.psy.gla.ac.uk/). Emails advertising this study were sent to individuals who had registered in the subject pool of the School of Psychology. Those individuals who were interested in this study were invited to complete two screening questionnaires: Autism-spectrum Quotient (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) and Depression Anxiety and Stress Scales (DASS; Lovibond & Lovibond, 1995) via the webpage http://experiments.psy.gla.ac.uk/experiments/assessment.php?id=205. The online environment allowed respondents to complete the questionnaires at their own convenience. Respondents were informed that these two measures would take approximately 10-20 minutes to complete. From the online screening test, the information of the respondents was collected under a unique unrecognisable code; information including their email address, age, gender and nationality, together with their scores for each test. A total of 689 individuals finished measures of AQ and DASS in the initial screening phrase, with females overrepresented in this sample (n=489).

The respondents who finished these measures were assigned to a group based on their scores on the AQ. Though some participants had disclosed that they had a diagnosis of ASD, the data were collected based purely on their scores on the AQ. In the paper of Baron-Cohen et al. (2001) original paper, 80% of adults with ASD scored at or above 32 in the AQ, whereas only 2% of typical controls did. Therefore, the value of 32 on the AQ was proposed as a cut-off score for screening autism in the general population. In another study by Woodbury-smith, Robinson, Baron-cohen, Robinson, and Wheelwright (2005), a cut-off score of 26 was used to be indicative of Asperger's Disorder. Considering these two papers, in the present research a cut-off score of 31 (31 and above) was chosen for grouping individuals with high levels of autistic traits (HAQ group), while a cut off score of 18 (18 and below) was chosen for grouping individuals with low levels of autistic traits (LAQ group). For DASS, a cut- off score of 21 was set, and individuals who scored at 21 or above in the anxiety subscale were regarded as being highly anxious, while individuals who scored at 20 or below were regarded as having low levels of anxiety. It should be noted that given that the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) was used as formal measure assessing traits of anxiety in this thesis, the scores of respondents on the DASS at this stage are not reported. Those respondents who were in their first year of psychology at the University of Glasgow received one academic credit for their time. After the data from the on-line screening tests were analysed, those respondents who were eligible for inclusion were invited to participate in the next part of the study.

4.3.2 Additional screening for MR scanning

In addition to the screening tests (e.g., AQ and DASS) carried out to group the participants, those individuals who were interested in registering for MRI scanning were sent a prebooking checklist to examine whether there were any contraindications to their participation in an MRI. A full check was also carried out by the scanner operator before scanning. The final sample selected for each study will be described in the method section of the respective chapters (see Chapter 5, Chapter 6, Chapter 7).

4.4 Measures and materials

4.4.1 Measures

This section introduced a number of self-reported measures used in this thesis to examine the relevant characteristics of the participants, including the Autism-spectrum Quotient (AQ), the State-Trait Anxiety Inventory (STAI), and the Depression Anxiety and Stress Scales (DASS). Before introducing these measures, the realibity of using self-reported measures in research will be discussed.

Self-reported measures are popular in research as they provide a relatively less labour-intensive, cost-effective, and flexible way of collecting large amounts of data quickly from respondents in diverse geographical contexts. All of three mentioned measures (AQ, STAI, and DASS) have been qualified to be administrated in the non-clinical community population.

The Autism-Spectrum Quotient (AQ) is a widely used measurement, which can be used in non-clinical sample of school or college students to examine autistic traits among them (e.g., Krumm, Ferraro, & Ingvalson, 2017; White, Ollendick, & Bray, 2011; Brosnan & Mills, 2016; Stevenson & Hart, 2017). The AQ was reported to have both good internal consistency and test–retest reliability (e.g., Baron-Cohen et al. 2001). In addition to the validation studies, there are some empirical studies also reporting high test–retest reliability the AQ based on college students sample (e.g., Stevenson & Hart, 2017). In addition to examine the presence of autistic traits in general population, the AQ has been widely used in studies examining the role of autistic traits in affecting cognitive performance in a large number of school or college students (e.g., Hsiao, Tseng, Huang, & Gau, 2013). Hsiao, et al. (2013) examined the associations of autistic traits and social and school adjustment in children and adolescents and found that high level of autistic traits were correlated with poor academic performance, negative attitudes toward school tasks, and poor peer relationships.

In anxiety research, self-reported measures were placed in a prominent and well-founded position. The use of self-reported measures has advantages in measuring one's anxiety. This may be due to that anxiety is an internal state which based on unobservable cognitive processes; the individual's self-description of these internal events tend to provide valuable information that cannot be accessible through more objective measurement tools. Indeed, using factor analysis, Cattell and Scheier (1963) evaluated 13 studies involving a range of anxiety indices and reported that the measurement that provides consistently high loading on the anxiety factor were those based on self-reported data. In this view, self-reported instruments enables researchers to collect what the respondents were experiencing in a reliable way.

Since its inception, both the State-Trait Anxiety Inventory (STAI) and the Depression Anxiety and Stress Scales (DASS) were largely administrated in high school and college students and were shown as a robust way measuring anxiety symptoms among them (e.g., Al-Gelban, 2007; Bayram & Bilgel, 2008; Demirbatir, 2012; Mahmoud, Staten, Hall, & Lennie, 2012; Roy, Seilesh, & Doshi, 2015; Vaidya & Mulgaonkar, 2007). Both scales are developed from students-based sample research and demonstrate excellent psychometric properties (Spielberger, 1985; Lovibond & Lovibond, 1995).The SYAI has been successfully applied to high school and college students, adults, military personnel, prison inmates, and a wide variety of psychiatric and medical patients. The test-retest reliability coefficients of the STAI-trait anxiety were quite high, such as 0.86 for high school students. These instruments are widely used method to uncover individuals' experience and feelings. There are a number of published studies using STAI to measure a range of performance in educational settings (Derryberry & Reed, 2002; Eysenck et al., 2007; Hayes, Macleod, & Hammond, 2009). Taken together, the use of self-reported questionnaires, such as the STAI and DASS were adequate in the present research.

Autism-Spectrum Quotient Autism-spectrum Quotient (AQ, Baron-Cohen et al., 2001) is a standardized self-report questionnaire designed to assess the presence of autistic traits in a general population with average or above average IQ. It was first developed as a self-report measure for adult (Baron-Cohen, et al., 2001), Subsequently, it has other versions developed for different age groups, such as a parent-report measure for adolescents (aged 12-15 years) (The autism-spectrum quotient (AQ)–adolescent version, Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006. and for children (aged 4-11 years) (Children's Version (AQ-Child), Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008). Nowadays, a toddler version also exists (Quantitative Checklist for Autism in Toddlers: Q-CHAT, Allison et al., 2008). The AQ consists of 50 items assessing traits correlated with ASD in five domains: social skills, attention switching, attention to details, communication, and imagination (Baron-Cohen et al., 2001). Respondents were instructed to rate the extent to which they found the item suit them (definitely agree, slightly agree, slightly disagree or disagree), on a 4-point scale. The order of the rating scales was counterbalanced to avoid a response bias, thus half of positive and half of negative responses indicate autistic traits. Responses are scored using a binary system, where an endorsement of the autistic traits would be scored as +1, while the opposite response would be scored as a 0. The score of AQ is the sum of the individual item score, ranging from 0-50. Higher scores predict more traits of autism. It was demonstrated to have good test-retest reliability, good internal consistency (Baron-Cohen et al., 2001) as well as good discriminative validity. In the original paper, a score of 32 was proposed as an indicator of a clinically significant level of autistic traits (Baron-Cohen et al., 2001).

State-Trait Anxiety Inventory The STAI (STAI: Spielberger, 1983; Spielberger, et al., 1970) was chosen as it allows differentiation of anxiety between trait anxiety and state anxiety. The original STAI (Form X) was developed in 1970 by Spielberger and colleagues. Then, in 1983, a revised version STAI-Form Y was published. According to Spielberger (1983), state anxiety is characterised by a "subjective and transitory feeling of tension, worry, and nervousness". It is defined as an active emotional state, and can vary in intensity. Trait anxiety, in contrast, refers to a general tendency to be anxious in responding to perceived threats, and is a relatively stable characteristic of an individual, though it can be influenced by negative evaluations from others (Purdue & Spielberger, 1966). Trait anxiety has been linked to the personality trait of neuroticism (Smoller & Tsuang, 1998).

The STAI comprises 40 items, 20 items for measuring State-Anxiety (Form Y-1), and 20 items for measuring Trait-Anxiety (Form Y-2). For STAI Form Y-1, respondents were asked how they feel “right now, at this moment”. Responses were rated on a 4-point Likert scale ranging from 1 (not at all), 2 (somewhat), 3 (moderately) to 4 (very much so). For STAI Form Y-2, respondents were asked how they feel “generally, in general.” Responses were rated on a 4-point Likert scale ranging from 1 (almost never), 2(sometimes), 3(often), to 4 (almost always). The STAI state and trait anxiety subscales each have two types of item: anxiety absent items and anxiety present questions, with the anxiety absent items being reverse scored. The possible scores for each subscale range from 20-80.

The STAI is a widely used assessment of anxiety and has been translated and adapted into 48 languages (Julian, 2011). It is reported as having a high discriminate and convergent validity with other measures. For example, the STAI is reported to show significant correlation with the Taylor Manifest Anxiety Scale (0.73) and Cattell and Scheier’s Anxiety Scale Questionnaire (0.85) (Julian, 2011). The STAI is also reported to have excellent internal consistency (0.86-0.95) and test –retest reliability (0.65 to 0.75, over a 2-month interval) (Spielberger, 1983).

It needs to note that in the present thesis, only the traits anxiety subscale from STAI was included into the analysis. The trait anxiety, as has been discussed in Chapter 2, represents as a relatively stable tendency to react to threat (e.g., William et al., 1988). Reasons for using trait anxiety over state anxiety include: most prior studies in anxiety research have focused on using trait anxiety approach rather than the state anxiety approach, based on which, substantial important findings have been obtained. For example, using trait anxiety approach, the attentional control was found to be negatively correlated with anxiety (e.g., Ayduk, Gyurak, & Luerssen, 2010; Derryberry & Reed, 2002). In addition, trait anxiety seems to have more effect on the executive system than the state anxiety. For example, Ursache and Raver (2014) examined the contributions of trait and state anxiety on cognitive performance in executive functioning tasks in school-aged children and found that greater trait (not state) anxiety were associated with their poorer performance on shifting and inhibition tasks. Owens and colleagues reported the negative associations between trait anxiety and academic performance, though these associations were also mediated by verbal working memory and central executive functioning (Owens, Stevenson, Hadwin, & Norgate, 2012). In the Ng and Lee's (2015) study, whether the trait test anxiety has a direct or indirect effect via state anxiety, on 11-year-old children's mental arithmetic task performance were examined. Result of this study suggest that trait test anxiety has a direct and negative effect on working memory, however, this effect was not mediated by state anxiety.

Depression Anxiety and Stress Scales The Depression Anxiety and Stress Scale (DASS; (Lovibond & Lovibond, 1995) was used for online screening assessment in this research. The DASS is a standardised self-report test that aims to assess three domains of symptomatology in adults over the past week of their lives, namely depression, anxiety and stress. The DASS was also designed to maximise discriminability validity between these three domains (Brown, Chorpita, Korotitsch, & Barlow, 1997). It has two versions: the full 42-item version comprising three sub-scales with 14 items in each, and a simplified 21-item version comprising three sub-scales with 7 items in each. The depression subscale measures symptoms of depression, such as feelings of sadness, hopelessness, worthlessness, and low self-esteem. The anxiety subscale measures symptoms of anxiety, such as physiological hyperarousal, autonomic arousal, and fear. The stress subscale measures aspects of non-specific arousal, such as tension, irritability, and agitation. Each item is scored on their response, ranging from 0 (did not apply to me at all) to 4 (applied to me very much, or most of the time). For the simplified 21-item scale, the score for each item is doubled to produce their final score. A number of cut-off scores were proposed by Lovibond and Lovibond

(1995) to categorise severity levels of depressive, anxiety, and stress- related symptomatology: Depression (normal—0-9, mild—10-13, moderate—14-20, severe— 21-27, extremely severe—over 28); Anxiety (normal—0-7, mild—8-9, moderate—10-14, severe—15-19, extremely severe—over 20); Stress (normal—0-14, mild—15-18, moderate—19- 25, severe—26-33, extremely severe—over 34). The DASS was originally designed for non-clinical populations, but there is evidence suggesting that it can also be used in clinical populations (e.g., Brown, Chorpita, Korotitsch, & Barlow, 1997).

The DASS demonstrates high levels of internal consistency on all subscales: depression (0.91-0.97), anxiety (0.81-0.92) and stress (0.88-0.95). The Cronbach's alphas for the DASS-21 subscales have been examined in clinical and nonclinical samples and found to be 0.94 for Depression, 0.87 for Anxiety, and 0.91 for Stress (Antony, Bieling, Cox, Enns, & Swinson, 1998). It is also reported to be significantly correlated with other established measures, such as the DASS anxiety subscale correlating with the Beck Anxiety Inventory (BAI; Beck et al., 1988) ($r=0.81$), and the DASS depression subscale correlating with the Beck Depression Inventory (BDI; Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961) ($r=0.74$) (Lovibond & Lovibond, 1995).

4.4.2 Materials

The past few decades have witnessed significant progress in facial and expression recognition research, during which databases have moved towards automated facial expressions that vary over time (e.g., video recordings) and over space (e.g., rapidly changing). The stimuli used in the present research were emotional expressions presented in faces, voices, and face-voice pairs. In order to find stimuli that were closer to those expressions encountered in real settings, a natural and spontaneous facial behaviour database (Zhang et al., 2014: Binghamton–Pittsburgh 4D spontaneous facial expression database) was used. These facial behaviours provide unique temporal information about emotions that is not available in static displays, thus allowing us to monitor moment-to-moment changes in the emotions expressed by others.

As for the vocal stimuli, this research utilised a subset of human vocalisations: non-verbal vocal affect bursts selected from Montreal Affective Voices (Belin, Fillion-Bilodeau, & Gosselin, 2008), such as screams and laughs. It is suggested that non-linguistic vocalisations are used innately to communicate emotional and mental states, especially in situations where these states are changing. In addition, the use of non-verbal vocalisations allowed us to investigate voice perception with a minimal semantic confound.

Stimuli library 1: The Binghamton–Pittsburgh 4D (BP4D) spontaneous facial expression database Forty-one participants (23 women, 18 men, aged from 18-29) from various ethnic backgrounds (11 Asian, 6 African-American, 4 Hispanic, 20 Euro-American) were recruited for creating the database. Participants were filmed with both a 3D dynamic face capturing system and a 2D frontal camera pixel, while responding to a varied series of 8 emotion inductions that elicited spontaneous expressions of anxiety, surprise, happiness, embarrassment, fear, pain, anger, and disgust. The tasks involved listening to a joke (happiness/amusement), watching and listening to a documentary film (sadness), experiencing a sudden and unexpected sound (surprise/startle), anticipating and experiencing a physical threat (fear/nervous), submerging their hand in iced water (physical pain), hearing harsh words from the professional actor/director (anger/upset), experiencing an unpleasant smell (disgust), and playing a game in which they had to improvise a "silly" song (embarrassment). The 3D models ranged in resolution between 30,000 and 50,000 vertices. For each sequence, manual FACS coding by highly certified coders was obtained. The 2D texture video data had a standard frame rate of 25 frames per second and a resolution of 1040×1392 pixels/frame. A cylindrical head tracker (Jang & Kanade, 2008) was used on the 2D videos for tracking rigid head motion. 83 facial feature points were tracked directly using a 2D Constrained Local Model (CLM) for the 2D facial expression sequences and a 3D Temporal Deformable Shape Model (TDSM) (Canavan, Sun, Zhang, & Yin, 2012) for the 3D dynamic surface.

In order to validate the data for prototypic emotion expression recognition, a Hidden Markov Model (HMM) was used to classify the six expressions (happiness, sadness, surprise, fear, anger, disgust), for each subject (of 16). This classifier used both spatial and temporal features of the expression sequences. 14 subjects were used in the training set and 2 subjects for testing. An average classification accuracy rate of 70.2% was achieved.

Stimuli library 2: Montreal Affective Voices Montreal Affective Voices (Belin et al., 2008) is a validated tool for research in auditory affective processing, and was used as an auditory counterpart to the facial stimuli in the present research. This database consists of non-linguistic emotional bursts corresponding to the emotions of happiness, pleasure, anger, disgust, fear, pain, sadness, and surprise. These non-emotional vocalisations, expressed using "ah" sounds, were recorded as neutral sounds and were associated with the lowest median pitch and very small pitch variation. The vocalisations were recorded in a sound-insulated room, using a UMT800 condenser microphone (Microtech Gefell) at a distance of approximately 30cm. Digitisation was done at a 96-kHz sampling rate and 16-bit resolution, using an Audiophile 2496 PCI soundcard (M-Audio). Individual files were then edited in short, meaningful segments and were normalised for maximum peak intensity and downsampled at 44.1 kHz, using Adobe Audition (Adobe Systems, Inc.). For each actor and vocalisation category, only the best ones were kept for the validation stage. As a result, 90 samples from 10 adults (5 females and 5 males) were used. The duration of the vocalisations ranged from 385ms (surprise) to 2229ms (sad).

4.5 An introduction to fMRI

4.5.1 MRI and fMRI

The following section introduces the fMRI neuroimaging technique, which was employed in the present research. To start, an introduction to the concept of magnetic resonance imaging (MRI), and the fundamental processes involved in acquiring a MRI image will be discussed. Next, a specific MRI technique, functional magnetic resonance imaging (fMRI) will be introduced. This will then be followed by a description of fMRI designs (block design and event-related design) and the procedures of data pre-processing.

Magnetic Resonance Imaging (MRI) is an imaging method that uses strong magnetic fields to create images of biological tissue over time (Huettel, Song & McCarthy, 2004). During a MRI scan, a participant is placed in a strong static magnetic field to align the magnetisation of atoms in the body. To create an image, the scanner uses a series of changing magnetic gradients and oscillating electromagnetic fields, known as a pulse sequence, to systematically alter the alignment of this magnetisation (Huettel et al., 2004). This causes the nuclei to produce a magnetic signal, which is detectable by the scanner; from this, the scanner can construct an image of the scanned area of the body. Using different pulse sequences, the scanner can provide images with different properties for a variety of research purposes (Bernstein, King & Zhou, 2004).
Functional Magnetic Resonance Imaging (fMRI) is a specific MRI technique that measures the haemodynamic response related to neural activity in the brain, enabling the observation of brain function in vivo (Calvert & Thesen, 2004). It is suggested that neurons do not store energy, and that the energy consumption of neurons leads to changes in blood flow and the amount of deoxyhaemoglobin in the blood. In the l990s, Ogawa, Lee, Kay, and Tank (1990) demonstrated that the hemodynamic response corresponding to neural activity in the brain alters the contrast of T2* weighted images. This is called Blood-Oxygenation-Level-Dependent (BOLD) contrast. Thus, magnetic resonance (MR) scans do not directly measure brain activity, instead, they detect signals originating from the different magnetic properties of deoxygenated blood compared to oxygenated blood (Pauling & Coryell, 1936), thus providing an index of neural activity regarding a specific task (Ogawa et al., 1990; Weiller, May, Sach, Buhmann, & Rijntjes, 2006).

Nowadays, fMRI is widely used to help us understand and characterise brain functions. As a brain imaging technique, fMRI has several advantages. It has no known negative health effects, it is noninvasive and does not involve radiation, making it safe for the participants, and relative to other brain imaging techniques, such as Electroencephalography (EEG), it has excellent spatial resolution, allowing researchers to localise the brain areas recruited in different cognitive functions (Glover, 2011). In addition, relative to Positron emission tomography (PET), which requires the injection of radioactive material, fMRI does not require any injections (Cabeza & Nyberg, 2000). A wide range of studies have used fMRI to explore the neural correlates of emotion, and the integration of multisensory emotional information.

4.5.2 fMRI designs (block design and event-related design)

The choice of experimental design depends on the psychological nature of the task, the ability of the fMRI signal to track changes elicited by the task over time, and the specific contrasts that one is making. Typically, there are two main classes of experimental designs that are commonly used in fMRI studies: block designs and event-related designs (Dale & Buckner, 1997), though many studies involve a mixed design of both. In block designs, a series of trials from the same condition are presented within blocks, and this is then followed by a rest or fixation period. The average brain activations from the different block conditions are statistically contrasted with each other using cognitive subtraction. Brain activity is detected by block-to-block periodic BLOD signal changes that are linked to the task paradigm. The most frequently mentioned advantages of block designs are that they offer high statistical power to detect changes (Friston, Holmes, Price, Büchel, & Worsley, 1999) and are robust to uncertainties in the shape of the HRF (Rombouts et al., 1997). Also, the rapid and continuous presentations of trials in block designs have the benefit of reducing the overall scanning time compared to the event-related design paradigm. The high statistical power in block designs is suggested to result from the additive effect of rapid and continuous presentation of trials on the BLOD signal during a period of block time. Block designs are now used widely in developmental and paediatric neuroimaging studies, due to their good signal-to-noise ratio and relatively small overall scanning time, and this is the experimental paradigm employed in this thesis.

Event-related designs are a more recent design paradigm, developed by D'Esposito, Zarahn, & Aguirre (1999). Unlike block designs, in which stimuli are clustered into blocks of trials, stimuli in event-related designs are dispersed in a continuous random sequence. The event-related designs measure the immediate brain activity changes after introducing a specific event type. Event-related designs are advantageous in their flexibility, and the fact that they allow for the estimation of key features of the BLOD signals, which can be used to make inferences about the timings of activation across conditions.

4.5.3 Pre-processing of fMRI data

BOLD signals can suffer from many sources of noise during recordings. The noise can be generated by the participants themselves (i.e. physiology noise, head motion), the imaging hardware (e.g., scanner noise), or be externally generated. In order to increase the Signal to Noise Ratio (SNR) and increase the power for statistical analysis, data preprocessing is necessary. This section will provide a brief introduction to the preprocessing steps used on fMRI data in the present research.

Slice timing correction Generally speaking, fMRI data is acquired by a series of pulses to generate two-dimensional slices (Huettel et al., 2004). A typical scan can acquire up to 32 slices, depending on the capabilities of the scanner. The slices are acquired with equal spacing across the repetition time (TR), but at different time points. This can cause slice-timing problems, given that fMRI analysis (e.g., GLM) assumes that all the slices in a functional volume were recorded at the same time. In order to correct these time shifts, temporal interpolation is commonly used. In this method, the amplitude of the signal at the start of the TR is estimated using the values of nearby time points. Therefore, for each volume, the intensity of any voxels in that volume is corrected to the intensity values at the start of the acquisition of all the slices.

Motion correction Head motion is a critical source of noise in fMRI experiments. Typically, in fMRI analysis, each voxel is assumed to represent a specific location in the brain. If the head moves during scanning, the time course of one voxel may contaminate neighbouring voxels at different times. Even if materials such as cushions are used during the scanning to comfort the subject and minimise head motion, it is hardly possible to keep the head perfectly still. In this case, motion correction needs to be carried out on the MR data. The purpose of motion correction for fMRI data is to adjust the time series of images so that the voxel (x, y, z,) in every image corresponds to the same position in the brain.

Spatial smoothing When using multiple participants, spatial smoothing is required in order to cope with the functional anatomical variability between subjects. It allows us to increase the Signal to Noise Ratio (SNR) and enhance the power of the statistical analysis. One standard procedure for spatial smoothing is to convolve the fMRI signal with a Gaussian function of a specific width (Gaussian kernel).

Temporal filtering As discussed previously, the BOLD signals can be masked by physiological noises such as those from respiration, or heart beats. Temporal filtering is used to attenuate the noise frequencies, increasing the SNR. In general, there are two types of filtering: high-pass filtering and low-pass filtering. These types of filtering are opposing; high-pass filtering is carried out to remove low-frequency fluctuations, and lets high frequencies through, while low-pass filtering is carried out to remove high-frequency fluctuations, and lets low frequencies through. However, low-pass filtering has been criticised for its potential to reduce sensitivity to true activation, without increasing sensitivity to false activation (Della-Maggiore, Chau, Peres-Neto, & McIntosh, 2002), and so only high-pass filtering tends to be used.

Structural-functional co-registration It is known that structural images have high resolution, while functional images have relatively low resolution. In order to visualise the fMRI results in high resolution structural images, it is necessary to link the functional images to anatomical images.

Spatial normalisation The size and shape of the brain varies across participants. For this reason, in order to enable the consistency of results across participants, each brain was transformed into a standard space, in a process referred to as spatial normalisation. Talairach space (Talairach & Tournoux, 1988) and MNI space (Evans et al., 1993) are two commonly used coordinate systems for spatial normalisation.

4.5.4 Planned analyses

4.5.4.1 Planned analyses for fMRI data

Statistical analysis plays a central role in the data processing pipeline, and from which a number of goals can be achieved. These include localisation of the brain activation areas activated by a task, determination of the brain networks corresponding to a brain function, and detection of abnormal activity that may be related to disease or disorders. A number of methods have been proposed in the existing research for analysing fMRI data, amongst which the General Linear Model (GLM) introduced by Friston, Jezzard, and Turner (1994) has been one of the most commonly used methods.

In addition to identify the brain areas that are involved in performing specific experimental tasks, another possible function of fMRI data analysis relates to assign the active brain regions to different functional roles (Beauchamp, 2005), especially in multisensory integration research. It has been suggested that a number of events would take place when subjects were presented with multisensory stimuli, which may lead to the activation of multiple regions (i.e., uni-sensory regions, multisensory regions, motor regions etc.). From this point of view, multiple statistical criteria need to be met in order to classify a subset of these regions as being specifically involved in multisensory integration. Therefore, in this section, a brief introduction to the GLM in the context of fMRI data analysis will be firstly presented. Then, the different statistical criteria used in classifying multisensory regions will be discussed.

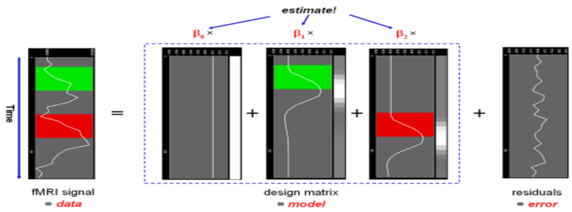
General Linear Model (GLM) General Linear Model (GLM) is defined as a model drive analysis. It is suitable for conducting parametric statistical test with one dependent variable, and has been used in the present thesis. The GLM model presents the time series as a linear combination of different signal components, and tests whether activity in a particular brain region is related to any of the known inputs. In this analysis, the fMRI data Y (dependent variable) was modelled as a linear combination (weighted sum) of the predictor variables plus an additive error term ε.

A standard GLM can be denoted in matrix notation as：

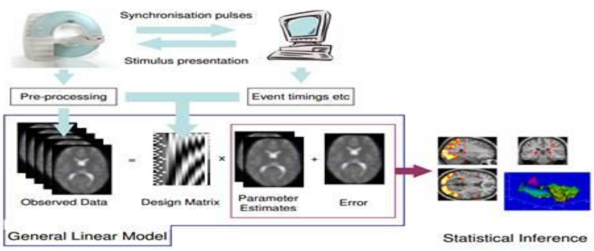
$$\begin{bmatrix} y_1 \\ \vdots \\ \vdots \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & \cdots & \cdots & \cdots & X_{1p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{n1} & \cdots & \cdots & \cdots & X_{np} \end{bmatrix} \begin{bmatrix} b_0 \\ \vdots \\ \vdots \\ b_p \end{bmatrix} + \begin{bmatrix} e_1 \\ \vdots \\ \vdots \\ \vdots \\ e_n \end{bmatrix}$$

To be simple, Y= Xb + ε

Also can be denoted as below:



Where Y corresponds to the column of observed fMRI time course, X is the statistical model of the data (design matrix consisting of a set of regressors); β is a row vector of parameter estimates for predictors, and needs to be estimated to determine how much each regression factor contributes to the overall fMRI time course. ε is a column vector of n random values (noise). (Picture taken from BrainVoyager Support website http://www.brainvoyager.com)



(Picture taken from fMRI Basics: single subject analysis using the general linear model)

4.5.4.2 Statistical Criteria for classifying multisensory integration regions

The prior literature has proposed a number of statistical criteria that can be used to classify multisensory integration regions, including the super-additive criteria, the max requirement criteria, the mean requirement criteria (Beauchamp, 2005a,b; Calvert, Hansen, Iversen, & Brammer, 2001; Love, Pollick, & Latinus, 2011). In this section, a brief introduction to these three criteria is presented. In this thesis, the super-additive criterion was used.

The super-additive criterion The “super-additive” or "supra-additivity" criterion assumes that the brain regions recruited for multisensory integration processing should be greater than the sum of those involved in unisensory processing (Beauchamp, 2005a). This can be represented in equation form as AV > (A+V). Studies that have used this criterion have reported the involvement of a number of regions in the occipital and temporal cortex (Joassin, Pesenti, et al., 2011; Joassin, Maurage, & Campanella, 2011). In the original fMRI study by (Calvert, Campbell, & Brammer, 2000), using this criterion, the superior temporal sulcus (STS) was found to show a greater response than the sum of the responses to two unisensory modalities. In a study by Love et al. (2011), super-additive effects were also found in the bilateral occipital regions and right precentral gyrus. However, it has also been reported that the super additive effects represent the results of the bimodal response as compared to the sum of a positive and a negative unimodal response. Given the fact that deactivation in unisensory condition may lead to a falsely defined multisensory region, a super-additive response at the neuronal level will not necessarily be reflected in a super-additive change of the BOLD fMRI signal (Beauchamp, 2005). For this reason, any interpretation of super-additive effects in fMRI results needs to be carried out in a cautious manner.

The max-criterion/conjunction analysis The max criterion assumes that the multisensory response is greater than the maximum of either unisensory response or multisensory enhancement. This can be represented in equation form as AV> Max (A, V), or (AV > A) AND (AV > V) (Van Atteveldt et al., 2004). Qualitatively, this criterion is relatively more liberal than the super-additive criterion. Using this criterion, a number of studies have consistently reported multisensory enhancement for well-known multisensory integration regions (Beauchamp et al., 2004; Beauchamp, 2005a; Van Atteveldt et al., 2004). However, the max criterion has its limitations, and has been reported to possibly lead to a slight loss in sensitivity. In this sense, one also needs to be cautious in using this criterion in an investigatory capacity.

The mean criterion The mean criterion is another means of localising multisensory regions. It assumes that the multisensory response is greater than the mean of both uni-sensory responses (Beauchamp, 2005b). This can be represented in equation form as AV>mean (A, V). This criterion is more liberal than either the super-additive criterion or the max-criterion, and thus is more able to identify the multisensory regions than either of the other criteria. However, this criterion is argued as being too liberal to be reliable. For example, even in unisensory regions, responses to audio-visual stimuli are greater than the mean of the auditory and visual responses. In this case, the mean criterion may classify the unisensory regions as multisensory regions.

4.5.4.2 Planned analyses for behavioural data

This section will begin with a discussion of the differences between ordinary regression analysis and multilevel analysis. The differences between these two analysis types constitute the main reason for choosing multilevel modelling in the behaviour experiment (Study 1). This discussion will then be followed by a description of model formulations used to assess two types of data (the response time and the probability of success in the emotion recognition) in the R statistical computing environment (R Core Team, 2013).

The use of multilevel modelling In order to analyse data from the behavioural experiment, we choose to use multilevel modelling for the following reasons. First, the use of multilevel modelling is driven by the characteristic of the present dataset. As indicated by Gelman and Hill (2007), multilevel modelling allows one to achieve adequate statistical power if the dataset contains variables measured at different levels of a hierarchy, or clustered by different factors. This was the case for our dataset, which was clustered by a mixture of factors: condition (face, voice, face-voice), and emotion (happiness, surprise, fear, anger, disgust, sadness, and neutral).

In addition, compared to traditional linear regression models, multimodal analysis offers benefits in terms of achieving appropriate data structure. As stated by Baayen, Davidson, and Bates, (2008), it is common for traditional linear regression analysis to carry out averaging over subjects or trials before entering the data into a specific model, but this procedure may remove the inside-group variability. Multilevel modeling does not require prior averaging; instead, the original data is inputted straight into the statistical model, and this makes it possible to gain a more accurate understanding of the structure of the data.

Using R environment (lme4 package) There is a wide range of software available for conducting multilevel modelling. In the present study, the multilevel modelling took place in an open source statistical programming environment R (R development core team, 2007), using the lme4 package (Bates, 2007). This package was reported to be able to offer fast and reliable algorithms for parameter estimation (Baayen et al., 2008). In the analysis, factors of group (HAQ vs. LAQ), scores of anxiety, and emotion (happiness, surprise, fear, anger, disgust, sadness, and neutral) were modelled into the model. Response time was analysed using Linear Mixed Model (LMM; lme4 package), as appears to the left of the tilde operator (~). The following syntax was present: lmer (response time~ group*anxiety+ emotion + random participant factor. The probability of success in the emotion recognition was analysed using Generalized Linear Mixed Model (GLMM; lme4 package). A binomial family was specified in the GLMM model to estimate the log-odds ratio for the corresponding factors in the model. Participants' responses were interpreted as dichotomous and recorded as 1 and 0, where 1 represented a correct response and 0 an incorrect response. The model for analysing number of successes was: probabilities of correct answers ~ group * anxiety

+ emotion + random participant factor, family=binomial. Both are general syntaxes, and adaptions were made depending on difference of analysis. Please see the method section of the behaviour experiment for details.

4.6 Ethical issues

Ethical issues should always be considered in any research. For the present studies, efforts were made to ensure the protection of research participants while pursuing the research goals. The ethics committee assisted the researcher in ethical considerations. Prior to undertaking any participant recruitment, two ethical applications were submitted to the College of Science & Engineering in the University of Glasgow, and these were both approved. One application was for the behaviour study (Study 1) under application number 30013007, and the other was for the fMRI studies (Studies 2 & 3), under application number 300150043. For application 30013007, detailed information about the study was included in the ethics application form, comprising the research purpose, research design, research procedure, data protection etc. Along with this, the volunteer information sheet and consent form were provided. For application 300150043, detailed information about the study was included in the ethics application form, comprising the research purpose, research design, funded parties, research procedure, data protection etc. Also, the Study Information Consent for participants–MRI (detailed information regarding research purpose, why have I been chosen, what will happen to me if I take part, what is the device involved, what are the possible risks/side effects of taking part, what are the possible benefits of taking part, confidentiality, etc.), and an fMRI study consent form were provided. In addition to this, a project application was submitted to The Centre for Cognitive Neuroimaging (CCNI) and approved under CCNI project number 184 followed by a review of CCNI presentation. All research steps were guided by ethical standards.

Informed consent "The first ethical principle to consider is the principle of autonomy, which implies the right to self-determination and the right to full disclosure" (Hungler & Polit, 1999). Cohen, Manion & Morrison (2011) also emphasised the four components of informed consent, which were "competence, voluntarism, full information and comprehension". In order to ensure these principles, during the initial communication, a cover letter which contained the purpose of the research inquiry, and a summary of tasks was sent to the eligible respondents. Before the respondents made their decision about participating in the research, a Study Information Sheet and examples of experimental stimuli were sent to them to make sure they fully understood the research. They were advised that they could contact the researcher via email at any stage of the research. All consent forms were obtained before conducting the research. All participants were informed that their participation was entirely voluntary, and that they could withdraw from the research at any time and for any reason, without explaining why.

Confidentiality One very significant aspect of these studies was the protection of participants' privacy, and attention was paid to this in the design. All the participants were assigned a unique code to ensure anonymity. All the completed forms, answered questionnaires, content forms and other relevant materials were stored in a safe place, which could be only accessed by the researcher. The raw data were saved in an experimental folder in the computer, which could only be accessed by the researcher. All the raw data were saved using unique codes as identifiers, thus participants could not be identified by their names.

Safety and Health All the participants in the research were adults. The researcher cared about the participants. As stated in the ethical application form (application number 30013007): "To date, no side effects have been documented for participants who viewed emotional stimulus. The procedure is long and some participants might find it tiring. We will do our best to assure the comfort of our participants -The Question 4"; "The task of recognising emotions from different perceptual information has been done previously and does not raise any particular ethical issues for the typical population. Individuals who are high in autistic traits might find more difficulty in viewing and judging emotional stimuli, but they will be free to withdraw at any time. Some individuals might be concerned about their amount of autistic traits or their evaluation of anxious symptomatology. We will give this information out on request and also provide links to mental health care providers to anybody who was concerned—The question 5". Similarly, in the ethical application from (application number 300150043): "To date, no side effects have been documented for participants who were scanned by MRI. This study is not designed specifically for treatment, so there will not be direct benefits for treatment in regards to individuals with high autistic-like traits and (or) high levels of anxiety traits - Question 4"; "There is no clear evidence that MRI scanning may cause unnecessary anxiety among participants. Similar research on emotion perception on the typical population, autistic individuals and individuals with social anxiety disorder do not raise any particular ethical issues. There is the possibility that due to the emotional nature of the stimuli, some participants might find the experiment uncomfortable. We now stress in the information sheet that participants will see examples before continuing on to the main experiment and will be free to withdraw if they find experiencing the stimuli uncomfortable. We do not state the names of the stimuli in the instructions since we do not want to bias the participants. Individuals who are high in autistic traits might have some sensory sensitivity in viewing or listening stimuli. We will try our best to make the brightness, contrast and volume of the stimuli as friendly as possible to each participant. If individuals are uncomfortable with the stimuli, they will be free to withdraw at any time. Highly anxious individuals may feel uncomfortable being in the small space of an MRI scanner, if so participants can withdraw from the experiment at any point in the experiment- Question 5”.

5. Emotion recognition in people with autistic traits and comorbid anxiety: a behavioural study

5.1 Abstract

Although atypical emotion processing has been widely reported in Autism Spectrum Disorder (ASD), most investigations have focused on emotions presented in uni-modalites, such as facial or vocal expressions; only a few have investigated multimodal emotion processing. The co-occurrence of anxiety with ASD has been frequently reported, but the evidence for anxiety modulating emotion recognition in ASD is still lacking. The current research was therefore designed to explore emotion recognition in individuals with significant autistic traits, taking into account uni- and multimodal presentations as well as the co-occurrence of anxiety, which is not included in the ASD criteria but which is frequently associated with ASD. 50 individuals' (25 with HAQ, 25 with LAQ) recognition of the six basic emotion states (happiness, anger, surprise, sadness, disgust, fear) and one neutral state were assessed using unimodal (face or voice) and multimodal (face-voice) pairs. Results suggested that individuals with high levels of autistic traits were able to recognise emotions displayed across different modalities, suggesting a lack of general deficit in emotion perception among them. The presence of comorbid anxiety appeared to counteract the effects of autistic traits in the recognition of emotions (e.g., fear, surprise, anger), and this effect tended to be different for the two groups. More specifically, for the recognition of fear expression, greater anxiety was associated with less probability of correct responses in the HAQ but more probability of correct answers in the LAQs. As for the reaction times in other emotions, anxiety tended to be significantly associated with longer response latencies in the HAQ group, but shorter response latencies in the LAQ group for the recognition of emotional expressions, for negative emotions in particular (e.g., anger, fear, and sadness), and this effect of anxiety was not restricted to specific modalities.

5.2 Introduction

Emotion processing is a fundamental component of social cognition. The ability to understand emotional expressions and to derive socially relevant information from different channels is important for our successful social interaction (Adolphs, 2002; Izard et al., 2001). It is well acknowledged that emotions prevail in classrooms (Meyer & Turner, 2002). In the classroom context, learner's abilities to recognise emotional expressions in others were found to be associated with one's language competence (e.g., Trentacosta, 2006), attentional control (e.g., Nelson, Martin, Havill, & Kamphaus, 1999), motivation processes (e.g., Carver, 2004) and outcomes, such as school performance (e.g., Linnenbrink & Pintrich, 2002). For example, a study by Vassiou, Mouratidis, Andreou, and Kafetsios (2016) examined the role of students' emotion perception ability in their achievement goals, positive and negative affect and performance outcomes. Results suggested that students' emotion perception ability moderates relationships between achievement goals and class-related positive and negative affect and grades. In addition, impaired recognition of others' emotions may lead to social dysfunctions and reduced quality of life (e.g., Blair, 2005). For example, if some students fail to recognize expressed emotions by educators or classmates (e.g., anger, sad), they may continue to break rules or keep behaving in particular ways. They may be regarded as challenges to work with, leading to negative interactions and poor interpersonal communication. Such impairments have been observed in a number of disorders, including Autism Spectrum Disorder (ASD). ASD is a complex and heterogeneous disorder; and there is increasing evidence that autistic traits lie along the continuum of social-communication disability that is also distributed across the general population (Baron-Cohen, et al., 2001; Constantino & Todd, 2003).

Individuals with ASD often have difficulties in processing some types of emotional information. The majority of the empirical investigations in this field have focused on the identification of emotions in the visual domain, particularly from posed and exaggerated facial expressions, which often result in impaired performances in emotion recognition from those with ASD (e.g., Adolphs et al., 2001; Hobson et al., 1988; Howard et al., 2000; Pelphrey et al., 2002; Philip et al., 2010), with a few exceptions (Castelli, 2005; Grossman, Klin, Carter, & Volkmar, 2000; Jones et al., 2011; Tracy & Randles, 2011).

While emotions are often obvious through facial expressions, in real life they are not usually expressed solely by faces, but also by other sources, such as voice (e.g., Hubert et al., 2007; Moore, Hobson, & Lee, 1997). The available research examining the perception of emotions from vocalisations has again produced mixed results, with some studies reporting impaired identification of voice expressions (e.g., Jones et al., 2011; Lindner & Rosén, 2006; Mazefsky & Oswald, 2007; Philip et al., 2010; Rutherford et al., 2002), impaired detection of vocal cues associated with irony and sarcasm (e.g., Charbonneau et al., 2013; Wang et al., 2001; Wang et al., 2006; Wang et al., 2007), and difficulties with voice-face emotion matching (Boucher et al., 2000; Hobson et al., 1988; Loveland et al., 1995). Other studies have failed to find significant group differences in vocal affect naming tasks (e.g., Baker et al., 2010; Boucher et al., 2000; Jones et al., 2011; O’Connor, 2007). In many cases, these studies included semantic or lexical content in the tasks (e.g., Lindner & Rosén, 2006), raising the possibility of modulating affect by language or verbal functioning in their performance (Paul, Augustyn, Klin, & Volkmar, 2005).

The use of multisensory stimuli to explore the recognition of emotional expressions in ASD has been of particular interest during recent years, and there is evidence suggesting that individuals with ASD do not appropriately integrate multisensory information in emotion perception (Charbonneau et al., 2013; O’Connor, 2007; Xavier et al., 2015), which seems to correspond to the Weak Central Coherence Theory (Happé & Frith, 2006). However, after studying a group of children with Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS), Vannetzel, Chaby, Cautru, Cohen, and Plaza (2011) reported that these children were able to recognise emotions from multiple modalities, but they were impaired in their recognition of emotions in the visual and auditory conditions. This suggests that these participants were able to use the multimodal channel to compensate for uni-modal deficits. The discrepancy in the results across different studies may relate to a number of factors, such as age of participants, levels of functioning, sample sizes, the variability in methodology, and different experimental designs.

There is increasing evidence of anxiety co-occurring with ASD (Gobrial & Raghavan, 2012; Simonoff et al., 2008). The degree, severity and type of co-occurring anxiety may affect emotion processing in this group of individuals. However, to the researcher’s knowledge, little research has considered the co-occurrence of anxiety of the participants on emotion perception. Discrepancies in findings across these studies could therefore be due, in part, to different degrees of co-occurring anxiety among the participants.

To date, the findings on the processing of crossmodal emotional integration in ASD remain inconclusive, especially for the dynamic multimodal integration processing that are closer to what is encountered in more realistic and natural settings, and the way in which comorbid anxiety plays a role during emotion recognition has not been investigated. Therefore, the goal of the present study was to characterise the effects of autistic traits on emotion processing in unimodal (faces, voices) and crossmodal (emotionally congruent face-voice expressions) presentations. In addition, the question whether the effect of autistic traits on emotion perception is mediated by the degree of anxiety is also examined given that these traits are frequently reported to be correlated with each other. The facial stimuli were created from ecological and validated sets of natural facial expressions (Zhang et al., 2014), and the vocal stimuli were created using non-verbal vocal clips of emotional expressions (Belin et al., 2008). Participants were asked to categorise expressions of a range of basic emotions as quickly and accurately as possible when presented with auditory, visual and audio–visual stimuli.

It is suggested that individuals with ASD tend to be more adept at recognising basic emotional expressions as they become older (Rump et al., 2009), therefore the individuals with a high level of autistic traits in the present study (e.g., verbal adults) were expected to be mostly successful in recognising emotional expressions, especially when they were displayed in face-only and voice-only presentations. On the basis of past research (Charbonneau et al., 2013; O'Connor, 2007; Xavier et al., 2015) and the weak coherence account (Happé & Frith, 2006), individuals with considerable autistic traits were expected to benefit less from congruent face-voice presentations when identifying emotions. Co-occurring anxiety was expected to modulate emotion recognition in those with autistic traits; on the basis of previous research, it was predicted that those individuals with co-morbid anxiety would perform better in processing specific emotions, negative emotions in particular (e.g., fear, anger).

5.3 Method

5.3.1 Participants

Of 689 adults screened, a total of 58 participants were recruited via questionnaire screening sessions. Screening measures included the Autism Spectrum Quotient (AQ, measuring traits of autism; Baron-Cohen et al., 2001) and the State-Trait Anxiety Inventory (STAI, measuring anxious symptoms; Spielberger, 1983). Based on the scores from this scale, two groups of participants were obtained, using the cut offs of 31 and 18. Individuals who scored at 31 and above were classified into the high levels of autistic traits group (HAQ) while individuals who scored at 18 and below were classified into the low levels of autistic traits group (LAQ). Hand dominance for participants was assessed by use of the Edinburgh Handedness Inventory Questionnaire (Oldfield, 1971). All participants were reported to have normal or corrected to normal visual and hearing acuity. Written informed content was obtained for each participant according to a protocol approved by the ethics committee of the College of Science and Engineering, University of Glasgow.

Eight participants were excluded from the data analysis for a variety of reasons: one did not complete the full experiment; two of them pressed wrong buttons for most of the trials, making their data undetectable; another four were trimmed out as outliers. Therefore, 25 individuals (16 females, 9 males) with high autistic-like traits (HAQ) and 25 individuals (17 females, 8 males) with low autistic-like traits (LAQ) were included in the final analysis, see Table 5.1

Table 5.1--Demographic characteristics of the HAQ group and LAQ group

	HAQ (N=25)	LAQ (N=25)

Autism Quotient***	37.52±5.89	12.92±3.88
Participants (N)	25	25
Age	27.56±9.77	23.14±4.22
Gender	16 F, 9 M	17 F, 8M
Handedness	22R,3L/R	23R,2L/R
State Trait Anxiety Inventory (STAI) **	52.6±14.47	40.8±12.57

***p<0.001, **p<0.01, *p<0.05

5.3.2 Stimuli

The stimuli were expressions exhibiting emotions of happiness, sadness, surprise, anger, disgust, fear and neutral, presented in three different modalities: face only (F), voice only (V) and face-voice (FV). They were presented via an Apple Macintosh MacPro 3.1 desktop computer running OS 10.5 and an NVIDIA GeForce 8800GT video card. The visual cues were displayed on a 21-inch ViewSonic Graphics Series G220f CRT monitor running at 1024 X 768 screen resolution and 60Hz refresh rate. They were presented on a black background viewed at the mean viewing distance of approximately 90 cm. Auditory cues were presented through high quality headphones (Bayerdynamic DT770) at a mean sound level of 60 dB(a). The face information, presented for a duration of around 3 s, was selected from Binghamton–Pittsburgh 4D (BP4D) spontaneous facial expression database (Zhang et al., 2014). It consisted of facial behaviors of 3 males and 3 females for each individual emotion, resulting in 42 different facial behaviors. This database was chosen because it comprises spontaneous and natural facial behaviours, thus providing better examples of real world social interactions than do the static stimuli that were commonly used in past research.

The voices of 6 actors (3 male and 3 female) expressing 7 types of non-verbal affective vocalisations (yawns, laughs, screams, etc.), were selected from Montreal Affective Voices (Belin et al., 2008). The exposure duration of the vocalisations ranged from 0.38s (surprise) to 2.22s (sad). This database was chosen as it provided a standardised set of emotional vocalisations corresponding to the universal emotion categories, with the avoidance of potential confound from linguistic content.

The pairing (face-voice stimulus) was conducted by presenting emotional voices in the most informative part of the faces, and presenting neutral voices in the middle part of the faces, resulting in a total of 7 types of stimuli (happy, sad, surprised, angry, disgust, fear and neutral), one for each individual emotion. The gender and emotion in the face and the voice were always congruent. All face-voice pairs were 3s long with a frame rate of 25 frames per second, and were presented on a black background.

5.3.3 Procedure

Participants were tested individually in a single session that lasted approximately 40 mins. The protocol was run by Psychotoolbox-3 (Brainard, 1997; Pelli, 1997) in MatlabR2012a (Mathworks). Before the main task, a practice run was conducted in order to familiarise the participants with the instructions and tasks. During the practice, participants were asked to categorise the emotional expressions displayed in faces, voices, and face-voice. The stimuli used in the practice were different to those used in the main task. After the practice, participants were instructed to complete three tasks, namely the face emotion recognition task, voice emotion recognition task, and face-voice emotion recognition task. For each task, there were six different displays for each emotion (happiness, surprise, fear, anger, disgust, sadness) and neutral; each display was presented twice, resulting in 84 trials. Each trial started with a fixation cross "+" for 0.5s and was followed by the target stimulus. After the stimulus, participants were instructed to press one of seven buttons to indicate the emotion in the display.

The order of the three tasks was randomised across participants; the order of trials was randomised across each task. Correct answer and reaction times during the three emotion recognition tasks were recorded.

5.3.4 Statistical analyses

The data for the current study were analysed using an open source statistical programming environment R (R Development core Team, 2008). Due to the repeated measures design and multiple factors (seven possible answers) within the data, multilevel modelling with cross-classified structures was used to analyse both probabilities of correct answers and response time. First, response time was analysed using Linear Mixed Model (LMM; lme4 package) from the lme4 package (Bates, 2005; Bates & Sarkar, 2007) In this analysis, factors of group (HAQ vs. LAQ), scores of anxiety, and emotion (happiness, surprise, fear, anger, disgust, sadness, and neutral) were modelled into the model: model formulation: response time ~ group + anxiety + group * anxiety + emotion + random participant factor. The probabilities of correct answers were analysed with Generalized Linear Mixed Model (GLMM; lme4 package) using the glmer function (Bates, 2005). A binomial family was specified in the GLMM model to estimate the log-odds ratio for the corresponding factors in the model. Participants' responses were interpreted as dichotomous and recorded as 1 and 0, where 1 represented a correct response and 0 an incorrect response. The model for analysing number of successes was: model formulation: probabilities of correct answers ~

group + anxiety + group * anxiety + emotion + random participant factor, family=binomial. In order to visualise the interaction between group (AQ) and anxiety in emotion recognition, linear regression graphs (trendline) were also provided. In order to follow up interactions between anxiety and group (AQ) in emotion recognition, a further analysis was conducted to include scores of anxiety as a factor to examine how degrees of anxiety modulated the emotion recognition between groups.

For both models, the reported p values were calculated using the lmerTest package (Kuznetsova et al., 2013), and the level of significance was set at p=0.05. The level of autistic traits assessed on AQ was introduced as a between-subjects factor, by which participants were assigned to either a high or low AQ group (as discussed above). Scores of anxiety (assessed on STAI-T) were centred on their grand means.

5.4 Results

5.4.1 Demographics

As illustrated in Table 5.1, there is no significant difference between individuals with HAQ and individuals with LAQ based on their age, gender and handedness. There is a significant group difference between scores of State Trait Anxiety Inventory (STAI). That is, the HAQ group had significantly higher average STAI scores than the LAQ group.

5.4.2 Face emotion recognition task

Table 5.2 shows the main effect of group (AQ), the main effect of anxiety and the interaction between group (AQ) and anxiety in recognising emotional expressions in faces (probability of correct response, and response time). Individuals with HAQ were able to complete the face emotion recognition task (Ps>.05), and their probability of succeeding in recognising disgusted faces was even greater than those with LAQ (AQ: estimate=0.71, p=0.05). However, if we only consider the anxiety, individuals with high levels of anxiety tended to provide fewer correct responses in recognising disgusted faces than non-anxious individuals. In addition, there was a significant interaction between anxiety and group (AQ) in correctly recognising fear (estimate=-0.04, p=0.03) and surprise (estimate=0.05, p=0.01). With regards to response time, no main effects of group (AQ) or anxiety were found for any of the emotions (Ps>0.05). A significant interaction between group (AQ) and anxiety was found for recognition of only some of the emotions: anger (estimate=7.683e-02, p<0.001), fear (estimate= 7.798e-02, p<0.001), sadness (estimate=4.953e-02, p=0.002), and surprise (estimate=0.03, p=0.05).

Table 5.2 -- **Face emotion recognition task**- the main effect of group (AQ), main effect of anxiety, and interaction between group (AQ) and anxiety in recognising emotional expressions in faces.

	Probability of correct response			Response time		
	AQ (z, p)	Anxiety (z, p)	AQ*Anxiety (z, p)	AQ (t, p)	Anxiety (t, p)	AQ*Anxiety (t, p)
Anger	1.44, 0.15	-0.58, 0.56	-1.29, 0.20	1.67, 0.10	-0.11, 0.91	4.93, 3.67e-06***
Fear	-1.65, 0.10	-1.35, 0.18	-2.19, 0.03*	0.61, 0.54	-0.34, 0.73	5.01, 2.70e-06***
Sadness	0.93, 0.35	-1.27 0.20	0.14, 0.89	0.52, 0.61	-0.85, 0.40	3.18, 0.002*
Surprise	1.73, 0.08	-0.78, 0.44	2.48, 0.01*	-0.25, 0.80	-0.51, 0.61	1.70, 0.09
Neutral	1.13, 0.26	0.09, 0.93	-1.40, 0.16	0.42, 0.68	-0.62, 0.54	1.51, 0.13
Disgust	1.96, 0.05*	-3.19, 0.001***	0.02, 0.98	0.58, 0.56	0.34, 0.73	1.07, 0.28
Happiness	0.68, 0.50	0.23, 0.82	0.03, 0.97	-0.26, 0.80	0.08, 0.94	0.77, 0.44

95% confidence intervals are displayed (Signif. codes: ‘***’ 0.001， ‘**’ 0.01 ，‘*’ 0.05)

5.4.3 Voice emotion recognition task

Table 5.3 shows the main effect of group (AQ), main effect of anxiety, and the interaction between group (AQ) and anxiety in recognising emotional expressions in voices (probability of correct response, response time). The HAQ group was able to perform the voice emotion recognition task, and even showed greater probability of correct answers in recognising surprised voices than the LAQ group (estimate=0.70, p=0.02). The interaction between group (AQ) and anxiety traits was also significant in recognising this emotion (estimate=0.05, p=0.02). In addition, regardless of any autistic traits, individuals with a high level of anxiety were more able to recognise angry voices (estimate=0.03, p=0.02) than those with low levels of anxiety. However, this effect of anxiety was not found in recognising other emotions (Ps>0.05). Regarding the response times, individuals with HAQ tended to be slower than individuals with LAQ in responding to fearful vocalisations (estimate=5.031e-01, p=0.05). However, this effect was not found for the recognition of other emotions in voices; that is, for anger, sadness, surprise, neutral, disgust or happiness (Ps>0.05). Regardless of autistic traits, individuals with varying degrees of anxiety traits performed equally well in responding to vocal emotional expressions (all Ps>0.05). A significant interaction was found between group (AQ) and anxiety in the time taken to recognise some emotional expressions in voices; this was found for anger (estimate=4.397e-02, p=0.02), fear (estimate=5.130e-02, p=0.005), surprise (estimate=5.949e-02, p=0.001), and sadness (estimate=3.789e-02, p=0.04), but not other emotions (Ps>0.05).

Table 5.3 -- **Voice emotion recognition task**- the main effect of group (AQ), main effect of anxiety, and interaction between group (AQ) and anxiety in recognising emotional expressions in voices (probability of correct response, response time).

	Probability of correct response			Response time		
	AQ (z, p)	Anxiety (z, p)	AQ*Anxiety (z, p)	AQ (t, p)	Anxiety (t, p)	AQ*Anxiety (t, p)
Anger	1.61, 0.11	2.41, 0.02*	-0.61, 0.54	0.28, 0.78	0.48, 0.63	2.49, 0.02*
Fear	-1.52, 0.13	0.59, 0.56	-1.87, 0.06	1.98, 0.05*	0.62, 0.54	2.90, 0.005**
Sadness	-0.76, 0.49	0.09, 0.93	-1.36, 0.17	0.62, 0.54	0.53, 0.60	2.14, 0.04*
Surprise	2.38, 0.02*	-1.38, 0.17	2.24, 0.02*	0.96, 0.34	-0.51, 0.61	3.37, 0.001**
Neutral	1.59, 0.11	-0.96, 0.34	1.63, 0.10	-0.26, 0.79	0.02, 0.98	1.14, 0.26
Disgust	-0.94, 0.35	-1.27, 0.21	0.74, 0.46	1.21, 0.23	0.62, 0.54	1.08, 0.28
Happiness	-1.77, 0.08	-1.11, 0.27	0.92, 0.36	0.61, 0.54	0.71, 0.48	1.62, 0.11

95% confidence intervals are displayed (Signif. codes: '***' 0.001， '**' 0.01 ， '*' 0.05)

5.4.4 Face-voice emotion recognition task

Table 5.4 shows the main effect of group (AQ), main effect of anxiety, and interaction between group (AQ) and anxiety in recognising emotional expressions in face-voice presentations (probability of correct response, response time). For individuals with HAQ, the probability of success in recognising sadness and surprise displayed in the face-voice presentations was greater than for the individuals with LAQ (surprise:estimate=1.36, p<0.001; sadness:estimate=1.00, p=0.03). For the other emotions, the two groups of participants did not differ (Ps>0.05). However, regardless of the level of autistic traits, the recognition of these emotions (surprise and sadness) tended to be more difficult for individuals with high levels of anxiety than those with low levels of anxiety (surprise:estimate=-0.03, p=0.04; sadness:estimate=-0.03, p=0.04). Significant interactions between group (AQ) and anxiety were found for the probability of a correct response to recognising fear (estimate=-0.06, p=0.009) and surprise (estimate=0.07, p=0.007), but not other emotional expressions.

Regarding the response times, individuals with HAQ were slower to recognise fearful face-voice stimuli (estimate=5.185e-01, p=0.02) than those with LAQ. The two groups were comparable in their responses to the other emotions. In addition, there was a statistically significant interaction between group (AQ) and anxiety in the comparisons of response times for recognising fear (estimate=8.129e-02, p<0.001) and sadness (estimate=3.395e-02, p=0.03), but not other emotions.

Table 5.4 -- **Face-voice emotion recognition task**- the main effect of group (AQ), main effect of anxiety, and interaction between group (AQ) and anxiety in recognising emotional expressions in face-voices (probability of correct response, response time).

	Probability of correct response			Response time		
	Aq (z, p)	Anxiety (z, p)	aq*anxiety (z, p)	Aq (t, p)	anxiety (t, p)	aq*anxiety (t, p)
Anger	1.63, 0.10	0.87, 0.38	0.36 0.72	1.45, 0.15	0.001, 0.10	1.08, 0.28
Fear	-1.21, 0.23	-1.22, 0.22	-2.60, 0.01*	2.30, 0.02	1.42, 0.16	5.19, 1.45e-06***
Sadness	2.16, 0.03*	-2.08, 0.04*	-0.80, 0.43	1.02, 0.31	1.90, 0.06	2.17, 0.03*
Surprise	3.91, 9.36e-05***	-2.08, 0.04*	2.71, 0.007**	0.44, 0.66	0.51, 0.61	0.29, 0.77
Neutral	1.50, 0.13	0.91, 0.36	0.51, 0.61	-0.27, 0.79	-0.68, 0.50	0.84, 0.40
Disgust	-0.05, 0.96	0.40, 0.69	0.62, 0.54	0.25, 0.81	0.37, 0.71	0.92, 0.36
Happiness	0.07, 0.95	-1.64, 0.10	0.77, 0.44	1.25, 0.21	1.12, 0.27	0.89, 0.38

95% confidence intervals are displayed (Signif. codes: '***' 0.001， '**' 0.01 ， '*' 0.05)

5.4.5 Multidimensional analysis in each group (HAQ, LAQ)

Probability of correct response As illustrated in Table 5.5, for the HAQ group the probability of correct answers in recognising fear expressions in the face tasks (estimate=-0.03, p=0.01) and face-voice tasks (estimate=-0.04, p=0.005) was found to be negatively associated with their anxiety levels. This suggested that high autistic trait individuals who also have greater anxiety tend to show inferior performance in recognising fearful faces and fearful face-voice displays, but this does not apply to the recognition of fear in voice, or to other emotions. Similarly, this negative effect of anxiety was also found in the LAQ group for the recognition of surprised faces across tasks (face:estimate=-0.03, p=0.02; voice:estimate=-0.03, p=0.02; face-voice:estimate=-0.06, p<0.001) and disgusted faces (estimate=-0.04, p=0.02). However, unlike the negative effect of anxiety, the probability of successfully recognising angry voices in individuals with LAQ was positively associated with their degree of anxiety, suggesting that anxious individuals with low levels of autistic traits tend to be more accurate in recognising angry voices (estimate=0.04, p=0.04).

Table 5.5 -- The main effect of anxiety in affecting **Probability of correct response** for individual emotion on three tasks (face, voice, face-voice) for each group (HAQ, LAQ).

HAQ	LAQ

	Face (F)	Voice (V)	Face-voice (FV)	Face (F)	Voice (V)	Face-voice (FV)
	(z, p)	(z, p)	(z, p)	(z, p)	(z, p)	(z, p)
Anger	-1.38, 0.17	1.32, 0.19	0.50, 0.62	0.49, 0.62	2.06, 0.04*	0.35, 0.73
Fear	-2.47, 0.01 *	-1.03, 0.30	-2.82, 0.005**	0.63, 0.53	1.56, 0.12	0.95, 0.34
Sadness	-0.81, 0.42	-1.23, 0.22	-1.94, 0.05*	-1.01, 0.31	0.85, 0.39	-0.95, 0.34
Surprise	1.18, 0.24	0.65, 0.51	0.46, 0.64	-2.35, 0.02*	-2.41, 0.02*	-3.41,0.0007*
Neutral	-0.90, 0.37	0.43, 0.67	0.91, 0.36	1.08, 0.28	-2.03, 0.04	0.32, 0.75
Disgust	-2.18, 0.03.	-0.48, 0.63	0.83, 0.41	-2.34, 0.02*	-1.21, 0.23	-0.12, 0.90
Happiness	0.17, 0.86	-0.19, 0.85	-0.73, 0.47	0.12, 0.91	-1.15, 0.25	-1.52, 0.13

95% confidence intervals are displayed (Signif. codes: '***' 0.001， '**' 0.01 ， '*' 0.05).

Table 5.6 **--** The main effect of anxiety in affecting **response time** for individual emotion on three tasks (face, voice, face-voice) in each group (HAQ, LAQ).

	HAQ			LAQ		
	Face (F)	Voice (V)	Face-voice (FV)	Face (F)	Voice (V)	Face-voice (FV)
	(t, p)	(t, p)	(t, p)	(t, p)	(t, p)	(t, p)
Anger	3.88,0.0003**	2.26,0.03*	0.72,0.48	-3.18, 0.003*	-1.33, 0.19	-0.86, 0.39
Fear	3.75,0.0004**	2.68,0.01*	4.39, 8.06e-05**	-3.37, 0.002**	-1.52, 0.14	-3.03,0.004*
Sadness	1.88,0.07	2.04,0.05	2.71,0.01*	-2.54, 0.02*	-1.07, 0.29	-0.21, 0.83
Surprise	0.95,0.34	2.17,0.04*	0.53,0.60	-1.40, 0.17	-2.57, 0.01*	0.18, 0.86
Neutral	0.72,0.47	0.88,0.38	0.11,0.92	-1.34, 0.19	-0.75, 0.46	-1.22,0.23
Disgust	1.14,0.26	1.29,0.20	0.86,0.40	-0.46, 0.65	-0.30, 0.76	-0.44, 0.66
Happiness	0.68,0.50	1.77,0.08	1.33,0.19	-0.44, 0.66	-0.61, 0.55	0.18, 0.85

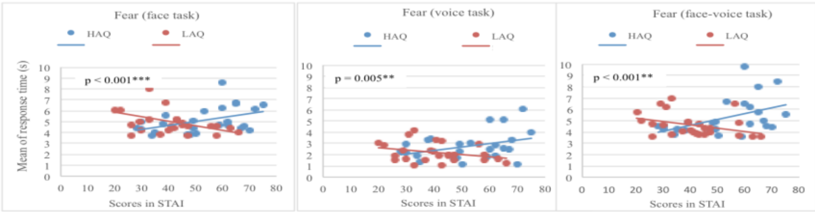
95% confidence intervals are displayed (Signif. codes: '***' 0.001 ， '**' 0.01 ， '*' 0.05)

Response time With regards to response time, a positive effect of anxiety was found in responses to a number of emotions in the HAQ group compared to the LAQ group, where a trend towards a negative effect was reported. Specifically, with greater anxiety, individuals with HAQ tended to be slower in responding to anger (estimate=3.756e-02, p<0.001) and fear (estimate=3.633e-02, p=0.0004) in face tasks, anger (estimate=2.622e-02, p=0.03), fear (estimate=3.109e-02, p=0.01), sadness (estimate=2.364e-02, p=0.049), and surprise (estimate= 2.524e-02, p=0.04) in voice tasks, as well as fear (estimate=5.172e-02, p<0.001) and sadness (estimate=3.188e-02, p=0.01) in face-voice tasks (Table 5.6). However, with greater anxiety, individuals with LAQ tended to be quicker in responding to anger (estimate=-3.927e-02, p=0.003), fear (estimate=-4.165e-02, p=0.002), and sadness (estimate=-3.137e-02, p=0.02) in face tasks, surprise (estimate=-3.424e-02, p=0.01) in voice tasks, and fear (estimate=-2.957e-02, p=0.004) in face-voice tasks.

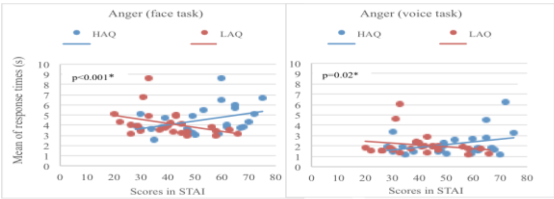
Figure 5.1 & 5.2 Interaction between group (AQ) and anxiety in emotion recognition across tasks. Linear regression graphs (trendline) were created in order to visualise the interaction between group (AQ) and anxiety in modulating response time and probability of correct response in three emotion recognition tasks.

Figure 5.1 -- Interaction between group (AQ) and anxiety in the **response time** for emotions on three tasks (face task, voice task, face-voice task) (only significant activations were shown) 95% confidence intervals are displayed (Signif. codes: '***' 0.001， '**' 0.01 ， '*' 0.05)

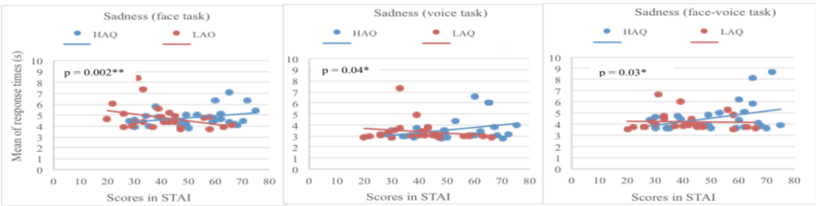
(a)



(b)



(c)



(d)

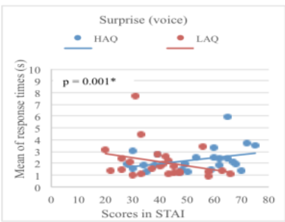
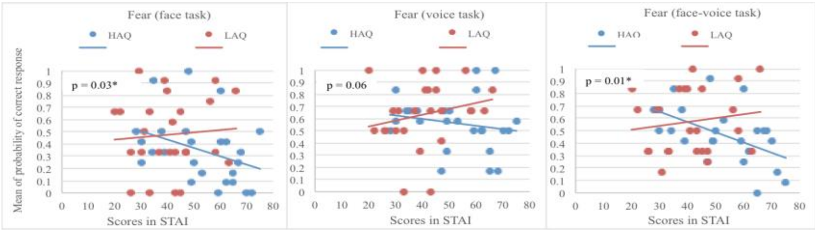
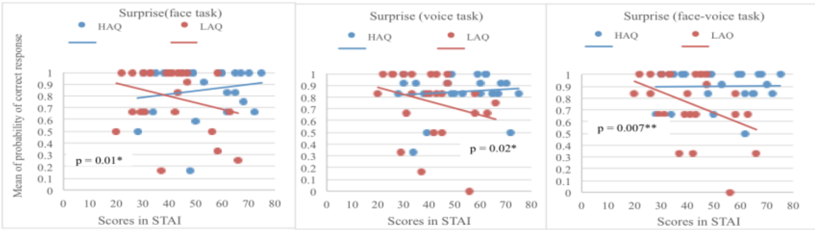


Figure 5.2 -- Interaction between group (AQ) and anxiety in the **probability of correct response** for emotions on three tasks (Face task, voice task, face-voice task). 95% confidence intervals are displayed (Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05).

(a)



(b)



5.5 Discussion

The goal of this research was to investigate (1) whether high autistic trait adults were impaired in recognising the emotional expressions of six basic emotions and a neutral one across modalities, and (2) whether there is a potential moderating effect of comorbid anxiety in their emotion recognition abilities across a range of six basic emotion states. A set of natural and spontaneous facial expressions, non-verbal emotional vocalisations, and a combination of both were used to display emotional expressions.

The results confirmed the existence of comorbid anxiety in people with autistic traits, that is, high autistic trait individuals are more likely to experience anxiety. This finding largely concurs with the prior literature, which reports an elevated rate of anxiety disorders in individuals with ASD (e.g., Gillott, Furniss, & Walter, 2001; Lopata, Volker, Putnam, Thomeer, & Nida, 2008; Muris et al., 1998). As expected, compared to an age and gender-matched group of individuals with LAQ, a trend of no general deficit was found in individuals with HAQ in recognising emotions presented in faces and voices, regardless of their co-morbid anxiety. This finding is consistent with both that of (Jones et al., 2011) who found no evidence of a fundamental emotion recognition deficit in adolescents with ASD in face and voice (verbal and non-verbal) domains, and past research on intact emotion recognition in face tasks (e.g., Baron-Cohen et al., 1993; Grossman & Tager-Flusberg, 2012; Piggot et al., 2004), and voice tasks (e.g., O'Connor, 2007). Indeed, it has been generally accepted that individuals with ASD who do not have intellectual disability are mostly successful in structured emotion processing tasks, such as the recognition of basic emotions. Interestingly, however, and counter to hypotheses, in the current study individuals with HAQ were found to have an intact ability to recognise emotions presented in face-voice presentations, and an even greater probability of correct responses in recognising face-voice presentations of surprise and disgust, which seems to be inconsistent with the theoretical models of weak central coherence in ASD (Happé & Frith, 2006). This absence of emotion recognition deficit across modalities at the behavioural level might be partly explained by demographic factors, such as the age or verbal abilities of samples. Indeed, participants in the present study were verbal adults, so their intact ability in recognising emotions may simply have been a result of the increased exposure to emotional information that occurs with age and the underlying maturation of general executive functions. This interpretation also echoes that of Prior et al., (1990), who suggested that high functioning children with autism process simple facial expressions successfully to an extent that is determined by their chronological and verbal mental age. Another possible explanation for this finding is the idea that the use of unambiguous stimuli, along with the sufficient processing time given to participants, may not have tested the limits of the participants' abilities, leading to comparable performances in recognising emotions between groups. In addition, the lack of group differences (between HAQ and LAQ) may have been, in part, due to the use of facial expressions with greater ecological validity (dynamic, spontaneous). The additional movements in the facial behaviors may have decreased ambiguity and bias in the emotional evaluation process, hence facilitating emotion recognition. Despite these interpretations, it is important to note that intact performances by the HAQ group do not rule out the possibility that they used alternative strategies to (e.g., more cognition - or language-mediated- or more featured based emotion-processing strategies) to compensate for their emotion recognition deficit. For the recognition of emotion in cross-modal presentations, it is possible that the HAQs might have focused on one sensory modality to compensate for their cross-modal deficit, hence masking their difficulties. From this perspective, it is relatively risky to conclude that this lack of behavioral group difference represents an intact ability to integrate multimodal sources. The investigation of neurobiological underpinnings may be beneficial in increasing our understanding of the overlap between autistic traits and anxiety. From this angle, functional MRIs, which allow the measuring of the functional and anatomical networks of the brain, may be a promising technique and could be used in future investigations. FMRIs may be more sensitive than psychological methods in detecting the subtle underlying functional differences in certain mental processes that are impacted by autistic traits and anxiety.

As expected, co-morbid anxiety did moderate the relationship between autistic traits and the recognition of emotions (e.g., fear, surprise, anger), and this effect tended to be different for the two groups. Specifically, with greater anxiety, individuals with HAQ were found to be less accurate in recognising the emotion of fear. In contrast, individuals with LAQ demonstrated more probability of success in recognising fear expressions. Similarly, in terms of response times, anxiety tended to be significantly associated with longer response latencies in the HAQ group, but shorter response latencies in the LAQ group for the recognition of emotional expressions, for negative emotions in particular (e.g., anger, fear, and sadness), and this effect of anxiety was not restricted to specific modalities. This effect of anxiety in the LAQ individuals is consistent with past research that reports associations between dysfunctional emotion recognition (e.g., cognitive bias towards threat-related information) and elevated anxiety symptoms (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Koizumi et al., 2011), which in turn promote or maintain anxiety.

Before explaining the collaborative relationship between autistic traits and anxiety in emotion recognition, it is necessary to consider the patterns of emotion (or information) processing which characterise individuals with anxiety disorders and individuals with ASD, and the interactions between these two types of pattern. It is suggested that individuals with ASD tend to rely heavily on compensatory mechanisms (e.g., rule-based analytic strategies) rather than automatic strategies in their perception of emotional facial expressions (Rutherford & McIntosh, 2007). The use of compensatory mechanisms is associated with increased mental effort to respond to an input, which may lead to longer reaction times. In addition, anxious individuals are often reported to compensate for impaired processing efficiency with additional effort (e.g., Hadwin, Brogan, & Stevenson, 2005). These information processing patterns in individuals who are high in autistic traits and individuals high in trait anxiety both require the devoting of more central executive processing resources to the performance of the task. Given the limited capacity of the information processing system, a person thus has fewer spare processing resources for coping with task demands.

Considering the task demands for responding to a stimulus, it is assumed that when a person is only affected by trait anxiety, or uses only ASD-related atypical information processing strategies, the adverse effect on behavioural performance is no longer present due to the ceiling effects in the recognition of basic emotions. However, when anxiety-related features occur together with the atypical information processing strategies in people with autistic traits, the person needs to make an extra effort to compensate for the combined negative effect to achieve a satisfactory performance, which is then shown by the longer reaction times, even in tasks, which are not too challenging.

There are some limitations to the current study, which need to be noted. First, the present study is potentially important in that it provides evidence of emotion processing relating to the full range of basic emotions across different domains. However, it is also important to consider that in the present study, the participants were given unambiguous expressions and sufficient processing time, and under these situations ceiling effects in performance may have masked potential group differences. In line with this, future research may benefit from the development of experimental procedures that could tap into the more profound understanding of the meaning of emotions, such as emotion recognition in more ambiguous, subtle stimuli, or that could modify the experimental design by allowing limited time for responding.

This study consisted of 50 participants (25 each in the HAQ and LAQ groups). However, considering that the present study involved two variables (traits of anxiety and traits of autism), it would be beneficial to recruit a larger sample size, in order to have participants well-distributed along each level of these two factors. In addition, additional cross-sectional studies of varying age groups and longitudinal investigations are expected in the future, to determine the trajectory of the development of emotion perception in multiple domains in people with autistic traits and comorbid anxiety. The present study may shed light on the patterns of performance when processing emotions in such a population. However, anxiety is not the only condition that occurs along with ASD. Further studies could consider other conditions such as depression and ADHD, which also co-occur with ASD. Last but not least, by focusing on the emotion processing from others, the present work has overlooked the other cognitive processes that comprise other facets of social functioning, such as the emotion regulation, self-emotion awareness (e.g., Mayer, Salovey, & Caruso, 2000). More efforts can be made on these areas in the future.

In conclusion, individuals with HAQ are more likely to have higher levels of anxiety than those with LAQ. In this study, regardless of anxiety, individuals with HAQ were able to recognise emotions displayed across different modalities, suggesting a lack of general deficit in emotion perception among them. The presence of comorbid anxiety appeared to counteract the effects of autistic traits in the processing of emotions. Specifically, greater anxiety was associated with worse performance in recognising emotions in individuals with HAQ, but better performance in individuals with LAQ. Given the modulating effect of anxiety in the emotion recognition tasks between groups, it needs to be noted that the anxiety comorbidity in people with autistic traits and ASD should not be ignored in research studies. It is expected that much can be gained when ASD and anxiety or other comorbid disorders are studied together. These results promote a further understanding towards the social and behavioral phenotypes in individuals with considerable autistic traits and may carry important implications for practice. In addition, the present study provides novel evidence regarding the role of individuals' characteristics (e.g., anxiety) in emotion recognition performance, informing that characteristics of participants should not be ignored.

6. Perception of expressions from faces and voices and of their combination in the autistic brain: an fMRI study

6.1 Abstract

Multi-modal integration requires to combine and integrate information from different sources to create a unified percept. In social interactions, it is a crucial ability and has been frequently explored in typical developing populations. Nevertheless, it still remains unclear how emotional e the neural mechanisms underlying this phenomenon in ASD remains unclear. Using functional magnetic resonance imaging (fMRI), the present study investigated the cerebral correlates of emotion processing conveyed by faces and voices, and of their combination in individuals with high levels of autistic traits. During a block design experiment, the BOLD signal was recorded while 15 adults with high levels of autistic traits (HAQ) and 14 age-, gender -matched adults with low levels of autistic traits (LAQ) perceiving emotional expressions from the face, the voice, and the face-voice. A subtraction contrast (super-additive criteria) [FV- (F+V)] was used to isolate the brain areas specifically involved in multimodal emotion integration. Results of this study as follows: compared to individuals with LAQ, individuals with HAQ showed a hypo-activation of brain areas dedicated to multimodal integration, happy and disgust in particular, although this activation was not entirely impaired. However, both groups activated similar patterns of brain response in response to face-voice combination (mainly in temporal regions). While both groups activated a number of frontal and temporal regions (e.g., STG, MFG, IFG) in response to unimodal emotional expressions (face, voice), different brain network activation were observed in response to communicative cues between the two groups.

6.2 Introduction

Faces and voices are significant sources of emotional information. Accurate recognition of emotions from these sources is crucial for social competence and interpersonal functioning. Previous studies using neuro-imaging techniques have provided considerable evidence for underlying neural-correlates associated with autism spectrum disorders (ASD) in the perception of expressions from faces (e.g., Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, 2007; Corbett et al., 2009; Critchley et al., 2000; Schultz et al., 2000) and voices (e.g., Eigsti, Schuh, Mencl, Schultz, & Paul, 2012; Gervais et al., 2004), thus extending our understanding of the neurodevelopmental hypothesis of ASD.

However, in natural circumstances, a face is usually accompanied by a voice. Crossmodal processing is thus the rule rather than the exception, and the ability to combine and integrate information from different sources is a vital process that serves to facilitate perceptual precision and reduce ambiguity (de Gelder & Vroomen, 2000). In recent years, neuro-imaging studies have allowed us to make significant discoveries concerning multisensory integration mechanisms in typically developing individuals. A number of brain regions have been identified as being involved in this process, such as the middle frontal and superior temporal sulci, and the superior parietal lobule (e.g., Love, Pollick, & Latinus, 2011; Joassin, Pesenti, et al., 2011; Joassin, Maurage, & Campanella, 2011).

Despite increasing evidence of a neural basis for multisensory integration amongst typically developing individuals, the neural mechanisms of multimodal integration in ASD have been, to date, relatively unexplored. Only a few studies have looked into the spatial localisations of the brain regions involved in audio-visual processing, and these have reported neurological differences in ASD, using fMRI as a methodology (Doyle-Thomas, Goldberg, Szatmari, & Hall, 2013; Hall et al., 2003; Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008; Wang, Lee, Sigman, & Dapretto, 2006). The results of these studies have suggested that compared to typically developing individuals, individuals with ASD are more likely to show decreased activation in a number of brain regions, including the inferior frontal regions, the right fusiform gyrus (Hall et al., 2003), medial prefrontal cortex (Wang et al., 2006), orbitofrontal cortex, superior temporal, parahippocampal, and posterior cingulate gyri and occipital regions (Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008), and frontal and temporal association cortices (Doyle-Thomas et al., 2013), with increased activation in the thalamus and anterior cingulate gyrus (Hall et al., 2003). These results have provided insights into the functional and structural differences that exist in individuals with ASD, which may partly relate to a difference in the binding abilities needed to connect and integrate information from different sources, or the compensatory mechanisms recruited by autistic individuals for processing information from different sensorial inputs.

There is very limited data on cross-modality integration in ASD. Although some of the above studies (e.g., Doyle-Thomas et al., 2013; Loveland, Steinberg, Pearson, Mansour, & Reddoch, 2008) included emotional information in the stimuli, there is still little evidence of emotion-specialised neural-pathways during crossmodal processing. Moreover, the neural-basis of emotion processing in ASD has often been explored using paradigms with low ecological validity, such as unimodal-only stimuli (separate presentations of faces and voices). It is thus unclear whether the similar patterns of processing mechanisms would be maintained in experimental designs that were more ecological and closer to real life, specifically when crossmodal stimuli were used. The above behavioural study demonstrated that individuals with HAQ were able to recognise emotional expressions displayed across modalities. However, two groups having a comparable performance at the behavioural level does not necessarily imply the use of the same neural systems, as previous research has indicated differences in neural processing despite comparable behavioural performances in autism (McKay et al., 2012). Therefore, it may be most relevant to examine the neural responses to dynamic multimodal stimuli that are closer to what is usually encountered in more realistic and natural settings.

In view of the present limitations relating to cross-modal research in emotion processing by the ASD population, the central aim of the present study was to explore the neural correlates engaged in the processing of face-voice emotional expressions in individuals with high levels of autistic traits, as measured by the Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). In order to evaluate this issue fully, the underlying brain correlates in single modalities (e.g., face only, and voice only) were also investigated. Given that in the above behavioral study, anxiety was found to modulate emotion recognition performance among the participants, the correlation between (subclinical) anxiety traits as quantified by the STAI and brain activity for emotion processing in individuals with considerable autistic traits was also examined. This provided an insight into the processing of a wide range of emotional expressions across modalities. In line with previous findings in ASD (e.g., Wang, Lee, Sigman, & Dapretto, 2006; Doyle-Thomas et al., 2013; Loveland et al., 2008), it was predicted that the presence of considerable autistic traits would lead to differences in neural responses to face-voice pairs. More specifically, if the brain alteration occurring in individuals with autistic traits was related to more global brain alteration, and corresponded to the accumulation of unimodal deficits, the specific crossmodal activation should be globally preserved in this population. Alternatively, if the abnormal crossmodal activation in autistic traits resulted from atypical crossmodal integration, the specific brain activation in this population should be marked by the alteration of frequently reported crossmodal integration areas (e.g., the superior parietal lobule, and the middle frontal gyrus).

6.3 Method

6.3.1 Participants

A total of 34 right-handed individuals participated in this study. Written informed content was obtained for each participant according to a protocol approved by the ethics committee of the College of Science and Engineering, University of Glasgow. The participants' autistic traits were measured by the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). Based on the scores from the AQ, two groups of participants (individuals with HAQ, and individuals with LAQ) were obtained, using the cut off values of 31 and 18. Hand dominance of participants was assessed by use of the Edinburgh Handedness Inventory Questionnaire (Oldfield, 1971). All participants were reported to have normal or corrected to normal visual and hearing acuity. 5 participants were excluded from the analysis due to full scan incompleteness or run-time errors. Therefore, 15 individuals (11females, 4males) with high autistic-like traits (HAQ) and 14 individuals (11females, 3males) with low autistic-like traits (LAQ) were included into the analysis, as illustrated in Table 6.1.

Table 6.1—Demographic characteristics of the HAQ group and LAQ group

Characteristic	HAQ(N=15)	LAQ(N=14)
Autism Quotient**	38.67(5.73)	11.79(4.17)
Age	27.81(10.01)	23.14(4.22)
Gender	11 F, 4 M	11 F, 3M

**p<0.01, *p<0.05

6.3.2 Stimuli

In line with the above behavioral experiment, participants were confronted with facial and vocal cues presented either separately (unimodal conditions) or together (crossmodal condition, with emotionally congruent face-voice pairs). The facial cues were selected from Binghamton–Pittsburgh 4D (BP4D) spontaneous facial expression database (Zhang et al., 2014). The face stimuli consisted of 5 males and 5 females, each showing expressions of happiness, sadness, disgust, fear, and neutral, resulting in 50 different facial behaviors. The vocal cues, consisting of samples from 10 individuals (5 males and 5 females) were selected from a non-verbal battery- Montreal Affective Voices (Belin et al., 2008), depicting the same emotional expressions as the facial stimuli. All face-voice pairs were 3s long with a frame rate of 25 frames per second, and were presented on a black background. Thus, the stimuli used in the present study were 50 faces, 50 voices, and 50 face-voice pairs showing the emotions of happiness, sad, disgust, fear, and neutral.

6.3.3 Design

The fMRI scanning consisted of two runs. For each run, stimuli consisted of 50 faces, 50 voices, and 50 face-voice pairs showing emotions of happy, sad, disgust, fear, and neutral. Each stimulus was presented twice, resulting a total of 300 stimuli. Being different from the explicit emotion labeling task used in the behavior study, the present study involved an implicit emotion processing tasks in which participants passively view and/or listen to emotional stimuli presented in faces, voices, and face-voices. Using implicit emotion processing task in the present study has its pragmatic advantages. For example, the use of implicit emotion processing task tend to make the block design easier to implement, and also significantly reduces the burden (e.g., prolong time for completing tasks in-scanner, or anxiety caused due to the task demanding in-scanner) on participants. Therefore, Blood Oxygenation Level-Dependent (BOLD) signal changes were recorded while participants perceived the stimuli in the 2 experimental runs. Each run lasted for 714 seconds and comprised 30 blocks. Each run began with 20 seconds black screen before the video trials began and ended with 12 seconds black screen. Each block lasted for 16 s with 5 different stimuli expressing the same emotion in same modality. Emotion in one block was preceded and followed by another block in a different emotion. The order of the blocks in each run was pseudo-randomized. Catch trials were used during the scanning to ensure that participants are alert and attending to the task. All of catch trials were excluded from further data analyses. Stimuli were presented using Presentation 14.9 designed by NeuroBehavioral Systems (NBS), via electrostatic earphones (NordicNeuroLab, Norway) at a sound pressure level of 80 dB.

6.3.4 Data acquisition

Structure and functional images were collected on a 3T Tim Trio MRI scanner (Siemens, Germany). Functional images were acquired using blood-oxygen-level-dependent (BLOD) contrast sequence (Gradient-echo EPI sequence, TR=2000ms, TE=30ms, FA=90°, dimension = 210mm x 210 mm, voxel size = 3mm×3mm×3 mm), covering the whole brain. Each functional run comprised 357 volumes and each image volume consisted of 32 slices acquired in ascending interleaved sequence. The first two volumes of functional data were excluded to allow for signal stabilisation. After the acquisition of functional images, a T1-weighted high-resolution anatomical image was acquired to allow for spatial registration of the functional images (192 contiguous 1mm axial slices, dimensions: 256mm*256mm, TR= 1900ms, TE=2.52ms, inversion time= 900ms, flip angle=9°), lasting 5 minutes.

6.3.5 fMRI Data analysis

Both fMRI data pre-processing and analysis were performed using Brainvoyager QX (2.8) (Brain Innovation). After homogeneity correction, the structural scan was transformed into Talairach space (Talairach & Tournoux, 1988). For functional images, slice scan time correction was performed using sinc interpolation. In addition, the functional images were realigned to the first functional scan just before the individual structural scan, to correct for within- and between-run spatially motion. Then, the functional volumes were applied with a temporal high pass filter (general linear model (GLM) with Fourier basis set of 2 cycles sine/cosine) and smoothed spatially using a Gaussion kernel of 6mm full-width half-maximum. After the preprocessing, the data were then co-registered to the individual anatomical data sets and normalised to Talairach stereotaxic space.

Condition-related changes in regional brain activity were estimated for each participant using General Linear Model (GLM), in which the response evoked by each condition of interest was modeled by a standard hemodynamic response function, For each participant, one single design matrix including all conditions across two runs was constructed and modelled as 15 regressors: 5 emotions (happiness, sadness, disgust, fear, neutral) *3 modalities (F, V, FV). Motion confounds based on six realignment parameters were created after applying Spikes, Detrended and Detrended Derivative detection. All resulting confound variables were included into the GLM model as additional regressors of non-interest. The contrasts of interest were computed at the individual level to determine the brain regions elicited by happy-neutral (F), happy-neutral (V), happy-neutral (FV), sad-neutral (F), sad-neutral (V), sad-neutral (FV), disgust-neutral (F), disgust-neutral (V), disgust-neutral (FV), fear-neutral (F), fear-neutral (V), fear-neutral (FV), neutral-implicit baseline (F), neutral-implicit baseline (V), neutral-implicit baseline (FV). To obtain the brain activations directly dedicated to crossmodal integration, a classical subtraction technique was used, assuming the multisensory response exceeds the sum of the unisensory responses after adjustment for baseline activity (Joassin, Pesenti, et al., 2011; Joassin, Maurage, et al., 2011). Specifically, the facial (F) and vocal (V) unimodal conditions were substracted from the face-voice bimodal condition (FV) using the following formula: FV-[F+V]. Therefore, five types of face-voice integration contrasts were computed: happy-neutral: FV- (F+V), sad-neutral: FV-(F+V), fear-neutral: FV-(F+V), disgust-neutral: FV-(F+V), neutral-implicit baseline: FV-(F+V). The resulting contrast images were entered into group analyses. For separate groups, one-sample t tests were conducted to identify clusters of significant activity for each pair of contrast. Between-group differences were examined using two-sample t tests. To account for multiple comparisons, all activated clusters were thresholded with a primary threshold of voxel-wise $p<0.001$, and then corrected for multiple comparisons using cluster threshold. After 1000 iterations of a Monte Carlo simulation, the minimum cluster size threshold that yielded a cluster-level false-positive rate of 5% was applied to the statistical maps. All clusters reported in the present study survived this whole-brain control of multiple comparisons. Last but not least, condition & trait-anxiety interactions were examined by extracting parameter estimates of activity (beta weights) from the cluster for each participant, each condition.

6.4 Results

Data for 5 contrasts from the analysis were presented: Neutral (neutral-implicit baseline) (Table 6.2), Happiness (happiness-neutral) (Table 6.3), Disgust (disgust-neutral) (Table 6.4), Fear (fear-neutral) (Table 6.5), Sadness (sadness-neutral) (Table 6.6). For each contrast, brain activity of both within groups and between groups elicited by the face (F), the voice (V), the face-voice combination (FV), and the face-voice integration [FV- (F+V)] were detailed respectively. Between group differences were also indicated when they were present, as shown in Figures 6.1-6.11.

Neutral

Face

Compared to implicit baseline (neutral-implicit baseline contrast), neutral faces elicited the following significant activations (see Table 6.2a)

- LAQ: significant activations were found in the right postcentral gyrus, inferior frontal gyrus, lingual gyrus, superior temporal gyrus, thalamus, left fusiform gyrus, and middle frontal gyrus.
- HAQ: significant activations were found in the right cuneus, the left superior frontal gyrus, and fusiform gyrus.
- Group comparison: HAQ group presented decreased activation in the right postcentral gyrus, left cingulate gyrus, insula, and inferior parietal lobe as compared to LAQ group.

Voice

Compared to implicit baseline (neutral-implicit baseline contrast), neutral voices elicited the following significant activations (see Table 6.2b)

- LAQ: significant activations were found in the bilateral superior temporal gyrus.

- HAQ: significant activations were found in the bilateral superior temporal gyrus, right precentral gyrus, and cuneus.

- Group comparison: HAQ group presented increased activation in the right lentiform nucleus, left precentral gyrus, and superior temporal gyrus, as compared to LAQ group.

Face-voice combination

Compared to implicit baseline (neutral-implicit baseline contrast), neutral face-voice displays elicited the following significant activations (see Table 6.2c)

- LAQ: significant activations were found in the bilateral fusiform, superior temporal gyrus, and the right lingual gyrus.

- HAQ: significant activations were found in the bilateral culmen, inferior frontal gyrus, right superior temporal gyrus, and the left transverse temporal gyrus.

- Group comparison: no significant activation was found.

Face-voice integration

The FV- (F+V) contrast was computed in both groups to isolate the face-voice integration regions. Compared to implicit baseline, regions that are specifically involved in face-voice integration process for the neutral were as follows (see Table 6.2d)

- LAQ: significant activations were found in the right fusiform.

- HAQ: significant activations were found in the right fusiform.

- Group comparison: no significant activation was found.

Table 6.2 -- Brain activation showing significant activation among HAQ group, LAQ group and group comparisons for (a) neutral faces (F), (b) neutral voices (V), (c) neutral face-voice combination (FV), (d) neutral face-voice integration [FV- (F+V)].

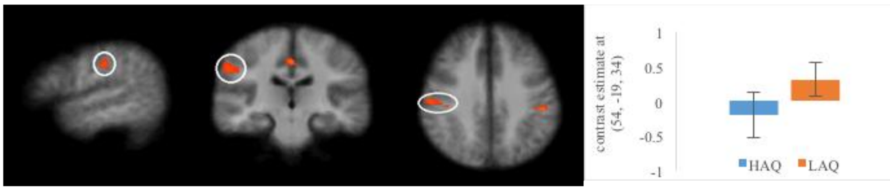
Contrast	Group	Brain regions	Talairach coordinate of peak voxel (x, y, z)	L/R	BA	t-statistic	No. of voxels
(a) neutral: F	LAQ	Postcentral Gyrus	(60, 13, 25)	R	3	5.31	372
		Inferior Frontal Gyrus	(55,23,19)	R	45	6.85	2775
		Postcentral Gyrus	(48,-25,46)	R	2	5.07	494
		Lingual Gyrus	(18,-85,-5)	R	18	8.09	14701
		Superior Temporal Gyrus	(39,-34,4)	R	41	5.56	344
		Thalamus	(18,-28,-2)	R	-	5.26	200
		Fusiform Gyrus	(-36,-43,-17)	L	-	8.17	15277
		Middle Frontal Gyrus	(-48,14,34)	L	9	5.57	226
	HAQ	Cuneus	(15,-98,1)	R	-	10.93	10334
		Superior Frontal Gyrus	(-12,39,52)	L	8	7.81	640

		Fusiform Gyrus	(-36,-73,-11)	L	19	8.47	4004
		Fusiform Gyrus	(-36,-40,-17)	L	20	8.53	1488
	LAQ>HAQ	Postcentral Gyrus	(54,-19,34)	R	2	4.66	514
		Cingulate Gyrus	(0,-22,40)	L	24	4.47	490
		Insula	(-39,-7,7)	L	13	4.72	459
		Inferior Parietal Lobe	(-48,-31,49)	L	40	5.09	2096
	HAQ>LAQ	No significant activation					
(b) neutral: V	LAQ	Superior Temporal Gyrus	(45,-19,7)	R	13	9.22	9701
		Superior Temporal Gyrus	(-42,-19,7)	L	13	9.72	6678
	HAQ	Superior Temporal Gyrus	(51,-13,4)	R	22	12.47	19347
		Precentral Gyrus	(48,-10,46)	R	4	6.80	503
		Cuneus	(9,-94,22)	R	19	5.99	1009
		Cuneus	(9,-91,7)	R	17	6.05	344
		Superior Temporal Gyrus	(-42,-25,7)	L	13	11.76	15868
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	Lentiform Nucleus	(27,-16,1)	R	-	6.81	506
		Precentral Gyrus	(-42,-16,37)	L	4	4.39	95
		Superior Temporal Gyrus	(-42,-37,4)	L	**13**	4.89	152
(c) neutral: FV	LAQ	Superior Temporal Gyrus	(42,-22,10)	R	13	8.68	7729
		Lingual Gyrus	(18,-85,-5)	R	18	9.70	8138
		Fusiform Gyrus	(36,-49,-14)	R	37	6.16	773
		Fusiform Gyrus	(-21,-85,-11)	L	18	10.02	7563
		Superior Temporal Gyrus	(-48,-16,4)	L	22	7.58	4232
		Fusiform Gyrus	(-36,-43,-17)	L	-	5.86	384
	HAQ	Superior Temporal Gyrus	(60,-13,4)	R	22	12.41	17425
		Inferior Frontal Gyrus	(42,8,25)	R	9	6.88	1829
		Cuneus	(18,-95,4)	R	17	10.69	12750
		Cuneus	(-12,-97,-2)	L	17	8.49	6300
		Transverse Temporal Gyrus	(-42,-25,10)	L	41	10.48	10171
		Inferior Frontal Gyrus	(-51,23,19)	L	45	5.63	313
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					
(d) neutral: FV- (F +V)	LAQ	Fusiform Gyrus	(27,-91,-12)	R	18	5.14	346
	HAQ	Fusiform Gyrus	(24,-91,-12)	R	18	5.89	597
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					

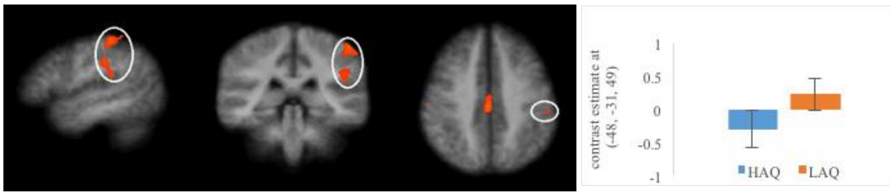
x,y,z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere. All the reported regions were thresholded at $p<0.001$, at the corrected level

Figure 6.1--Brain regions showing decreased activation among individuals with HAQ when compared with individuals with LAQ for processing neutral faces, involving right Postcentral Gyrus (54, -19, 34) BA2, left Postcentral Gyrus (-48, -31, 49) BA40, left Insular cortex (-39, -7, 7) BA13, and left Cingulate Gyrus (0, -22, 40) BA24.

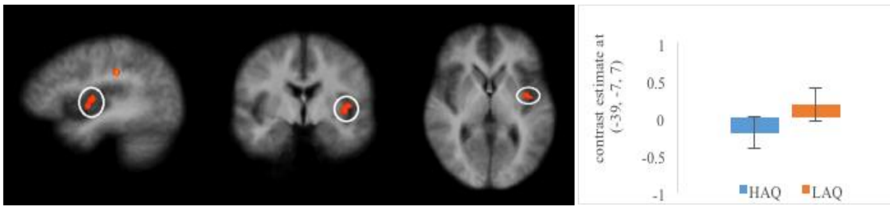
right Postcentral Gyrus(54, -19, 34)



left Inferior Parietal Lobe (-48, -31, 49)



left Insular cortex (-39, -7, 7)



left Cingulate Gyrus (0, -22, 40)

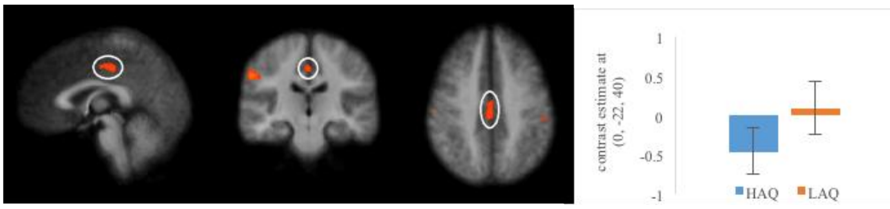
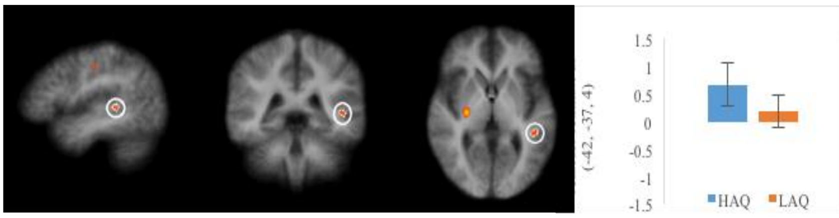
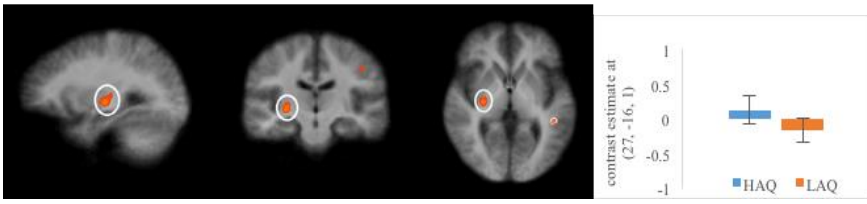


Figure 6.2--Compared with individuals with LAQ for processing neutral voices, involving left Superior Temporal Gyrus (-42,-37,4) BA41, right Lentiform Nucleus (27,-16,1), and left Precentral Gyrus (-42,-16,37) BA4.

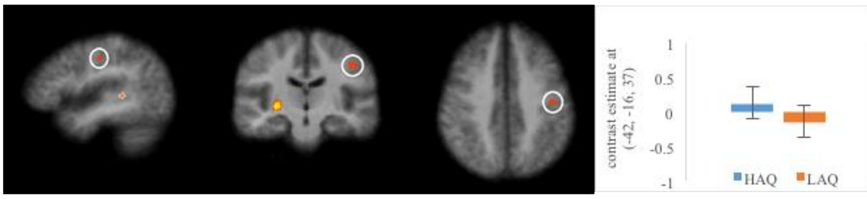
left Superior Temporal Gyrus (-42, -37, 4)



right Lentiform Nucleus (27, -16, 1)



left Precentral Gyrus (-42, -16, 37)



Happy

Face

Compared to neutral voices (happiness-neutral: F), happy faces elicited the following significant activations (see Table 6.3a)

- LAQ: no significant activation was found.
- HAQ: no significant activation was found.
- Group comparison: no significant activation was found.

Voice

Compared to neutral voices (happiness-neutral: V, happy voices elicited the following significant activations (see Table 6.3b)

- LAQ: no significant activation was found.
- HAQ: no significant activation was found.
- Group comparison: no significant activation was found.

Face-voice combination

Compared to neutral voices (happiness-neutral: FV), happy face-voice displays elicited the following significant activations (see Table 6.3c)

- LAQ: significant activations were found in the left superior temporal gyrus.
- HAQ: no significant activation was found.
- Group comparison: HAQ group presented decreased activations in the right superior temporal gyrus, and cingulate gyrus as compared to LAQ group.

Face-voice integration

The FV- (F+V) contrast was computed in both groups to isolate the face-voice integration areas. Compared to neutral face-voice pairs [happiness-neutral: FV- (F+V), regions that are specifically involved in face-voice integration processes of happiness were as follows (see Table 6.3d)

- LAQ: significant activations were found in the bilateral cingulate gyrus, superior temporal gyrus, thalamus, the right precentral gyrus, the left medial frontal gyrus, middle frontal gyrus, superior frontal gyrus, and the inferior parietal lobule.
- HAQ: no significant activation was found.
- Group comparison: HAQ group presented decreased activation in the right declive as compared to LAQ group.

Table 6.3. Brain activation showing significant activation among HAQ group, LAQ group and group comparisons for (a) happiness-neutral faces: F, (b) happiness-neutral voices: V, (c) happiness-neutral face-voice combination: FV, (d) happiness face-voice integration [happiness-neutral: FV- (F+V)].

Contrast	Group	Brain regions	Talairach coordinate of peak voxel (x, y, z)	L / R	BA	t-statistic	No. of voxels
(a) happiness-neutral: F	LAQ	No significant activation					
	HAQ	No significant activation					
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					
(b) happiness-neutral: V	LAQ	No significant activation					
	HAQ	No significant activation					
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					
(c) happiness-neutral: FV	LAQ	Superior Temporal Gyrus	(-45,-19,1)	L	22	6.07	1218
		Superior Temporal Gyrus	(-45,-46,22)	L	13	6.98	665
	HAQ	No significant activation					
	LAQ>HAQ	Superior Temporal Gyrus	(51,-43,13)	R	22	4.13	83
		Superior Temporal Gyrus	(42,-37,1)	R	41	4.04	161
		Cingulate Gyrus	(21,-34,34)	R	31	4.15	170
	HAQ>LAQ	No significant activation					
(d) happiness-neutral: FV- (F+V)	LAQ	Superior Temporal Gyrus	(51, -22,7)	R	41	6.5	1509
		Precentral Gyrus	(45,5,37)	R	9	5.49	212
		Precentral Gyrus	(42, -13,52)	R	4	6	241
		Cingulate Gyrus	(12, -28,34)	R	31	5.18	223
		Thalamus	(9, -13,4)	R	-	6.14	399
		Cingulate Gyrus	(9, -43,37)	R	31	6.45	352
		Declive	(9, -67, -17)	R	-	5.57	238
		Cingulate Gyrus	(0, -1,28)	L	24	6.46	430
		Medial Frontal Gyrus	(-3,11,46)	L	6	6.02	705
		Thalamus	(-6, -19,10)	L	-	5.24	688
		Superior Frontal Gyrus	(-30,50,25)	L	10	5.08	204
		Superior Temporal Gyrus	(-54, -28,16)	L	42	5.54	1243
		Middle Frontal Gyrus	(-45,8,37)	L	9	6.24	434

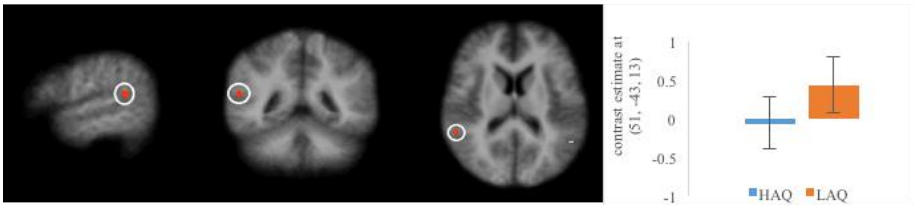
	Inferior Parietal Lobule	(-42, -43,43)	L	40	6.64	597
	Superior Temporal Gyrus	(-63, -16,7)	L	22	5.59	339
HAQ	No significant activation					
LAQ>HAQ	Declive	(9, -82, -20)	R	-	4.97	534
HAQ>LAQ	No significant activation					

x,y,z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere

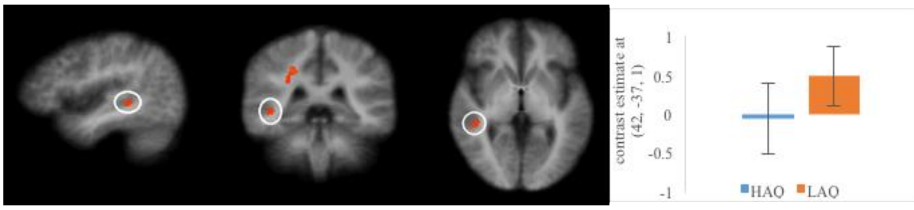
All the reported regions were thresholded at p<0.001, at the corrected level.

Figure 6.3—Brain regions showing less activation among individuals with HAQ when compared with individuals with LAQ for processing happy face-voice combination: right Superior Temporal Gyrus (51, -43, 13) BA22, right Superior Temporal Gyrus (42, -37, 1) BA41, right Cingulate Gyrus (21, -34, 34) BA31.

right Superior Temporal Gyrus (51, -43,13)



right Superior Temporal Gyrus (42,-37,1)



right Cingulate Gyrus (21,-34,34)

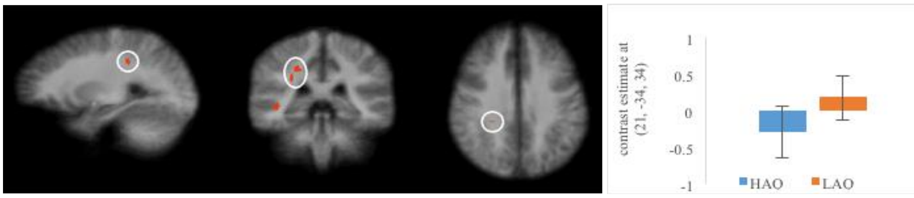
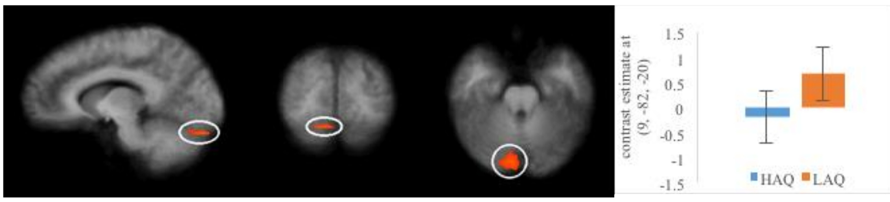


Figure 6.4.Brain regions showing crossmodal integration for happiness emotion. right Declive (9,-82,-20).

right Declive (9,-82,-20)



Disgust

Face

Compared to neutral faces (disgust-neutral: F), disgusted faces elicited the following significant activations (see Table 6.4a)

- LAQ: significant activations were found in the bilateral middle temporal gyrus and right inferior frontal gyrus, superior temporal gyrus.
- HAQ: significant activations were found in a broad brain network, involving bilateral declive, inferior frontal gyrus, right parahippocampal gyrus, midbrain, and left cingulate gyrus, superior frontal gyrus, lentiform nucleus, fusiform gyrus, superior temporal gyrus.
- Group comparison: HAQ group presented increased activation in the right thalamus, precuneus as compared to LAQ group.

Voice

Compared to neutral voices (disgust-neutral: V), disgusted voices elicited the following significant activations (see Table 6.4b)

- LAQ: significant activations were found in the right superior temporal gyrus.
- HAQ: no significant activation was found.
- Group comparison: HAQ group presented reduced activation in the left parahippocampal gyrus, as compared to LAQ group.

Face-voice combination

Compared to neutral face-voice pairs (disgust-neutral: FV), disgusted face-voice displays elicited the following significant activations (see Table 6.4c)

- LAQ: significant activations were found in the right superior temporal gyrus, and left middle temporal gyrus.
- HAQ: significant activations were found in the right inferior temporal gyrus, and left superior temporal gyrus.
- Group comparison: HAQ group presented increased activations in the bilateral superior frontal gyrus, as compared to LAQ group.

Face-voice integration

The FV- (F+V) contrast was computed in both groups to isolate the face-voice integration areas. Compared to neutral face-voice pairs [disgust-neutral: FV- (F+V)], regions that are specifically involved in face-voice integration processes of disgust were as follows (see Table 6.4d)

- LAQ: significant activations were found in the right middle frontal gyrus, right paracentral lobule and left postcentral gyrus.
- HAQ: no significant activation was found.
- Group comparison: no significant activations was found.

Table 6.4 -- Brain activation showing significant activation among HAQ group, LAQ group and group comparisons for (a) disgust-neutral faces: F, (b) disgust-neutral voices: V, (c) disgust-neutral face-voice combination: FV, (d) disgust face-voice integration [disgust-neutral: FV-(F+V)].

Contrast	Group	Brain regions	Talairach coordinate of peak voxel (x, y, z)	L/R	BA	T-statistic	Number. of voxels
(a) disgust-neutral: F	LAQ	Middle Temporal Gyrus	(51, -61,4)	R	37	6.33	2449
		Inferior Frontal Gyrus	(54,23,16)	R	45	6.62	874
		Superior Temporal Gyrus	(45, -34,1)	R	22	5.63	431
		Middle Temporal Gyrus	(-48, -46,7)	L	21	6.34	2207
	HAQ	Declive	(42, -61, -20)	R	-	10.53	10351
		Inferior Frontal Gyrus	(48,21, -11)	R	47	5.97	1579
		Parahippocampal Gyrus	(30, -7, -11)	R	-	6.48	139
		Declive	(21, -73, -14)	R	-	5.68	579
		Midbrain	(12, -13, -5)	R	-	6.12	195
		Cingulate Gyrus	(0, -52,28)	L	31	5.56	295
		Superior Frontal Gyrus	(-3,56,28)	L	9	5.29	285
		Lentiform Nucleus	(-21, -16, -5)	L	-	6.58	667
		Fusiform Gyrus	(-21, -79, -14)	L	19	4.82	148
		Declive	(-36, -67, -21)	L	-	6.83	697
		Superior Temporal Gyrus	(-57, -49,10)	L	22	7.26	5126
		Inferior Frontal Gyrus	(-48,23,7)	L	45	5.46	602
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	Thalamus	(18, -34,1)	R	-	4.66	189
		Precuneus	(12, -40,52)	R	7	4.37	111
(b) disgust-neutral: V	LAQ	Superior Temporal Gyrus	(60, -10,1)	R	22	6.61	221
	HAQ	No significant activation					
	LAQ>HAQ	Parahippocampal Gyrus	(-39, -43,1)	L	-	4.97	375
	HAQ>LAQ	No significant activation					
(c) disgust-neutral: FV	LAQ	Superior Temporal Gyrus	(45, -37,4)	R	41	5.39	665
		Middle Temporal Gyrus	(-48, -64,7)	L	37	4.91	673
	HAQ	Inferior Temporal Gyrus	(45, -64, -2)	R	37	5.25	1091
		Superior Temporal Gyrus	(-45, -43,22)	L	13	8.72	848
		Superior Temporal Gyrus	(-45, -52,7)	L	39	5.77	630
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	Superior Frontal Gyrus	(18,56,1)	R	10	5.05	301
		Superior Frontal Gyrus	(-21,62,16)	L	10	4.29	115
(d) disgust-neutral: FV-(F+V)	LAQ	Middle Frontal Gyrus	(30,38,31)	R	9	6.26	281
		Middle Frontal Gyrus	(24,23,34)	R	8	6.06	209
		Paracentral Lobule	(12, -46,61)	R	5	7.53	401
		Postcentral Gyrus	(-21, -28,55)	L	6	5.44	148

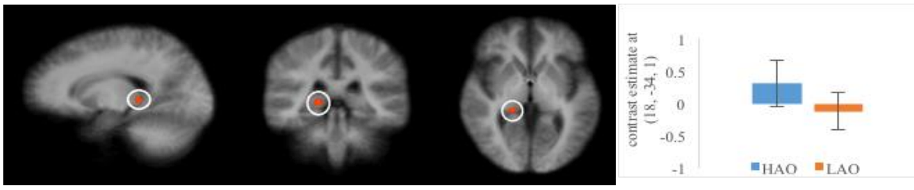
HAQ	No significant activation
LAQ>HAQ	No significant activation
HAQ>LAQ	No significant activation

x,y,z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere

All the reported regions were thresholded at p<0.001, at the corrected level.

Figure 6.5--Brain regions showing greater activation among individuals with HAQ when compared with individuals with LAQ for processing disgusted faces, involving right thalamus (18, -34,1), right precuneus (12, -40,52) BA7.

right thalamus (18, -34,1)



right precuneus (12, -40,52)

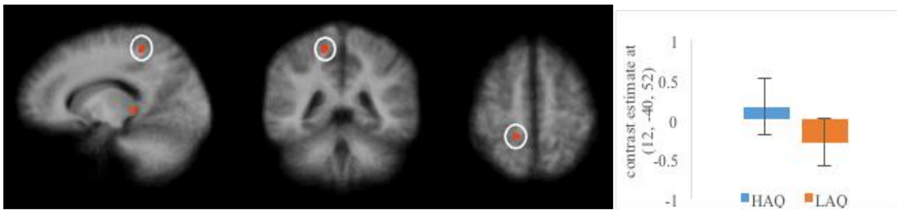


Figure 6.6--Brain regions showing less activation among individuals with HAQ when compared with individuals with LAQ for processing disgusted voices at the left parahippocampal gyrus (-39, -43,1), BA19

left Parahippocampal Gyrus (-39, -43, 1)

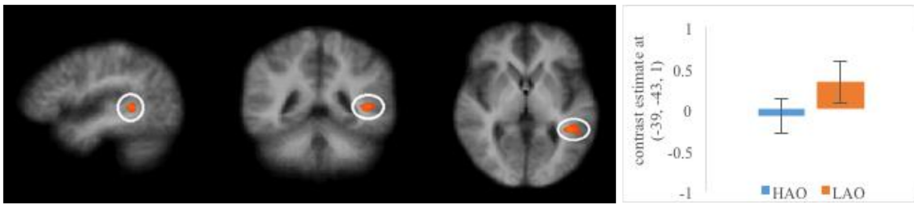
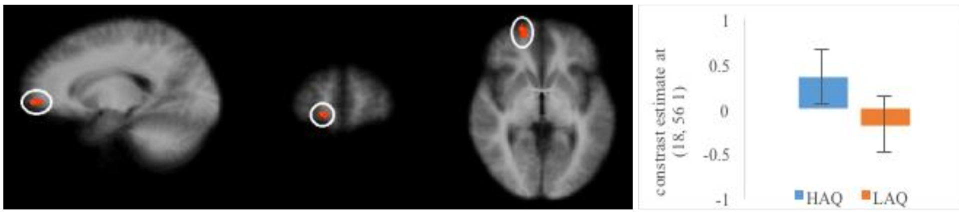
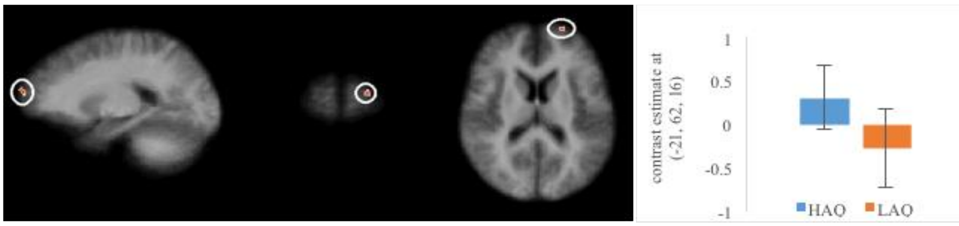


Figure 6.7--Brain regions showing greater activation among individuals with HAQ when compared with individuals with LAQ for processing disgusted face-voice combination (FV) at right Superior Frontal Gyrus (18,56,1) and left Superior Frontal Gyrus (-21,62,16), BA10.

right Superior Frontal Gyrus (18, 56, 1)



left Superior Frontal Gyrus (-21, 62, 16)



Fear

Face

Compared to neutral faces (fear-neutral: F), fearful faces elicited the following significant activations (see Table 6.5a)

- LAQ: significant activations were found in the right inferior temporal gyrus.

- HAQ: significant activations were found in a broad brain network, involving bilateral inferior frontal gyrus, superior temporal gyrus, right sub-gyral, superior frontal gyrus, and left middle occipital gyrus.

- Group comparison: HAQ group presented increased activation in the left inferior parietal lobule, and postcentral gyrus as compared to LAQ group.

Voice

Compared to neutral voices (fear-neutral: V), fearful voices elicited the following significant activations (see Table 6.5b)

- LAQ: significant activations were found in the right caudate and superior frontal gyrus.

- HAQ: no significant activation was found.

- Group comparison: the HAQ group presented reduced activation in the right postcentral gyrus, caudate, and left precentral gyrus, as compared to LAQ group.

Face-voice combination

Compared to neutral face-voice pairs (fear-neutral: FV), fearful face-voice pairs elicited the following significant activations (see Table 6.5c)

- LAQ: significant activations were found in the right inferior temporal gyrus.

- HAQ: no significant activation was found

- Group comparison: no significant activation was found.

Face-voice integration

The FV- (F+V) contrast was computed in both groups to isolate the face-voice integration areas. Compared to neutral (fear-neutral: FV- (F+V)), regions that are specifically involved in face-voice integration processes of fear were as follows (see Table 6.5d)

- LAQ: no significant activation was found

- HAQ: no significant activation was found.

- Group comparison: no significant activation was found.

Table 6.5 -- Brain activation showing significant activation among HAQ group, LAQ group and group comparisons for (a) fear-neutral faces: F, (b) fear-neutral voices: V, (c) fear-neutral face-voice combination: FV, (d) fear face-voice integration [fear-neutral: FV- (F+V)].

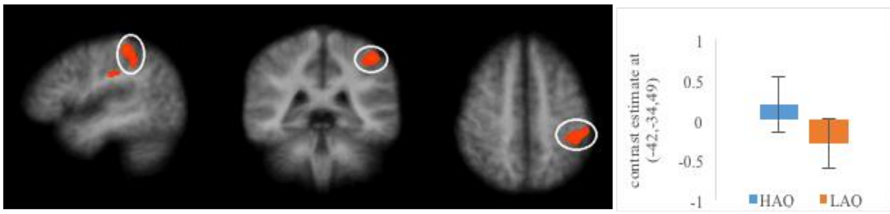
Contrast	Group	Brain regions	Talairach coordinate of peak voxel (x, y, z)	L/R	BA	t-statistic	Number of voxels
(a) fear-neutral: F	LAQ	Inferior Temporal Gyrus	(52, -64, -2)	R	19	5.12	296
	HAQ	Middle Temporal Gyrus	(48, -34,1)	R	-	8.07	6761
		Inferior Frontal Gyrus	(42,23,13)	R	45	6.45	1181
		Sub-Gyral	(45, -4, -8)	R	21	6.95	717
		Superior Temporal Gyrus	(42,11, -14)	R	38	5.49	508
		Superior Frontal Gyrus	(3,11,58)	R	6	5.33	440
		Middle Occipital Gyrus	(-42, -67,4)	L	37	5.44	785
		Superior Temporal Gyrus	(-57, -46,13)	L	22	7	2309
		Inferior Frontal Gyrus	(-45,14,19)	L	9	7.84	494
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	Inferior Parietal Lobule	(-42, -34,49)	L	40	4.45	1611
		Postcentral Gyrus	(-42, -22,28)	L	2	4.03	146
(b) fear-neutral: V	LAQ	Caudate	(21, -10,19)	R	-	5.92	398
		Superior Frontal Gyrus	(18,53,38)	R	9	4.92	119
	HAQ	No significant activation					
	LAQ>HAQ	Postcentral Gyrus	(64, -19,31)	R	1	5	125
		Caudate	(21, -7,19)	R	-	4.6	146
		Precentral Gyrus	(-51, -10,40)	L	4	4.28	155

	HAQ>LAQ	No significant activation					
(c) fear-neutral FV	LAQ	Inferior Temporal Gyrus	(55, -64, -2)	R	19	4.68	163
	HAQ	No significant activation					
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					
(d) fear-neutral: FV-(F+V)	LAQ	No significant activation					
	HAQ	No significant activation					
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					

x,y,z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere. All the reported regions were thresholded at p<0.001, at the corrected level.

Figure 6.8--Brain regions showing greater activation among individuals with HAQ when compared with individuals with LAQ for processing fear faces, involving left Inferior Parietal Lobule (-42, -34,49) BA40; left Postcentral Gyrus (-42, -22,28) BA2

left Inferior Parietal Lobule (-42, -34, 49)



left Postcentral Gyrus (-42, -22, 28)

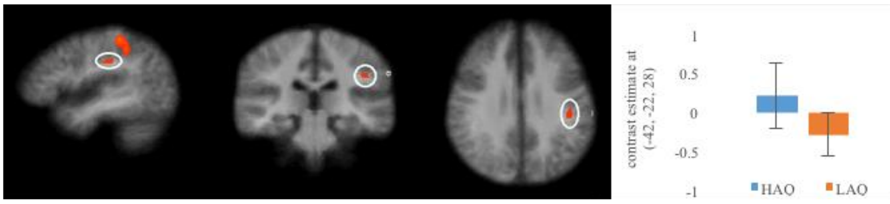
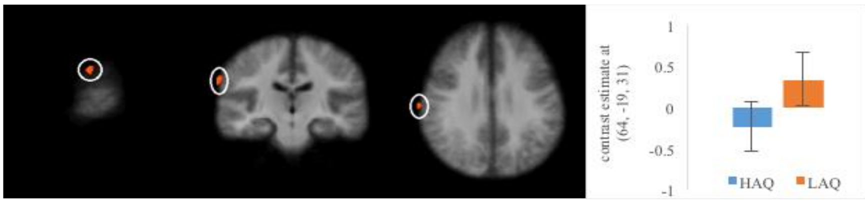
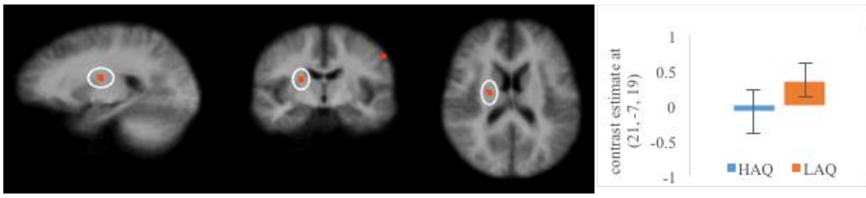


Figure 6.9--Brain regions showing less activation among individuals with HAQ when compared with individuals with LAQ for processing fear voices, involving right Postcentral Gyrus (64, -19,31) BA1; right Caudate (21, -7,19); left Precentral Gyrus (-51, -10,40) BA4.

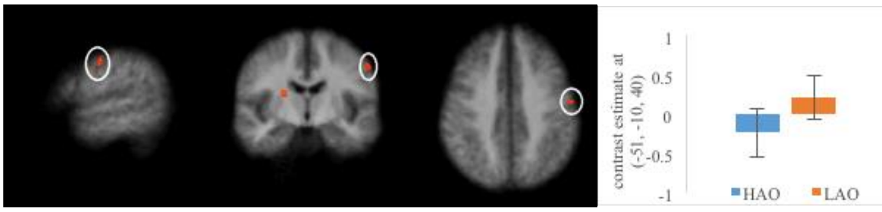
right Postcentral Gyrus (64, -19, 31)



right Caudate (21, -7, 19)



left Precentral Gyrus (-51, -10, 40)



Sadness

Face

Compared to neutral faces (sadness-neutral: F), sad faces elicited the following significant activations (see Table 6.6a)

- LAQ: no significant activation was found.

- HAQ: significant activations were found in the right middle temporal gyrus.

- Group comparison: HAQ group presented increased activation in the left sub-gyral, and inferior temporal gyrus, as compared to LAQ group.

Voice

Compared to neutral voices (sad-neutral: V), sad voices elicited the following significant activations (see Table 6.6b)

- LAQ: significant activations were found in the bilateral superior temporal gyrus.

- HAQ: significant activations were found in the bilateral superior temporal gyrus

- Group comparison: HAQ group presented reduced activation in the right superior temporal gyrus, as compared to LAQ group.

Face-voice combination

Compared to neutral face-voice pairs (sad-neutral:FV), sad face-voice pairs elicited the following significant activations (see Table 6.6c)

- LAQ: significant activations were found in the bilateral superior temporal gyrus.

- HAQ: significant activations were found in the bilateral superior temporal gyrus.

- Group comparison: no significant activation was found.

Face-voice integration

The FV- (F+V) contrast was computed in both groups to isolate the face-voice integration areas. Compared to neutral (sad-neutral: FV- (F+V)), regions that are specifically involved in face-voice integration processes of face-voice sadness were as follows (see Table 6.6d)

- LAQ: no significant activation was found

- HAQ: no significant activation was found.

- Group comparison: no significant activation was found.

Table 6.6 -- Sad – Brain activation showing significant activation among HAQ group, LAQ group and group comparisons for (a) sadness-neutral faces: F, (b) sadness-neutral voices: V, (c) sadness-neutral face-voice combination: FV, (d) sadness face-voice integration [sadness-neutral: FV- (F+V)].

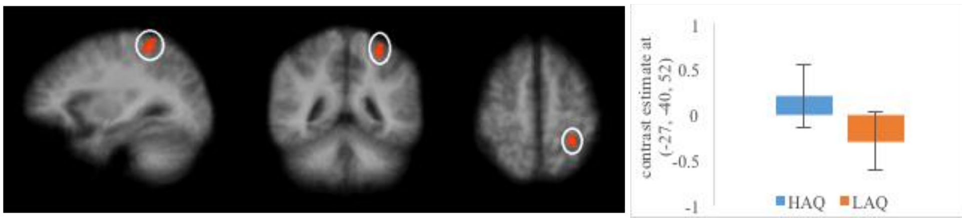
Contrast	Group	Brain regions	Talairach coordinate of peak voxel (x, y, z)	L/R	BA	t-statistic	Number of voxels
(a) sadness-neutral:F	LAQ	No significant activation					
	HAQ	Middle Temporal Gyrus	(51, -31, -5)	R	21	4.6	122
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	Sub-Gyral	(-27, -40,52)	L	40	4.45	408
		Inferior Temporal Gyrus	(-55, -31, -17)	L	20	4.49	276
(b) sadness-neutral: V	LAQ	Superior Temporal Gyrus	(60, -13,1)	R		12.18	12928
		Superior Temporal Gyrus	(57,5, -8)	R	38	6.12	143
		Superior Temporal Gyrus	(-42, -34,7)	L	41	8.48	8770
	HAQ	Superior Temporal Gyrus	(51, -13,7)	R	22	9.04	6842
		Superior Temporal Gyrus	(-45, -19,4)	L	22	7.77	6360
	LAQ>HAQ	Superior Temporal Gyrus	(60, -43,13)	R	22	4.11	161
	HAQ>LAQ	No significant activation					
(c) sadness-neutral: FV	LAQ	Superior Temporal Gyrus	(51, -10, -2)	R	22	6.31	9549
		Superior Temporal Gyrus	(-36, -31,7)	L	41	8	8925

	HAQ	Superior Temporal Gyrus	(51, -16,4)	R	22	8.97	9606
		Superior Temporal Gyrus	(-42, -28,4)	L	41	8.16	11435
	LAQ>HAQ	No significant activation					
	HAQ>LAQ	No significant activation					
(d) sadness-neutral: FV-(F+V)	LAQ	Inferior Occipital Gyrus	(28, -94, -8)	R	17	6.30	547
	HAQ	Inferior Occipital Gyrus	(33, -88, -11)	R	18	5.90	232
		Anterior Cingulate	(24,29,19)	R	32	5.46	319
		Cingulate Gyrus	(21,8,31)	R	32	5.10	496

x,y,z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere. All the reported regions were thresholded at p<0.001, at the corrected level.

Figure 6.10--Brain regions showing greater activation among individuals with HAQ when compared with individuals with LAQ for processing sad faces, involving left Sub-Gyral (-27, -40,52) BA40; left Inferior Temporal Gyrus (-55, -31, -17) BA20

left Sub-Gyral (-27, -40,52)



left Inferior Temporal Gyrus (-55, -31, -17)

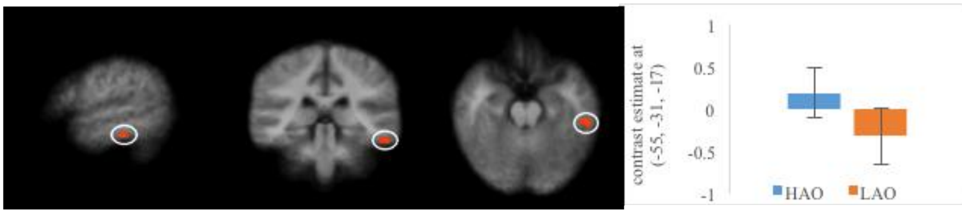
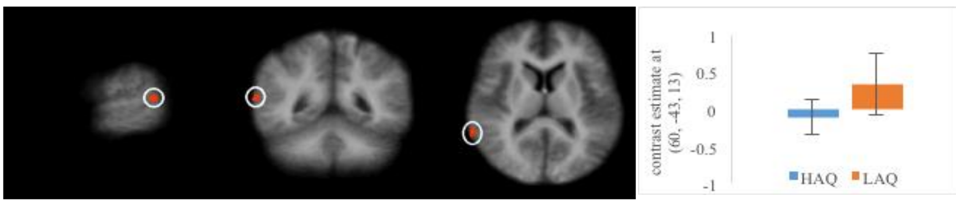


Figure 6.11--Brain regions showing significant increased activation among individuals with HAQ when compared with individuals with LAQ for processing sad voices, involving right Superior Temporal Gyrus (60, -43,13) BA22

right Superior Temporal Gyrus (60, -43,13)



Correlation between anxiety symptoms and brain activation

It has been found that individuals with HAQ tend to show more severe anxiety symptoms. The correlation of anxiety symptoms in the brain activations revealed in individuals with HAQ was also examined. However, the lack of a clear association between anxiety symptoms and bran functions in individuals with HAQ was found, except a few regions in specific contrasts. As can be seen in the Table 6.7, the right superior temporal gyrus was positively correlated with the level of anxiety in the condition of fearful face contrasted with neutral face. Similarly, the right precentral gyrus was positively correlated with the level of anxiety in response to neutral vocalizations. The significant right Declive activation in response to disgusted face contrasted with neutral face was positively correlated with level of anxiety while negatively corrected with level of anxiety in response to emotional vocalizations contrasted with neutral vocalizations.

Table 6.7 -- Correlation between emotion processing and anxiety symptoms in the HAQ group (n=15).

Brain regions	Talairach coordinate of peak voxel (x, y, z)	BA	r.	p value	Number of voxels
neutral V		4	0.58		
right precentral gyrus	(48, -10, 46)			0.02	503
disgust-neutral: F		-	0.53		
right Declive	(21, -73, -14)			0.04	579
emotion-neutral: V		-	-0.6		
right Declive	(12, -76, -14)			0.02	1007
fear-neutral: F					
right superior temporal gyrus	(42, 11, -14)	38	0.54	0.04	508

x,y, z are stereptaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere.

All the reported regions were thresholded at p<0.001, at the corrected level.

6.5 Discussion

In the present study, fMRI was used to investigate the neural correlates among individuals with high levels of autistic traits and individuals with low levels of autistic traits during processing of four primary emotions (happiness, disgust, fear, sad) and neutral from the face and the voice, and to investigate how emotional expressions from different sources are combined in the brain. As suggested from the analysis, the hypothesis of altered brain activity in response to face-voice presentations in individuals with HAQ was only partially supported. Specifically, hypo brain activation in individuals with HAQ was found in a limited number of emotions, such as the processing of emotion from happiness and disgust, but not in other emotions. In addition, the present study has also implicated a number of regions, including the IPL, STG, IFG, STG, MFG, and IFG for processing unimodal emotional expressions in individuals with HAQ. These results will be discussed in the following section.

Multisensory integration regions

One of the main goals for the present study was to classify the brain areas recruited for processing face-voice integration. In order to do this, super-additive criterion was used to classify the brain activations dedicated to multimodal integration for each emotion. The super-additive criterion is a common approach to classifying multisensory integration (Calvert, Campbell, & Brammer, 2000), and assumes that the multisensory integration response exceeds the sum of the unisensory responses.

Neutral: Super-additive enhancement for [FV- (F+V): neutral] was found in the right fusiform gyrus for both groups. It seems interesting that multimodal integration of neutral face-voice pairs led to unimodal processing (e.g., face processing). As a matter of fact, the enhanced activation of unimodal areas in multimodal conditions has also been reported in prior literature in typical populations (e.g., Calvert et al., 1999; Joassin, Pesenti, et al., 2011; Maurage & Campanella, 2013), and is explained as being a result of increased connectivity between unimodal areas during cross-modal processing. In addition, for processing neutral face-voice combination, both groups evoked activation in regions for bio-modal processing (e.g., IFG, STG). Regions of IFG and STG were frequently reported to be involved in audio-visual processing in previous studies (e.g., Ojanen et al., 2005; Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007). There is also evidence of greater brain activity in the IFG and STG when processing audio-visual information than when processing unimodal information (e.g., Skipper, Nusbaum, & Small, 2005; Robins, Hunyadi, & Schultz, 2009; Park et al., 2010). Thus, the present results add to the existing literature and confirm the implications of these regions in crossmodal processing. However, there is no group difference of brain activity for processing crossmodal presentations of neutral.

Happiness: Super-additive enhancement for the emotion of happy [FV- (F+V): happy-neutral] was found in a broad brain network in the LAQ group (but not in the HAQ group), in areas including the bilateral STG, left SFG, left MFG, left IPL and bilateral thalamus. These results confirmed the findings of Pourtois, de Gelder, Bol, and Crommelinck (2005) which demonstrated the activation of the left SFG, MFG, and IPL for face-voice emotion integration using conjunction analysis. In addition, the results confirmed the STG as a key area for multimodal integration (e.g., Ethofer, Anders, Erb, Herbert, et al., 2006; Park et al., 2010). These results tend to provide solid evidence for a happy-specific multimodal integration network in typical populations. However, the significant superadditivity was not found in the HAQ group. Despite of this, individuals with HAQ were found to show less activation in the STG than the LAQ group when responding to happy face-voice combinations. This finding was consistent with a prior study by Loveland, Steinberg, Pearson, Mansour, and Reddoch (2008) which documented less activation in STG in responding to face-voice emotional pairs in ASD.

Disgust：Significant super-additive enhancement was found in specific crossmodal areas in the LAQ group but not in the HAQ group, namely the MFG, which was known to be implicated for processing multimodal integration (e.g., Park et al., 2010). The present results of MFG in disgust may suggest a more general role of MFG in multimodal integration, and suggest that it is not restricted to the processing of happiness as discussed above. At the same time, the absence of activation in crossmodal integration in the HAQ may suggest the crossmodal integration impairment in this population. However, the HAQs, while failed to elicit significant activation in any brain regions for processing cross-modal integration of disgust, showed increased activation in region of superior frontal gyrus in response to disgusted face-voice combinations.

Fear and sadness: Unexpectedly, no significant activation dedicated for fear and sadness crossmodal integration in either group or group differences.It is not yet clear why there is no significant activation revealed on this issue, but one possibility is that the regions for multi-sensory integrative processes and emotion integrative processes were relatively overlapped, leading to the loss of these overlapped brain regions when the neutral condition was introduced as contrast baseline. Alternatively, it is also possible that the crossmodal integrative regions for processing fear and sadness are so different as the crossmodal integrative regions for processing neutral, leading to the absence of significant activation for the subtraction of brain activity between them. However, both groups showed significant activation in the STG in response to the face-voice combination (sad FV), confirming the activation of STG in response to congruent audio-visual stimuli in prior literature (e.g., Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007; Pourtois et al., 2005).

Brain response for modality specific processing

In this study, neural responses to separate emotions (happiness, disgust, fear, sadness and neutral) expressed in uni-modality (F, V) were also examined. A few brain regions in the temporal and frontal lobes were activated during the processing of emotions as compared to baseline conditions (e.g., neutral expression). Significant activity in the temporal lobes and frontal lobes, specifically in the STG, MTG and IFG has been observed across many emotions and across modalities in both the HAQ and LAQ groups. These brain regions were well documented to be implicated in processing social information and emotion understanding in past research (e.g., Redcay, 2008; Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998; Rizzolatti & Craighero, 2004).

Superior temporal gyrus

As observed, compared to individuals with LAQ, individuals with HAQ showed hyper-activation in the STG in response to neutral vocalizations, but hypo-activation in the STG in response to emotional vocalisations, such as sad vocalisations. The difference in the STG between the two groups could be interpreted as an over-attribution of emotions to neutral in the LAQ group, and an over-attribution of neutral to emotions in the HAQ group.

Inferior parietal lobule and Inferior frontal gyrus

In response to the fearful faces, a broader brain network was recruited by the HAQ group involving parts of temporal lobule (BA38, BA22), frontal lobule (BA6, BA9, BA45), occipital lobe (BA37) whereas the LAQ group only elicited activity in the ITG. Additionally, individuals with HAQ displayed greater activation in the inferior parietal lobule and postcentral gyrus than individuals with LAQ, in response to fearful faces. These results are consistent with a study by Doyle-Thomas et al. (2013) examining the audio-visual emotional matching processing. In addition to its role in audio-visual integration (Calvert, 2001; Calvert et al., 2000), the inferior parietal lobule is known to be involved in the "action-attention" patterns of brain activation (Cohen, van Gaal, Ridderinkhof, & Lamme, 2009). Doyle-Thomas et al. (2013) discussed these results and explained that individuals with ASD relied on this network for attentional and integrative purposes. In this sense, the greater activation in the IPL, together with the broader involvement of frontal regions for individuals with HAQ, maybe also interpreted as the recruitment parietal-frontal attention networks as an alternate compensatory system. If this explanation is correct, the use of compensatory systems in individual with HAQ relates not only to multimodal integration processing, but also shows flexibility extending to uni-modal stimuli processing where necessary, especially for fearful face processing. Another possible explanation for this activity in parts of temporal lobule, frontal lobule and the IPL in the HAQ group is more effortful and less automatic processing required to pay attention and process fearful faces. Indeed, activation in frontotemporal areas has been reported to be increased with a more cognitively demanding process (Wang et al., 2006). In addition, the presence of mirror neurons, for examples, in regions of IPL and IFG could also be explained that may be that the HAQ group are able to feel the emotions internally though they may be not good in manifesting these feelings externally. Bastiaansen et al. (2011) suggested that MNS activity increased along with age and improved social functioning, and this may account for the lack of group difference in IFG activation in the present study. Unexpectedly, no significant correlation between level of anxiety and patterns of brain activation in the HAQ group was obtained. This may suggest a different mechanism in individuals with HAQ and comorbid anxiety compared to individuals with high levels of anxiety only during the processing of emotional expressions. Alternatively, the lack of significant correlation between levels of anxiety and patterns of brain activation may be, in part, due to the small sample size which may hinder the detection of brain activity difference along with the degrees of anxiety in individuals wit HAQs.

A few limitations of the current study should be noted. First, due to the time constraints and difficult recruiting process, the present study involved population size that was relatively small (n=29), given the heterogeneous nature of this population. The small sample size may have reduced the effect size for detecting more subtle, but highly informative changes in brain functions between the two groups during the processing of emotional expressions. It may also have hindered the analysis of subgroups (e.g., the HAQ group, n=15) that may have demonstrated different brain responses related to anxiety, which may have influenced the overall brain activity. Second, the data presented in the present study are female biased, compared to most of the prior research which was male-dominated (e.g., Baron-Cohen et al., 2009). It is possible that male-dominated participants profiles may result in different activation patterns. Indeed, early PET imaging studies have reported gender differences in the patterns of brain activation during emotion-related tasks (e.g., George et al., 1996). In this sense, the results of the present study may not allow us to draw robust conclusions, and may not be directly generalisable to the whole autistic population. Third, the stimuli used in the current study were combined dynamic facial behaviours and vocalisations. These facial behaviours indicated moment-to-moment changes in emotional states, providing a good approximation of naturalistic interaction. However, the stimuli may still have evoked some unnatural feelings in the participants due to the lack of synchronisation between facial behaviours and vocalisations when constructing stimuli. Future studies should attempt to control this limit. Fourth, as has been discussed above, despite the inclusion of a neutral baseline condition being advantageous for allowing us to examine the integration regions that are dedicated for emotion processing in the multisensory integration analysis, the possible loss of visualisation of brain regions that overlapped between sensory integration and emotion integration cannot be excluded. Future studies with a more appropriate baseline condition are thus expected. Finally, in the present study, a passive-perceiving task was used in order to save time and fit for the block design fMRI. This experimental paradigm limited our ability to identifying the precise state at which an atypical processing strategy originated, and begs the following question: does the crossmodal deficit start at an early, perceptive stage or only during a later processing step?

Notwithstanding the limitations, the present study provides evidence of audio-visual integration and modality/emotion specific brain correlates across a large number of emotions in individuals with considerable autistic traits. Understanding the emotional signals presented from different sources is pivotal for elucidating social communication and behaviour in this population. These results may have clinical implications for a better understanding of the neural correlates in ASD involved in processing social and communicative information, especially in females.

In summary, the current study examined the neural correlates during the processing of a set of primary emotions from faces and voices between individuals with HAQ and individuals with LAQ, and the networks involved in face-voice integration processing. Compared to individuals with LAQ, individuals with HAQ showed a hypo-activation of brain areas dedicated to multimodal emotional integration (happy and disgust in particular), although this activation was not entirely impaired. A number of brain regions, such as STG, IFG, MFG, and IPL have been identified to be specifically involved in multimodal emotion integration, using super-additive criteria. In response to emotional stimuli in single modality, the HAQ group activated a number of frontal and temporal regions (e.g., STG, MFG, IFG), which may suggested a more effortful and less automatic processing in individual with HAQ.

7. Incongruence in cross-modal emotional integration in autistic traits - an fMRI Study

7.1 Abstract

In everyday life, emotional information is often conveyed by both the face and the voice. Consequently, information presented by one source can alter the way in which information from another source is perceived, leading to emotional incongruence if information from the two sources differs. In the present fMRI study, I examined how neural circuitry responds to emotional incongruence, paying particular attention to how changes in explicit instructions modulated the regional brain activity in a group of individuals with high levels of autistic traits

(HAQ). Participants were adults with high level of autistic traits (HAQ, n=16) and level of autistic traits (LAQ, n=13). Whole brain fMRI data were collected when participants were instructed to attend one modality (e.g., face or voice) while concurrently being exposed to the other, emotion-congruent or emotion-incongruent, modality (e.g., voice or face). Unlike individuals with LAQ, individuals with HAQ exhibited decreased activation in several areas at least partly overlapping with the default mode network in response to emotion-incongruence, including the posterior cingulate cortex, superior occipital gyrus and precuneus, regardless of instructions. This suggested a lack of behaviour adjustment, more effortful processing or high attentional demands in responding to incongruence. Compared to individuals with LAQ, individuals with HAQ showed a stronger incongruence effect when they were instructed to attend to a voice while ignoring a face. This increased incongruence effect was associated with regions of the right superior frontal gyrus, left superior occipital gyrus and left middle frontal gyrus. However, less of an incongruence effect was observed when they were instructed to attend to a face while ignoring a voice, as compared to individuals with LAQ. These results may indicate that the ability of high autistic trait individuals to recruit brain networks in responding to emotional incongruence may be a result of the combined effect of attentional demands and information processing propensity.

7.2 Introduction

Deficits in social communication are core characteristic of Autism Spectrum Disorder (ASD), and have been repeatedly linked to deficits in emotion processing, making it an important research topic across a variety of areas, including cognitive neuroscience, psychology, and computer science. Autism Spectrum Disorder (ASD) is by definition a complex and heterogeneous disorder. There is increasing evidence to suggest that autism lies along the continuum of social-communication disability that is also present in the general population (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001).

Abnormalities in attending to and extracting salient information from social cues (e.g., faces, voices or eye gaze) in individuals with ASD have long been reported in previous studies

(Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Donohue, Darling, & Mitroff, 2012; Hobson, Oustont, & Lee, 1989; Klin, 1991; Rutherford, 2007; Van Lancker, Cornelius, & Kreiman, 1989). At the neurobiological level, these atypical patterns of emotion recognition have been linked to anomalies in the neural circuits involved in processing faces (e.g., fusiform gyrus), processing voices (e.g., superior temporal sulcus) or demonstrating "theory of mind" (e.g. medial prefrontal cortex) (Hall, Szechtman, & Nahmias, 2003; Bozikas et al., 2006; Gervais et al., 2004; Happé et al., 1996; Wendt, 2003).

These studies in ASD have, however, mainly focused on uni-modal emotion processing, whereas in natural social interactions, emotions are generally expressed and perceived through multiple modalities. For example, we usually hear a voice while simultaneously seeing a face. The ability to extract relevant information from different sources and integrate this into a unified and coherent percept is a skill with adaptive significance (Campanella & Belin, 2007).

To date, only a few studies have looked into the spatial localisations of the brain regions involved in audio-visual processing in ASD (Doyle-Thomas, Goldberg, Szatmari, & Hall, 2013; Hall et al., 2003; Loveland et al., 2008; Wang, Lee, Sigman, & Dapretto, 2006). The results of these studies have suggested that compared to typically developing individuals, individuals with ASD are more likely to show decreased activation in a number of brain regions, including the inferior frontal regions, the right fusiform gyrus (Hall et al., 2003), the medial prefrontal cortex (Wang et al., 2006), the orbitofrontal cortex, the superior temporal, parahippocampal, posterior cingulate gyri and occipital regions (Loveland, et al., 2008), and the frontal and temporal association cortices (Doyle-Thomas et al., 2013) while increased activation in the thalamus and the anterior cingulate gyrus (Hall et al., 2003).

Importantly, information from different sources may not always be congruent (Loveland et al., 2008), in which cases, information from one source may alter the perception of information from the other source. In recent years, neuroimaging studies have sought to elucidate the neural underpinnings of incongruence processing in the typical population (e.g., Carter & Van Veen, 2007; Haas, Omura, Constable, & Canli, 2006; Kerns et al., 2004; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009). This research has emphasized the significant role of the anterior cingulate cortex (ACC) and the prefrontal regions, such as the dorsolateral prefrontal cortex (DLPFC) and posterior medial frontal cortex (PMFC) in detecting and resolving incongruence. However, very few studies have explored the neural correlates of cross-model incongruence processing in ASD. Watanabe et al., (2012) assessed the neural correlates when participants were processing non-matching cues between verbal and nonverbal information (e.g., facial expressions, verbal prosody and semantic words) and reported significantly decreased brain activation in a number of regions in individuals with ASD, including the right inferior frontal gyrus (rIFG), bilateral anterior insula, anterior cingulate cortex/ventral medial prefrontal cortex (ACC/vmPFC), and dorsal medial prefrontal cortex (dPFC).

Despite anomalies in the research to date, there is evidence to suggest that individuals with ASD tend to demonstrate more typical patterns of brain activation when tasks require more cognitive or explicit processing. For example, using fMRI, Wang, Lee, Sigman, & Dapretto (2007) reported decreased activation in the medial prefrontal cortex (mPFC) and right superior temporal gyrus (rSTG) in individuals with ASD while they performed an irony comprehension task. However, the level of activation in the mPFC was increased in individuals with ASD but not in TDs in explicit instruction conditions.

As discussed above, even though atypical patterns of emotion processing in the visual, auditory and audio-visual domains are frequently reported in individuals with ASD, there have been few attempts to determine the neural correlates of incongruence processing in a face-voice paradigm in this population. In addition, it has not yet been clarified if different patterns of brain activation occur in the context of being instructed to either attend to a face, or attend to a voice. In addition, anxiety characterize impairment in information processing may cause additional variance, confounding the patterns of emotion processing in ASD. As far as I know, there is still an open question regarding the neural basis of incongruity in ASD when anxiety is also considered.

Given these considerations, the goal of the present study was to examine the neural correlates underlying the incongruence effect, as defined by a contrast between incongruence and congruence, in a group of individuals with high levels of autistic traits, compared to individuals with low levels of autistic traits, as measured by the Autism-Spectrum Quotient (AQ; Baron-Cohen, et al., 2001). In addition, I intended to assess whether brain activity changed across the two groups in the context of different instructions (attending to the face or attending to the voice). Last but not least, the correlation between (subclinical) anxiety traits as quantified by the STAI and brain activity for incongruity was explored In line with previous findings on incongruence processing in ASD (e.g., Wang et al., 2007; Watanabe et al., 2012), I predicted that individuals with considerable autistic traits would present with reduced activation in regions that were significant for incongruence processing (e.g., ACC or prefrontal regions), independent of the instructions. On the basis of the above study by Wang et al., (2007), I also assumed that individuals with a higher level of autistic traits would elicit more normative patterns of brain activation under explicit instructions.

7.3 Method

7.3.1 Participants

A total of 34 right-handed participants were involved in this study. Written informed content was obtained for each participant according to a protocol approved by the ethics committee of the College of Science and Engineering, University of Glasgow. The participants' autistic traits were assessed by the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). Based on the scores from the AQ, two groups of participants (individuals with HAQ and individuals with LAQ) were obtained, using a cut off of 31 and 18. Hand dominance for participants was assessed by use of the Edinburgh Handedness Inventory Questionnaire (Oldfield, 1971). All participants were reported to have normal or corrected to normal visual and hearing acuity. 5 participants were excluded from the analysis due to full scan incompleteness or run-time errors. Therefore, 16 individuals (11 females, 5 males) with high autistic-like traits (HAQ) and 13 individuals (10 females, 3 males) with low autistic-like traits (LAQ) were included in the analysis, as illustrated in Table 7.1.

Table 7.1--Demographic characteristics of the HAQ group and LAQ group

Characteristic	HAQ (N=16)	LAQ (N=13)
Autism Quotient**	38.67(5.73)	12.15(4.1)
Age	27.87(10.04)	23.23(4.38)
Gender	11F, 5M	10F, 3M

**p<0.01, *p<0.05

7.3.2 Stimuli

The stimuli were face-voice pairs. The face information, selected from Binghamton–Pittsburgh 4D (BP4D) spontaneous facial expression database (Zhang et al., 2014), consisted of facial behaviors of 5 males and 5 females, each showing happy, neutral, and fearful expressions, resulting in 30 different facial behaviors. The voice information consisted of 10 audible yawns, 10 laughs and 10 screams (5 male and 5 female for each case), selected from Montreal Affective Voices (Belin et al., 2008). The pairing was done by presenting happy and fearful voices in the most informative part of the faces, and presenting neutral voices in the middle part of the faces, resulting in a total of nine types of emotional (in) congruent stimuli: a happy face paired with a happy voice (H/H), a happy face paired with a fearful voice (H/F), a happy face paired with a neutral voice (H/N), a fearful face paired with a fearful voice (F/F), a fearful face paired with a happy voice (F/H), a fearful face paired with a neutral voice (F/N), a neutral face paired with a neutral voice (N/N), a neutral face paired with a happy voice (N/H), a neutral face paired with a fearful voice (N/F). In addition, the pairing was matched with regard to gender, in the sense that a female face was always paired with a female voice and vice versa. All face-voice pairs were 3s long with a frame rate of 25 frames per second, and were presented on a black background.

7.3.3 Experimental design

The fMRI scanning consisted of two runs. For each run, each of the nine types of stimulus pairs (H/H, H/F, H/N, F/F, F/H, F/N, N/N, N/H, N/F) was presented 10 times in a pseudo-random order. Stimuli were presented in blocks of 5 events, with each block lasting 16s. Each run began with 20 seconds of a black screen before the video trials began, and ended with 12 seconds of a black screen. In order to avoid any possible order effects, three different pseudo-random sequences were created, and each sequence was shown to a third of the participants (the third sequence was shown to 12 participants). Being different from the explicit emotion labeling task used in the behavior study, the present study involved an implicit emotion processing tasks in which participants follow instructions and passively view and/or listen to emotional stimuli. Using implicit emotion processing task in the present study has its pragmatic advantages. For example, the use of implicit emotion processing task tend to make the block design easier to implement, and also significantly reduces the burden (e.g., prolong time for completing tasks in-scanner, or anxiety caused due to the task demanding in-scanner) on participants. During the scanning, participants were asked to either ignore the voice and just attend to the face (face-attend condition) or ignore the face and just attend to the voice (voice-attend condition). Catch trials were used during scanning to ensure that participants were alert and attending to the task. All of the catch trials were excluded from further data analyses. Each run lasted around 450 seconds. Stimuli were presented using the software Presentation 14.9, designed by NeuroBehavioral Systems (NBS), via electrostatic earphones (NordicNeuroLab, Norway) at a sound pressure level of 80 dB.

7.3.4 Data acquisition

Functional images were acquired with a 3T Tim Trio MRI scanner (Siemens, Germany) and a 32-channel head coil using blood-oxygen-level-dependent (BLOD) contrast (Gradient-echo EPI sequence, TR=2 s, TE=30ms, flip anger =90°, dimension = 210mm x 210 mm, voxel size resolution = 3mm x 3mm x 3 mm) covering the entire brain. Each image volume consisted of 32 slices acquired in ascending interleaved sequence. Each functional run comprised 225 volumes. The first two volumes of functional data were excluded to allow for signal stabilisation. After the acquisition of functional images, a T1-weighted high-resolution anatomical image was also acquired (192 contiguous 1mm axial slices, dimensions: 256mm*256mm, TR= 1900ms, TE=2.52ms, inversion time= 900ms, flip angle=9°), lasting 5 minutes.

7.3.5 Data analysis

Both fMRI data pre-processing and analysis were performed using Brainvoyager QX (2.8) (Brain Innovation). After inhomogeneity correction, the structural scan was transformed into Talairach space (Talairach & Tournoux, 1988). For functional images, slice scan time correction was performed using sinc interpolation. In addition, the functional images were realigned to the first functional scan just before the individual structural scan, to correct for within- and between-run spatially motion. Then, the functional volumes were applied with a temporal high pass filter (general linear model (GLM) with Fourier basis set of 2 cycles sine/cosine) and smoothed spatially using a Gaussion kernel of 6mm full-width half-maximum. After the preprocessing, the data were then co-registered to the individual anatomical data sets and normalised to Talairach stereotaxic space.

Condition-related changes in the regional brain activity were estimated for each participant using General Linear Model (GLM), in which the response evoked by each condition of interest was modeled by a standard hemodynamic response function. For each participant, one design matrix including all conditions and all runs was constructed and entered as 12 regressors: 2 attendance (face-attend, voice-attend)*2 incongruence (incongruence, congruence)*3 emotions (happiness, fear, neutral). Motion confounded variables based on six realignment parameters were created after applying Spikes, Detrended and Detrended Derivative detection. All resulting confound variables were included into the GLM model as additional regressors of non-interest.

I computed individual statistical images for the specific pairwise contrast of [incongruence vs. congruence], [face-attend (incongruence vs. congruence), voice-attend (incongruence vs. congruence)]. The resulting contrast images were entered into group analyses. For each group, one-sample t tests were conducted to identify clusters of significant activity for each contrast. Between-group differences were examined using two-sample t tests. These were obtained by creating an image file for each group with the significant activity across all activation conditions, and combining these images to get an inclusive image. To account for multiple comparisons, all activated clusters were thresholded with a primary threshold of voxel-wise $p<0.001$, and then corrected for multiple comparisons using cluster threshold. After 1000 iterations of a Monte Carlo simulation, the minimum cluster size threshold that yielded a cluster-level false-positive rate of 5% was applied to the statistical maps.

7.4 Results

Incongruence effect, independent of instructions To examine the neural correlates of the incongruence effect, I compared the summed incongruent conditions with the congruent conditions (incongruence vs. congruence). No incongruence effect was found in within-group or between-group comparisons. In addition, we compared the reverse contrast (congruence vs. incongruence) between the two groups. Again, no significant congruence effect was found in between-group comparisons. However, this contrast led to significant activation in the left inferior temporal gyrus in the LAQ group, and in the bilateral precuneus and right middle temporal gyrus, sub-gyral (hippocampus), dorsal posterior cingulate gyrus in the HAQ group (Table 7.2.a).

Incongruence effect (face-attend) To identify the brain regions involved in the face-attend incongruence condition, the summed brain activity across all the incongruent face-attend conditions was compared with all congruent face-attend conditions [face-attend (incongruence vs. congruence)]. Individuals with LAQ showed a greater incongruence effect than individuals with HAQ, leading to significantly greater activation in the right precuneus and the left superior parietal gyrus. However, the HAQ group showed a significant congruence effect [face-attend (congruence vs. incongruence)] in a broad brain network, involving the bilateral superior occipital gyrus, right sub-gyral (hippocampus), precuneus, left lingual gyrus, superior occipital gyrus, inferior frontal gyrus and superior temporal gyrus (Table 7.2.b).

Incongruence effect (voice-attend) To elucidate the neural correlates underlying the incongruence effect in the voice-attend condition, we compared the summed brain activity across all the incongruent voice-attend conditions with all the congruent voice-attend conditions [voice-attend (incongruence vs. congruence)]. This contrast revealed greater activation in the right superior frontal gyrus, the left superior occipital gyrus and the middle frontal gyrus in individuals with HAQ than individuals with LAQ. In contrast, the LAQ group revealed significant activation in the reverse contrast [voice-attend (congruence vs. incongruence)] in regions of the bilateral middle occipital gyrus and right middle temporal gyrus (Table 7.2.c)

Table 7.2 -- Effects of incongruence in LAQs and HAQs: (a) incongruence effect (irrespective of instructions), (b) incongruence effect in face-attend condition, (c) incongruence effect in voice-attend condition.

Brain regions	Talairach coordinate of peak voxel (x, y, z)	BA	t-statistic	No. of voxels
a. Incongruence effect, independent of instructions				
LAQs show negative activation to incongruence effect (congruence > incongruence)				
L Inferior Temporal Gyrus	(-48, -64,1)	37	5.2	149
HAQs show negative activation to incongruence effect (congruence > incongruence)				
R Middle Temporal Gyrus	(39, -76,19)	19	5.25	166
R Sub-Gyral	(33, -31, -2)	-	6.47	166
R Cingulate Gyrus	(15, -34,40)	31	5.6	251
R Cingulate Gyrus	(15, -55,25)	31	5.79	261
R Precuneus	(3, -61,19)	23	4.59	180
L Precuneus	(-15, -58,37)	7	5.97	221
b. Incongruence effect for face-attend condition				
LAQs show greater incongruence effect than HAQs				
R Precuneus	(18, -61,25)	31	4.63	395
L Middle Temporal Gyrus	(-27, -52,31)	39	4.67	231
HAQs show negative activation to incongruence effect (congruence > incongruence)				
R Middle Temporal Gyrus	(42, -73,19)	19	6.85	361
R Caudate	(36, -34, -2)	-	6.04	279
R Precuneus	(18, -79,41)	19	6.89	1288
R Precuneus	(15, -55,22)	31	5.51	370
L Cuneus	(0, -58,13)	23	5.36	503
L Lingual Gyrus	(-21, -76, -8)	18	4.82	129
L Superior Occipital Gyrus	(-30, -83,28)	19	5.12	558
L Inferior Frontal Gyrus	(-27,32, -8)	47	6	189
L Superior Temporal Gyrus	(-45, -7, -5)	22	5.84	199
c. Incongruence effect for voice-attend condition				
HAQs show positive activation to incongruence effect (incongruence > congruence)				
R Inferior Frontal Gyrus	(45,14,13)	44	5.97	172
R Superior Frontal Gyrus	(33,51,31)	9	6.5	875
HAQ show greater incongruence effect than LAQs				
R Superior Frontal Gyrus	(33,48,34)	9	4.87	1620
L Superior Occipital Gyrus	(-30,76,25)	19	3.96	186
L Middle Frontal Gyrus	(-33,41,31)	9	4.59	155
LAQs show negative activation to incongruence effect (congruence > incongruence)				
R Inferior Temporal Gyrus	(45, -52,4)	19	5.62	165
R Posterior Cingulate	(30, -67,10)	30	5.32	277
L Middle Occipital Gyrus	(-36, -64,13)	19	13.11	3559

x, y, z, stereotaxic coordinates of peak-height voxels. L=left hemisphere, R= right hemisphere. All the reported regions were thresholded at $p<0.001$, at the corrected level.

Correlation between anxiety symptoms and brain activation

Individuals with HAQ were found to show more severe anxiety symptoms as compared to those with LAQs. The correlation between traits of anxiety and the brain activation in was explored in the HAQ group. However, no significant correlations were reported on this issue (all Ps>0.05).

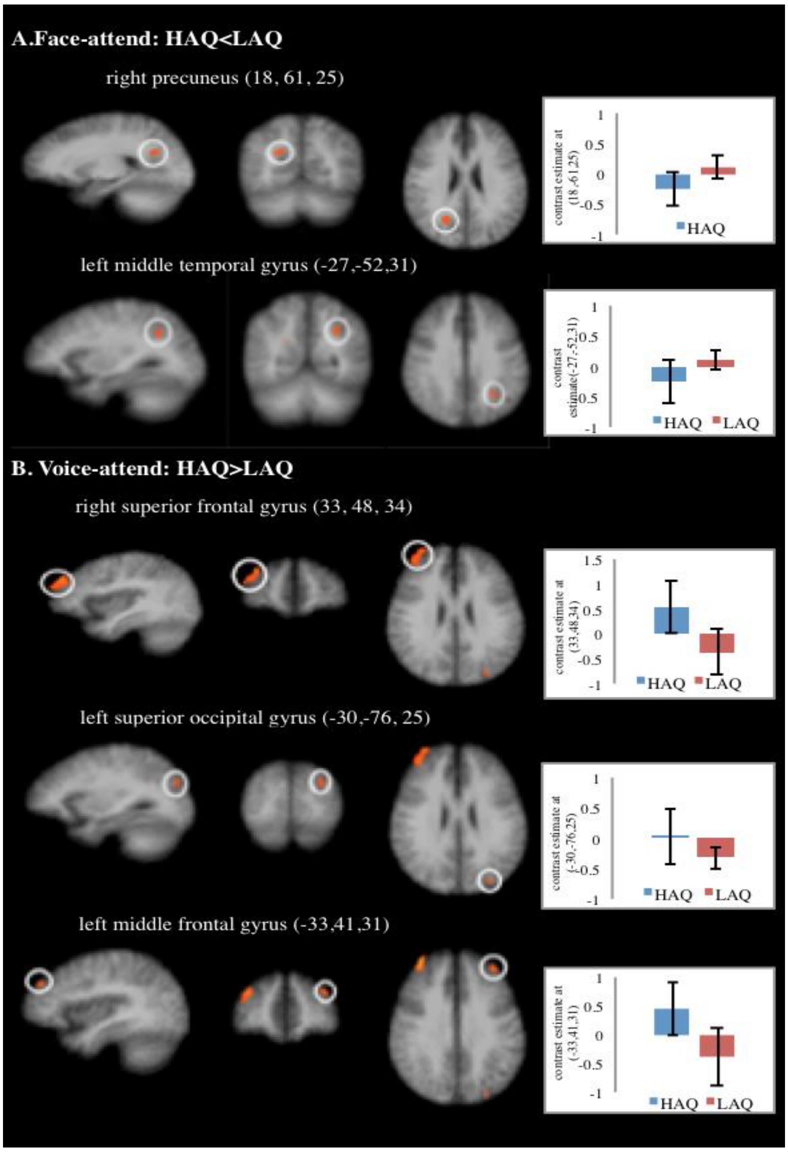


Figure 7.1 -- Group comparison showing significant brain activity in response to incongruence effect. A. Brain regions showing significant decreased activation in individuals with HAQ in comparison with individuals with LAQ for incongruence (face-attend). B. Brain regions showing significant increased activation in individuals with HAQ in comparison with individuals with LAQ for incongruence (voice-attend). Activation exceeds thresholds of $p<0.001$, corrected.

7.5 Discussion

Using fMRI, I explored the neural correlates of incongruence processing in a group of individuals with varying autistic traits in an emotional face-voice integration paradigm. During this experiment, while presenting blocks of emotionally incongruent face-voice pairs or blocks of emotionally congruent face-voice pairs, participants were asked to either attend to the face, or attend to the voice. Although they were not required to monitor the un-attended signal, it may have been a source of interference, which could have impacted on the processing of the attended-to source.

Contrary to our predictions, I did not find a significant incongruence effect in individuals with LAQ compared with individuals with HAQ. However, importantly, our findings extend previous work suggesting that changes to the explicit instructions (two forms of the task: attend to either the face or voice while ignoring the other) can modulate brain activity differently in different groups. Specifically, a greater incongruence effect was detected in individuals with HAQ when they were instructed to attend to the voice while ignoring the face, compared with individuals with LAQ. However, when they were asked to attend to the face while ignoring the voice, a greater incongruence effect was observed in the LAQ group as compared with the HAQ group.

Independently of the instructions, the incongruency effect (incongruent conditions vs. congruent conditions) did not evoke significantly increased activation in any brain regions over both groups. However, compared with the incongruent trials, the congruent trials resulted in increased activity in the left inferior temporal gyrus in individuals with LAQ while increased right middle temporal gyrus activity in individuals with HAQ. These results thus support the role of the middle temporal gyrus and inferior temporal gyrus in multisensory integration (e.g., Mesulam, 1998). In addition, the HAQ group also showed negative activation in regions of the sub-gyral (hippocampus), the posterior cingulate, and the bilateral precuneus in response to incongruence effect. These incongruence-related negative activations were largely involved in the default-mode network (DMN) (Buckner, Andrews-Hanna, & Schacter, 2008), which is reported to be deactivated during tasks requiring externally-oriented attention (e.g., Spreng et al., 2014). In addition, the hippocampus and the middle temporal gyrus are also regarded to be associated with memory retrieval or semantic memory processing (Huijbers, Pennartz, Cabeza, & Daselaar, 2011). In this sense, the deactivation of a number of regions during incongruence processing may reflect the lack of behaviour adjustment, more effortful processing or high attentional demands (e.g., Mantini & Vanduffel, 2013; Mckiernan, Kaufman, Kucera-thompson, & Binder, 2003) for individuals with HAQ.

In the face-attend conditions, a greater incongruence effect was found in the LAQ group than in the HAQ group, indicating more incidental processing of unattended information in the LAQs than the HAQs. In addition, individuals with HAQ involved a broader brain network when processing congruent stimulus pairs than incongruent stimulus pairs, involving areas such as the left inferior frontal gyrus. In previous studies, the left inferior frontal gyrus has been found to be involved in semantic processing (e.g., Binder, Desai, Graves, & Conant, 2009) and inference monitoring (Blasi et al., 2006). There is also evidence emphasising its important role in inference inhibition (e.g., Blasi et al., 2006; Dolcos & Mccarthy, 2006). If this explanation also applies to our study, the broader brain network in individuals with HAQ may be due to the need for additional cognitive effort to ignore and inhibit the unattended clue and integration processing. However, a greater incongruence effect was found in the HAQ group than the LAQ group in the voice-attend condition, suggesting more incidental processing of unattended information in the HAQs than the LAQs. This greater incongruence effect was associated with the DLPFC (BA9), a brain network that was previously reported to be involved in conflict-induced adjustment, such as in response selection and control implementation (e.g., Blasi et al., 2006). Thus, the increased activity in the DLPFC in the HAQs in comparison with the LAQs may reflect the involvement of additional brain resources in order to resolve the interference of unattended to information.

These results suggest an effect of attendance in modulating the incongruence effect between two groups. The findings could also reflect different processing preferences between the two groups. That is, when perceiving face-voice stimuli, individuals with HAQ are more likely to attend to information from the face over the voice. Therefore, the incidental processing of unattended information may have been greater, requiring more attention and effortful processing. This explanation is partially echoed by the study of Tell and Davidson (2014) who reported that individuals with ASD gave more weight to facial cues over situational cues in the perception of emotions from incongruent face-situation pairs.

The present study did not find an incongruence response at the ACC, despite the fact that this area was previously reported to be implicated in detecting and addressing conflicts (Carter & Van Veen, 2007b; Egner, Etkin, Gale, & Hirsch, 2008; Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2009b; Wittfoth et al., 2010), especially when the incentives and/or task demands increased (e.g., stimuli changing from congruence to incongruence, or “response conflict”) (e.g., Smith, Jones, Bullmore, Robbins, & Ersche, 2013). However, in the present study a block design was used, in which stimuli of the same type (either congruent or incongruent) were presented for the whole block of time. This may have decreased the task demands or intensity of conflict, leading to the absence of involvement of the ACC. Future studies may utilise an event-related design, which may provide additional evidence, particularly in the anterior cingulate.

There are potential limitations to the current study that need to be considered. First, the stimuli used in the current study were combined dynamic facial behaviors and vocalisation. These facial behaviors indicated moment-to-moment changes in emotional states, providing a good approximation of naturalistic interaction. However, the stimuli may still have evoked some unnatural feelings in the participants due to the out of sync between facial behaviours and vocalisations when constructing stimuli. Future studies should attempt to control this limit. Another possible concern is that the current study did not include an instruction-free condition, which prohibited us from making comparisons of regional brain activity between an instruction-free condition and the face-attend/voice-attend conditions. Future investigations could take this into consideration and include an instruction-free task in the experiment design, in order to clarify the incongruent effect in a more complete picture. Additionally, this study was also limited by the small sample size, making it difficult to generalise the results to the wider population and make firm conclusions. In addition, the small sample may also hind the analysis of subgroups (e.g., the HAQ group, n=16) that may demonstrate different brain responses related to anxiety, which may have influenced the overall brain activity. Therefore, the recruitment of larger sample size that are more representative of the ASD population would be beneficial in future investigations. To maximise the power of studies to identify significant differences between groups, future studies could examine dividing samples into subgroups (e.g., anxious high levels of autistic traits group vs. non-anxious high levels of autistic traits group).

In conclusion Negative activation in regions overlapping with the default-mode network in responding to incongruence effect in individual with HAQ may suggested a lack of behaviour adjustment, more effortful processing or higher attentional demands in this population. Despite of the lack of between-group difference independent of instruction, a stronger incongruence effect was seen in the voice-attend condition for individuals with HAQ, and in the face-attend condition for individuals with LAQ. These results tend to suggest that there may not be a general deficit in individuals with HAQ for processing incongruence. The use of different brain networks for processing emotional incongruence in individuals with high levels of autistic traits does not necessarily imply the presence of deficits. Instead, it may be a result of the combined effect of attentional demands and information processing propensity

8. General discussion

This chapter will state, summarise, and discuss the findings that can be drawn from the work presented, in order to gain a cohesive picture of these results. Methodological strengths and limitations will also be discussed, and some possible extensions of this work will be considered, including directions for future research.

With an estimated prevalence of around 1%, Autism Spectrum Disorders have a significant impact on society. Along with having restricted interests and demonstrating deficits in social imagination, individuals with ASD have difficulties in understanding the social world. One such difficulty is that of processing emotions from faces and voices, and that is the focus of the present thesis. It has been suggested that traits associated with autism are seen in varying levels throughout the general population (Baron-Cohen et al., 2001). It is therefore assumed that ASD can be explored and further understood by assessing individuals who demonstrate autistic traits, regardless of whether they have been given a clinical diagnosis of ASD or not. An increased understanding of the differences between individuals with high levels of autistic traits and individuals with low levels of autistic traits should benefit our understanding of the clinical impairments in ASD.

To enhance our understanding of emotion recognition performance and the mechanisms underlying emotion processing in individuals with significant levels of autistic traits, a series of three studies was conducted, aiming to address following main questions: the effect of autistic traits on the recognition of emotions from multiple modalities (face, voice, and face-voice); the counteract effect of anxiety in mediating the emotion recognition in autistic traits (Chapter 5), the cerebral correlates of emotion processing conveyed from the face and voice, and how emotional expressions from different sources are combined in the brain in individuals with high levels of autistic traits (Chapter 6), and finally, the neural circuitry activated in responding to emotional incongruity, and the patterns of brain activation occur in the context of different instructions (attending to the face or attending to the voice) (Chapter 7). The key points arising from the findings of these studies were as follows.

(1) Regardless of comorbid anxiety, individuals with high levels of autistic traits were able to identify a range of primary emotions presented in different domains (face, voice, and face-voice) (Chapter 5, study 1)

(2) The presence of comorbid anxiety appeared to counteract the effects of autistic traits in the recognition of emotions (e.g., fear, surprise, and anger), and this effect tended to be different for the two groups. More specifically, for the recognition of fear expression, greater anxiety was associated with less probability of correct response in individuals with high levels of autistic traits but more probability of correct answers in individuals with low levels of autistic traits. As for the reaction times, anxiety tended to be associated with longer response latencies in the HAQ group, but shorter response latencies in the LAQ group for the recognition of emotional expressions, for negative emotions in particular (e.g., anger, fear, and sadness), and this effect of anxiety was not restricted to specific modalities (Chapter 5, study 1).

(3) Individuals with high levels of autistic traits showed a hypo-activation of brain areas dedicated to multimodal integration, in particular when processing emotions of happiness and disgust. However, individuals with HAQ tend to recruit similar patterns of brain network as those with LAQ for processing face-voice combinations (Chapter 6, study 2).

(4) As for processing of emotions in single modality (face only or voice only), both groups (individuals with HAQ, individuals with LAQ) activated a number of frontal and temporal regions (e.g., STG, MFG, and IFG). However, there were some differences in the spread of the activated brain regions in response to different emotional expressions between two groups.

(5) The correlation between (subclinical) anxiety traits as quantified by the STAI and brain activity for emotion processing was examined, and no clear relationship was found (Chapter 6, study 2). Similarly, no significant relationship between anxiety and brain response in response to incongruity was found in individuals with HAQ (Chapter 7, study 3).

(6) In response to emotion-incongruence, individuals with HAQ exhibited decreased activation in several areas at least partly overlapping with the default mode network, regardless of instructions. Changes of explicit instructions between attending to face and attending to voice impacted upon the regional activity in both groups. Specifically, compared to individuals with LAQ, individuals with HAQ showed a stronger incongruence effect in regions of the right superior frontal gyrus, left superior occipital gyrus and left middle frontal gyrus when they were instructed to attend to a voice while ignoring a face. However, less of an incongruence effect was observed when they were instructed to attend to a face while ignoring a voice, as compared to individuals with LAQ (Chapter 7, study 3).

(7) After analysing the demographic data, it was found that individuals with HAQ had a significantly higher mean STAI score than individuals with LAQ.

8.1 Study overview

After reviewing existing research at both the behavioural and neural levels, the following points emerged. First, the prior literature in examining emotion recognition in ASD has been limited by an over-focus on the visual domain, especially on static faces, and there is little research from a multi-modal point of view. Second, the findings from these studies are inconsistent, which could be due to differences in task designs and the heterogeneous nature of the participants taking part. Third, despite the increasing agreement of the highly co-occurrence of anxiety symptoms in ASD, their collaborative effect in modulating emotion recognition has been largely unexplored. Given these, a behavioural study (Chapter 5) was carried out to examine (1) the effects of autistic traits on behavioural recognition of a full range of primary emotions in unimodal (faces, voices) and crossmodal (emotionally congruent face-voice expressions) presentations (2) whether the effect of autistic traits on emotion perception is mediated by the degree of anxiety. Results of this study suggested that individuals with considerable autistic traits were able to recognize emotional expressions presented across different modalities, if not considered the effect of anxiety. Contrary to some studies that have found deficits in recognising emotions from multimodal expressions (e.g., Magnée et al. 2008), this study showed that individuals with HAQ were found to have an intact ability to recognise emotions presented in face-voice presentations, and an even greater probability of correct responses in recognising face-voice presentations of surprise and disgust. In addition, as expected, co-morbid anxiety did moderate the relationship between autistic traits and the recognition of emotions (e.g., fear, surprise, anger), and this effect tended to be different for the two groups. Specifically, with greater anxiety, individuals with HAQ were found to be less accurate in recognising the emotion of fear. In contrast, individuals with LAQ demonstrated more probability of success in recognising fear expressions. In terms of response times, anxiety tended to be significantly associated with longer response latencies in the recognition of emotional expressions in the HAQ group, but shorter response latencies in the LAQ group, for negative emotions in particular (e.g., anger, fear, and sadness), and this effect of anxiety was not restricted to specific modalities (Chapter 5, study 1). These results from the behavioural study thus suggest that high levels of autistic traits individuals are able to recognise emotions across domains. In addition, these results provide novel evidence how anxiety can modulate emotion processing in individuals with HAQ. These results extended our understanding of emotion perception in this population and informed that characteristics of participants (e.g., anxiety) should not be ignored.

Despite of the intact behavioral performance of individuals with high levels of autistic traits, it does not rule out the possibility that they used alternative strategies (e.g., more cognition - or language-mediated- or more featured based emotion-processing strategies) to compensate for their emotion recognition deficit. In addition, though behavioral evidence is of great importance, there is also a need to understand the neural correlates of emotion processing across multiple modalities. To date, the underlying biological mechanisms utilised in social perception in ASD remain largely unexplored. Therefore, an fMRI study (Chapter 6) was conducted to explore how the brain regions responded to emotional stimuli across different modalities. This study allowed not only the emotion-specific brain responses for single modalities to be determined, but also those of multimodal integration and face-voice interactions. Results of this study demonstrated that individuals with HAQ tend to show a hypo-activation of brain areas dedicated to multimodal integration, particularly with the displays showing happy and disgust emotions. In addition, typical patterns of brain activation were used in individuals with HAQ in response to face-voice combinations (e.g., STG). Both groups (individuals with HAQ, individuals with LAQ) activated a number of frontal and temporal regions (e.g., STG, MFG, IFG) in response to single modality, however, there were significant differences in the spread of the activated brain regions between the two groups. Specifically, in response to emotional faces (e.g., disgust, fear), the HAQ group showed broader brain region activation than the LAQ group. However, in response to non-emotional faces (e.g., neutral faces), the LAQ group tended to show broader brain region activation than the HAQ group. Together with the findings from Chapter 5, these results suggest that differences in brain functions in response to emotional expressions between groups could be possible, despite a lack of behavioural group differences. However, it needs to be noted although the presence of interaction between group (AQ) and anxiety in impacting behavioural performance in recognizing emotional expressions (Study 1), the correlation between (subclinical) anxiety traits as quantified by the STAI and brain activity for emotion processing tend to be non-significant (Study 2).

It is well acknowledged that emotions are often encountered in a multimodal fashion. In a natural environment, an important issue in the perception of information from different sources is to detect and deal with the incongruity. Using fMRI, Chapter 7 examined the neural correlates in response to emotional incongruity (incongruence vs. congruence), paying particular attention to how changes of explicit instructions between attending to face and attending to voice modulated the regional activity. Unlike individuals with LAQ, individuals with HAQ exhibited decreased activation in several areas at least partly overlapping with the default mode network in response to emotion-incongruence, including the posterior cingulate cortex, superior occipital gyrus and precuneus, regardless of instructions. Compared to individuals with LAQ, individuals with HAQ showed a stronger incongruence effect in regions of the right superior frontal gyrus, left superior occipital gyrus and left middle frontal gyrus when they were instructed to attend to a voice while ignoring a face. However, less of an incongruence effect was observed when they were instructed to attend to a face while ignoring a voice, as compared to individuals with LAQ. No relationship was found between anxiety and brain response for incongruity in individuals with HAQ. This may suggest a different mechanism in individuals with HAQ and comorbid anxiety compared to individuals with high levels of anxiety.

Overall, the present research has considered several issues (e.g., behavioural performance in emotion recognition, brain responses for processing emotions from different channels, and neural circurity for dealing with emotional incongruity) and provides novel data that facilitates the understanding of emotion processing patterns in people with sub-clinical autistic traits. Emotion understanding in real life implies the multimodal integration of sometimes noisy and/or incongruent information from different channels. Therefore, emotion understanding of problems, even seemingly minor and negligible, in well-structured experimental settings could have a large impact on social life and daily life functioning.

Results from these investigations could be regarded as the contribution of this thesis. These findings hold implications for what educators/practitioners can do to support students' learning**.** These findings are not meant to be a prescription for how to deal with interactions for all students; instead, by providing an evidenced-based picture of what are likely to be experienced by individuals especially those with considerable autistic traits during emotional communication, these findings may be useful for educators/practitioners to consider thoughtfully and intentionally of what types of resources and support are provided. Thus educators/practitioners can have a powerful way to assist and respond to the demands of individuals during learning opportunities and classroom interactions. Also, these findings may be helpful for educators/practitioners to be more aware of their actions, therefore regulating their role and actions across activity settings. In addition, these findings may also be useful for informing the usefulness of educational and developmental programmes to help educators better prepare themselves when working with this population.

8.2 Pragmatic and practical implications

In the behavioural experiment, individuals with HAQ were not found to be impaired in recognising emotional expressions across different modalities, as compared to individuals with LAQ. However, intact performance in emotion recognition tasks at a behavioural level does not necessarily mean that individuals with HAQ processed information in the same way as individuals with LAQ. A further fMRI experiment suggested different patterns of brain activation during emotion processing in individuals with HAQ as compared to LAQ. For example, individuals with HAQ were found to show a hypo-activation in brain areas dedicated to multimodal integration, in particular when processing emotions of happiness and disgust. As for processing of emotions in single modality, even though both groups activated a number of frontal and temporal regions (e.g., STG, MFG, IFG), there were some differences in the spread of the activated brain regions in response to different emotional expressions between two groups.

This research also found that individuals with considerable autistic traits are highly co-occur with anxiety and greater anxiety in these individuals is related to slower response in emotion recognition tasks, negative emotions in particular (e.g., anger, fear, and sadness). As for the recognition of fear expression, greater anxiety was associated with less probability of correct answers in individuals with HAQ but more probability of correct answers in the LAQs. These findings have potentially important clinical and practical implications. There is possibility that individuals with considerable autistic traits still have social and emotional communication difficulties in natural social situations where rapid and efficient responses are required, even though they show relatively comparable performances in recognising basic emotions in an experimental setting. In addition, in response to emotion-incongruence, individuals with HAQ exhibited decreased activation in several areas at least partly overlapping with the default mode network, regardless of instructions. This may suggest a lack of behaviour adjustment, more effortful processing or high attentional demands in responding to conflict emotional expressions in individuals with HAQ. In face-attend conditions (focus on face information and ignore the voice information in perceiving face-voice pairs), the broader brain network in individuals with HAQ when processing congruent stimulus pairs than incongruent stimulus pairs may be due to the need for additional cognitive effort to ignore and inhibit the unattended clue and integration processing. In voice-attend conditions (focus on voice information and ignore the face information), the increased activity in the DLPFC in individuals with HAQ in comparison with the individuals with LAQ may reflect the involvement of additional brain resources in order to resolve the interference of unattended to information.

Knowing the differences between individuals with high levels of autistic traits and individuals with low levels of autistic traits in processing emotional information can be useful for educators/practitioners to be more intentional in practice and purposeful in their role during learning opportunities and/or classroom interactions. For example, if an educator is aware of the highly co-occurrence anxiety in individuals with high levels of autistic traits, the educator may think out the factors contributing to the vulnerability being anxious. Apart from the challenges experienced by high levels of autistic traits individuals during social interactions, a large number of events, such as unexpected changes or transitions and sensory overload can be particular stressors for this population. These suggested that it might be useful if educators could think about possible factors contributing to the increase in anxiety. If the increased anxiety is caused by unexpected changes, it might be helpful for educators to prepare the students for any change/transition to their routine (e.g., reminding them before a change/transition was taken place). In addition, these findings can be meaningful for educators/practitioners who may not have previously been knowledgeable of the differences among individuals who are high in autistic traits and individuals who are low in autistic traits and how different types of personality traits may affect their behaviors. For example, if an educator is aware of and understands student's challenging behaviors and difficulties in emotion interactions, he or she may show greater concern and empathy and be better able to help the student learn to behave in proper way (e.g., dividing a target task into smaller components, and teaching/assisting student to complete individual steps one by one). At the same time, the findings are helpful for providing evidence and documentation for educators/practitioners to be more aware of the interactions occurring in learning opportunities (e.g., an individual with high levels of autistic traits may interact with his/her surrounding very differently) and the choice of support and resources educators/practitioners make when they set up the learning environment. For example, as revealed from the present thesis, the combined effect of autistic traits and anxiety tend to slow down the student's responses to emotional expressions (e.g., anger, sadness). Along with this finding, it is not surprising that students with high levels of autistic traits and comorbid anxiety have difficulties in responding to emotions in educators or pictures/cartoons in the book. With this knowledge, the educator may have more patience with the student, thus making the student feel secure of less confused during learning opportunities, or the educators may adopt the expressions of emotion into explicit instructions. Last but not least, these findings help inform evidence-based interventions in this population, especially for the development of training and development programmes which attempt to facilitate social and adaptive functions in individuals who are high in autistic traits (e.g., social and emotional curriculum). For example, there are benefits to being able to identify problems individuals are experiencing (e.g., slow to respond to expressed emotions or show in sharing his/her ideas) that offer context-specific targets for individualised interventions. The following section will provide examples of what support and assistance can be made in different contexts/learning opportunities.

8.2.1 School-based social skills training

As discussed in the literature review chapter, difficulties in emotion recognition in individuals with ASD are more likely to have difficulties in emotion recognition than typical developing individuals. For this reason, autism and social researchers are keen to ascertain how best to help individuals with high levels of autistic traits to improve their social and communication skills. A number of techniques and strategies have previously been proposed, thanks to the efforts made by researchers in the last few decades. Bellini (2004) stated that social skill training programmes might be useful for individuals with ASD. Indeed, social skills training is one of the most in-demand services for individuals with ASD. There is a large literature on school-based social skills interventions for younger individuals with ASD (school aged children), which have focused on a range of skills such as initiating, reacting, giving and accepting compliments, sharing, and making eye contact (e.g., Baker, Koegel & Koegel, 1998; Kamps et al., 1992). Another important inclusion programme that has been demonstrated to be useful for individuals with social challenges is the use of Social Stories (Carothers & Taylor, 2004; Chan & O'Reilly, 2008). This programme was developed to help individuals learn how to act within particular social situations. In addition, several initiatives have been developed to teach emotional literary in mainstream schools, such as the Promoting Alternative Thinking Strategies (PATHS) curriculum (Greenberg, Kusche, Cook, & Quamma, 1995), and the Social and Emotional Aspects of Learning curriculum (SEAL) (DfES, 2005). These programmes bring social and emotional learning at an individual and at a whole school level and emphasize the role of an individual’s social and emotional competence in a group and as part of a wide school community.

The following section provides some general strategies that might be helpful for educators/practitioners working with individuals with considerable autistic traits, as well as how they make choices about setting up the classroom or learning environment for students, such as the use of small groups, peer tutoring, and parental involvement.

8.2.1.1 Small groups

While social interactions play a significant role in the cognitive, social, and language development of individuals (Bruce & Hansson, 2010), it is imperative that all individuals are equipped with comparable social skills. And this is particularly the case for individuals with considerable autistic traits due to the heterogeneous nature of the ASD. Some of the individuals may have normal intellect but find self-care tasks challenging, whereas others may often fail to naturally acquire social and emotional skills and often struggle to develop and maintain positive social interactions. In this view, the needs of support and sources for individuals may vary significantly. For this reason, any proposed interventions or programmes must take the heterogeneous nature into consideration and try to meet the needs of the individuals.

The use of the small group format may be helpful for tailoring social skills programmes to individual student needs. During this process, it is encouraged to use various data collection strategies to collect information from the participants (e.g., diagnostic information, parental information, like/dislikes, strength/weakness). This information is used to guide the actions of educators/practitioners. It is also encouraged to investigate strategies to ensure that the frequency, duration, and intensity of the social skills programmes are implemented as planned. It is also important for educators to take note of developmental changes occurring within individuals participating in these programmes. In addition, it may be helpful for participants if skills are explicitly taught, practised, and reinforced in events or situations that are variable and flexible. Some general tips may be helpful to consider when tutoring/training high level autistic individuals, for example breaking down activities into steps, making abstract/complicated issues more straightforward, and avoiding distractions, incorporation of individual-specific interests (Kagohara et al., 2013).

8.2.1.2 Parental involvement

In addition to the small group format (Ryan & Nı´Charraga´in, 2010), some researchers have suggested that the involvement of parents could benefit from implementing social skills programmes for individuals who experience social challenges (Beaumont & Sofronoff, 2008). One of the proposed advantages of parental involvement is that parents are able to support skill development between sessions, and can support the generalisation of learnt skills (Ryan & Nı´Charraga´in, 2010). Throughout children's development, parents are typically the most consistent figures, and are therefore best positioned to continue the training post-intervention, and encourage the maintenance of treatment gains in different settings, especially in naturally occurring everyday contexts (e.g., at home and in community settings) (Koegel, Bimbela, & Schreibman, 1996).

In addition to the benefits for the affected individual, parental training has been found to have benefits for the parents themselves. For example, parents involvement may be associated with an improvement in parental mental health and adjustment, feelings of parent self-efficacy (Sofronoff & Farbotko, 2002). For many parents, bringing up a child with considerable anxiety and autistic traits can be an overwhelming and traumatic experience and many of them require coping strategies. It is possible that during this process, parents have also become more confident in their parenting as they have learned to support the child's skill acquisition and to manage the child's anxiety. Therefore, this process may also be good for relieving parental stress and enhancing family wellbeing (White & Hastings, 2004).

The involvement of parents is also helpful as it allows parents to have a better understanding about what their child is facing and experiencing and why their child behaves from the child's point of view. This could be helpful for parents as they seek to improve their ability to manage the challenges their children have in social relationships.

8.2.1.3 Peer tutoring

A number of researchers have proposed the use of peer tutoring in practice to improve social skills in individuals with social challenges (Bowman-perrott, Burke, Zhang, & Zaini, 2014;Laushley & Heflin, 2000; Topping, Buches, Duran, & Keer, 2017). Take the communication skills as an example, participants in the programme may be taught to listen to others and wait to talk. Taking turns in a conversation, proposing ideas/plans, providing praise to others, saying thank-you, and apologizing are important elements of conversation. Along with peer tutoring settings, every individual has the opportunity to play a rotating role in the "tutor, tutee, and observer" model (e.g., Mcdonnell, Mathot-buckner, Thorson, & Fister, 2001). In fact, there are documented benefits of including peer tutoring in the improvement of academic and social learning, and the development of peer relationships in integrated education across age groups (Greenwood, Carta, Hart, Thurston, & Hal, 1989; Topping, 1996). For example, Topping (1996) pointed out that rotating of the roles during the reciprocal tutoring could potentially promote the novelty and self-esteem of participants. In addition, by learning and teaching, cognitive skills of participants, such as planning, monitoring and evaluating; and the cognitive processes of perceiving, selecting, inferring, applying and responding might be enhanced (Topping, 1996). During this process, participants may pay more attention to what their peers say and do, and to learn through imitation and interaction either as a tutor or tutee. This also enables individuals with social challenges to develop friendships with their peers. In these settings, each individual has the chance to take on different roles, which also encourages individuals to be more actively attentive.

It should be noted that in order to ensure successful integration in such a setting, typical developing peers must be taught how to be supportive, inclusive and respectful of what is needed by a person who have challenges in social understanding.

8.2.2 Conflict resolution

In the second fMRI experiment, the results of negative activation in regions involved in the default-model network in individuals with HAQ may indicate a lack of behaviour adjustment, more effortful processing or high attentional demands in responding to conflict emotional expressions in individuals with considerable autistic traits, regardless of instructions. In face-attend conditions (focus on face information and ignore the voice information in perceiving face-voice pairs), the broader brain network in individuals with HAQ when processing congruent stimulus pairs than incongruent stimulus pairs may be due to the need for additional cognitive effort to ignore and inhibit the unattended clue and integration processing. In voice-attend conditions (focus on voice information and ignore the face information), the increased activity in the dlPFC in individuals with HAQ in comparison with the individuals with LAQ may reflect the involvement of additional brain resources in order to resolve the interference of unattended to information (e.g., unattended face channel in voice-attend condition). These results imply the possibility that individuals with considerable autistic traits were less efficient or may need more effort to remain actively on-task and sustain attention to assigned tasks, though their performance in recognizing emotions in to-be-attended information were not examined at the behavioral level. It is suggested that individuals' attention may vary in different contexts depending on the demands of the task and ones' individual interest in meeting those demands (Downer, Booren, Lima, Luckner, & Pianta, 2010). With this in mind, it is possible that in situations where the activity may be less compelling, or the attention demands are high, individuals who are high in autistic traits may tend to be less efficient or need more support to complete the tasks. These findings hold implications for what teachers do to support students' learning. They encourage teachers to be thoughtful and intentional about incorporating opportunities so individuals with considerable autistic traits can successfully engage in activity settings. It is suggested that individuals who have the ability to actively engage in peer interactions also have these higher initiation skills to persist with tasks in classroom settings (Downer et al., 2010). With this in mind, the findings of this research might promote educators/practitioners to consider ways of facilitating more active engagement of students during learning opportunies or to create learning opportunities that help children initiate and lead in more structured settings.

Emotions in daily life are inherently multimodel (e.g., de Gelder & Vroomen, 2000). In some situations, in social communication and interactions, tensions may arise when ambiguity or emotional incongruence present among different sources of information. These tensions and conflicts can also be detrimental for effective collaborative learning if unresolved, as they may lead to negative emotions, frustration and even anger, impairing on-task behaivours (Ayoko, Callan, & Härtel, 2008). In less structured settings, these tensions may also lead to aggression if treated inappropriately. These individuals with considerable autistic traits who tend to be slow in noticing subtle changes in others' emotions and behaviours and respond proactively, are the very individuals in greatest need of support. In response to this, individuals with considerable autistic traits may benefit from being taught social and problem-solving skills. For example, individuals can be taught to build supportive and stable relationships with others through mutual understanding and cooperation and consider negotiate solutions instead of physical aggression and immediate reactions when facing tensions/conflicts. To promote this, they may also need to be taught to identify the means of behaviour and/or expressions, to clarify what response (e.g., behaviour, language, or expressions) is appropriate and what is inappropriate, and to express their feelings appropriately. Along with being taught through social and problem-solving skills, students were also encouraged to practice and role-play their understanding of these behaviours. Through various role-playing opportunities, individuals' abilities in taking different perspectives and viewpoints can be trained and refined so that they become more reflective and thoughtful about their behaviours.

8.2.3 Implications in the use of multisensory approaches for learning

It is well acknowledged that learners are constantly encouraged to use multiple sensory modalities to explore their environment. Multisensory approaches for learning are typically based on the assumption that learners learn best when the material is conveyed and presented through different sensory modalities (e.g., Preston, 1998). It is assumed that using more sensory modalities to teach a concept, results in more techniques tending to be used to remember the concept or the experience. Different sensory modalities also compensate for each other, thus facilitating the learning process (Carbo, Dunn, & Dunn, 1986).

An individual's learning style determines where and how their attention and effort are directed (Carbo et al., 1986). Individuals learn best when they use their learning style to their own advantage. However, some individuals may have different learning styles. Although it was not found a significant group difference in the recognition of emotions from face-voice stimuli, the fMRI data tended to suggest a hypo-activation of multisensory integration in individuals with high levels of autistic traits. Thus it is reasonable to infer that individuals with HAQ tended to benefit less from the incorporation of learning through multiple modalities and multisensory teaching strategies than individuals with LAQ. Current findings do not diminish the importance of multisensory learning, but may help provide evidence and documentation for educators/practitioners to be more aware of the implementation of multisensory approaches in the learning environment, suggesting that educators may want to purposefully facilitate different types of interactions. For example, individuals with HAQ might need more time and additional help (e.g., training) to increase their gains of learning and to retain the information from multiple sources.

Despite that the present work did not examine superior visual processing abilities in the HAQ group, it couldn't be denied that some individuals may have a predominantly visual learning style. The TEACCH approach has already been effectively implemented within research settings for individuals with ASD (Chatwin & Harley, 2007; Arthur-kelly et al., 2009), and this indicates the significance of visual supports in supporting learning processes and promoting independence for them. Even for some individuals who do not show superior processing of visual information, the use of visual aids when introducing abstract concepts (e.g., maps, labels, timelines, pictures of bodies) may compensate for difficulties with language comprehension. In this view, learning for high autistic trait individuals might benefit from the implementation of visual schedules and systems (e.g., pictures, svmbols) in integrated/general education settings. Indeed, previous research has indicated the effectiveness of the use of visual supports in teaching children with ASD in relation to mental states, through the use of visual representations such as thought-bubbles (Kerr & Durkin, 2004; Paynter & Peterson, 2010; Wellman et al., 2002).

8.2.4 Computer-based social and emotional skills training

Recent advances in computing science and intelligent systems are expected to have a positive impact on training/practices for individuals with considerable autistic traits (e.g., Kashihara, 2014; Sincák, Loreník, Viríkova, & Gamec, 2015). Given the less efficient emotion recognition in individuals with considerable autistic traits, especially for those with comorbid anxiety, the use of electronic devices (e.g., a computer, mobile device, digital tablet) that target the improvement of social and emotional skills may be useful to build supportive learning environment. For example, devices can be used to teach and support the participants' skills in basic/complex emotion recognition and emotion matching, role-playing, understanding humour/irony/false belief, differentiating between teasing and bullying, and coping with problems/mistakes (e.g., Keltner, Capps, Kring, Young, & Heerey, 2001). It might be helpful to adapt these tasks into games or videos, which could then be run on a computer or digital tablet. The use of machine technology has a range of advantages. First, machine technology seems to generate increased motivation and attention for high autistic trait individuals and is able to provide immediate feedback, which may promote interactions in an intuitive and natural way (Renae Beaumont & Sofronoff, 2008; Reeves & Nass, 1996). Second, machine technology provides a flexible and repeated pattern of the learning environment where the content, timing and location of a learning schedule can be arranged depending on the user's preference and needs (Golan & Baron-Cohen, 2006; Sharples, Taylor, & Vavoula, 2005). Also, the use of machine technology has the potential to support training across various skills (e.g., imitation, joint attention) and on a wide range of topics (e.g., simple mathematics, words, historical dates).

The computer-based social and emotional skills training programme can be widely used for individuals with low levels of autistic traits and individuals with high levels of autistic traits. Findings from the present thesis can be used for enhaning the training programmes for those individuals with considerable autistic triats. It can potentially provide guidance towards the content or the focus of the computer-based social and emotional skills training programmes. For example, when designing the programmes, more attention should be made to promote participants' fast responding to emotional expressions, negative emotions in particular and to modulate and sustain attention on tasks; Teach participants to decipher the feelings of certain emotions (e.g., fear, sadness, anger) in pictures/videos or infer what does a character feel in certain emotion-induced situations. Provide opportunities for participant to apply the knowledge of the emotions, negative emotions in particular, in various virtual reality scenes (e.g., dealing with perceived threat, dealing with bullying). Other examples for enhancing the application of this programme may include: teaching strategies for improving the information integration skills from different sources; teaching strategies or solutions for dealing with a conflict; teaching attention selection, attention sustain, and attention switching.

8.2.5 Education and development preparation for teachers

There is increasing recognition that social and emotional skills of teachers make a crucial contribution to the social and emotional development of their students (e.g., Hamre & Pianta, 2006; Klusmann, Richter, & Lüdtke, 2016). Specifically, social and emotional functioning of teachers impact the effectiveness of their role in developing supportive student-teacher relationships, in designing activities/tasks that depends upon students' strengths and abilities, and in teaching students problem-solving and conflict resolution skills. Second, the social practice of teachers can be a model for students for how to interact and form relationships with others.

The application of strategies in individuals with considerable autistic traits requires educators/practitioners to be aware of their actions and have a bettern understanding of the associations between emotion, cognition, and behaviours. Following this trend, educators/practitioners are expected to be more knowledgeable and reflective in developing effective and caring classroom management. As a result, it may be that some educators may need additional education, professional development, and ongoing support to develop the necessary skills and attitues to maximise their input during the interactions with students.

It is well acknowledged that educators deal with highly stressful emotional situations where developing and sustaining positive classroom dynamics may not always be easy for them. For many teachers, regulating negative emotions in the classroom can be challenging and is a commonly reported stressor, especially when interacting with emotionally or behaviorally demanding pupils (e.g., Carson & Templin, 2007). Given these considerations, apart from the training and interventions for students themselves, educators are encouraged to be provided with specific training to develop their emotional and social skills in meeting the educational needs of students, such as the Emotionally Intelligent teacher training (Brackett & Caruso, 2006). Findings from the present thesis may shed light some useful directions on training programmes for teachers in meeting the needs of individuals with considerable autistic traits.

8.3 Highly co-occuring anxiety in autistic traits

Anxiety-like responses in individuals with ASD have been described in DSM-IV as an "associated feature" and it is stated "there may be excessive fearfulness in response to harmless objects" (American Psychiatric Association, 1994). The analysis of the participants' demographic data confirmed the high prevalence of anxiety in individuals with a higher level of autistic traits. Indeed, there is evidence suggesting that individuals with HFA tend to experience anxiety across their school lives, social lives and family lives (e.g., Coupland, 2001; Kim, Szatmari, Bryson, Streiner, & Wilson, 2000). In this sense, results of the present work also confirmed the prior research.

The high prevalence of anxiety in adults with considerable autistic traits was found in this research, and these individuals tend to show less efficient in processing emotions, negative emotions in particular. These findings would have potential implications for the practical application of some treatment programmes, such as the implementation of Cognitive Behaviour Therapy (CBT). Kreslins, Robertson, and Melville (2015) in a review of the evidence for the use of psychosocial interventions for axneity in ASD claims that in the UK, individual or group CBT is often used to manage anxiety in more able children and youth with ASD. It is well acknowledged that CBT targets the underlying cognition and behaviours that maintain individuals' anxiety. At present, the adapted CBT has shown promise for dealing with anxiety in this population. Chalfant, Rapee, and Carroll (2007) examined the effectiveness of a 12-session CBT model [adapted "Cool Kids" programme (Lyneham, Abbott, Wignall, & Rapee, 2003)] in 47 autistic children with comorbid anxiety, and found that it resulted in reduced anxiety symptoms among them, as reported by themselves, their parents and their teachers. These results highlighted that CBT might be an effective treatment for anxious autistic individuals. However, as suggested from the present research, these affected individuals tend to be less efficient in responding to emotional expressions, negative emotions in particular. These findings would have potential implications for the effectiveness of implementing the treatment strategies. It might be possible that these emotion understanding problems would hinder the the application of CBT in individuals with high level of autistic traits, given that CBT relies on the inference of ones' emotional states and thoughts in order to shift cognitive styles and hence reduce anxious symptoms (Beck, 1976; Kendall et al., 1999)..Similarily, a number of modifications into CBT have been demonstrated to be effective in promising results from implementing this approach and would be recommended for management of anxiety among individuals with ASD/considerable autistic traits, such as increased parents involvement, the use of visual aids, incorporating individual-specific interests, improving social and communicative skills (e.g., Sze & Wood, 2007, 2008; White, Ollendick, Scahill, Oswald, & Albano, 2009).

As the adapted CBT requires the identification of individuals' own thoughts, feelings and emotions, affected individuals are expected to be taught with these skills prior to undergoing treatment. Future attempts may need to consider developing and implementing tools/techniques to help affected individuals in this regard in a socially acceptable manner. A number of tools that are demonstrated to be useful in this regard will be recommended. For example, the use of picture cards to teach social and communicative cues given that the individual with ASD learns better with the assistance of visual aids (e.g., Panerai et al., 2009). The use of Social Stories to help teach social skills to individuals with autism through stories that provides examples of common social situations (e.g., how to understand emotions in context). Along with social and emotional learning, individuals will also benefit from some other programmes that includes role-playing activities for emotion and social-perspective taking to promote empathy and social cohesiveness.

Another important outcome of implementing the CBT programme was that of enhancing self-management skills of the participants, which in turn affects participants' emotion perception abilities. It is suggested that self-management strategies enable individuals to control their own behaviours, leading to more adaptive responses and ultimately improving communication skills, and school and vocational skills (Southall & Gast, 2011). Implementing CBT requires participants to keep track of their own thoughts, emotions, or anxiety symptoms, all of which would be beneficial for practicing their self-management staegies, and in turn good for managing them. The significance of using self-management tends to be more obvious for transition-aged youth and young adults with ASD due to the lack of continuous support in university, the work place, or community settings (e.g., Getzel & Wehman, 2005).

Another clinical implication of high levels of anxiety in individuals with considerable autistic traits is related to diagnosis. It is suggested that individuals with ASD often first receive treatment for mood (e.g., anxiety, depression), especially in girls. It is difficult to determine when a child with ASD also has a mood or anxiety disorder, or whether these symptoms are better conceptualised as the emotion deregulation that is part of ASD. It is possible that, at least in some cases, the ASD itself is being mislabelled, which may lead to inappropriate treatments (Mazefsky, Kao, & Oswald, 2011). Although no significant impact of anxiety on brain activity in high autistic trait individuals has been reported, it is important to remember that one would not expect a single emotion perception to characterise comorbid anxiety in ASD, and in this sense, more research explicitly focusing on emotion understanding in ASD would help inform diagnostic boundaries.

Given that symptoms of anxiety co-occur highly with autistic traits, it is important to understand the trigger factors in this issue in order to help design a variable programme of management strategies and intervention to reduce anxiety. A number of variables are thought to contribute to the vulnerability to develop and to the maintainence of anxiety among them, such as poor social skills, inadequate social support, and poor coping skills (e.g., Bellini, 2004; Cooray & Bakala, 2005). In addition, it is possible that some high autistic trait individuals may also have sensory integration difficulties that lead to anxiety among them (e.g., crowded places, noise) (Grandin, 1995). Similary, it is acknowledged that some high levels of autistic traits individuals may have preference to stick with routines, hence an interruption of daily routines or the onset of unexpected/new events/situations may lead to significant anxiety and distress among them. Other factors likely to increase the risk of anxiety may also include enormous stress elicited by increased social and cognitive demands for coping with adulthood (e.g., Cooray & Bakala, 2005; Rogers, Hepburn, & Wehner, 2003).

8.4 Gender issues revealed from the research

In the existing literature, it is well acknowledged that more males than females are diagnosed with autism spectrum disorder (ASD). The widely reported male-female ration is 4-5:1 (Fombonne, Quirke, & Hagen, 2011). Much of the previous research has tended to include participants based on this ratio, or include only male participants, and such studies have contributed notably to our understanding of autism at the present time. However, the participant profile in the present study was female-biased, which seems to be contrary to the existing assumption of male-dominance in this condition. The female-biased participant profile may in part occur due to the female-bised subject pool itself (the database from which participants were recruited) which resulted in a higher chance that the researcher would have more females registering for the experiments. This bias was also reflected in the number of respondents to the online questionnaire, male-female 260:640.

This finding holds implications for clinicians, teachers and parents. It is possible that the male bias on the spectrum, although it may exist, may be less pronounced than was previously believed. In addition, research into gender differences indicates that females with ASD tend to show less stereotypical and repetitive behaviours than males, though they may show similar difficulties in social behaviour and communication (van Wijngaarden-Cremers, van Deurzen, Patricia, & van der Gaag, 2014). Therefore, the male dominance profile in autism may not tell the whole story; and there is a possibility that females with ASD might be overlooked or misdiagnosed since they do not show the typical male characteristics of autism. If this is the case, the down side of this phenomenon may be that historically, our understanding of autism has been substantially biased toward males in research and clinical practice.

Nowadays, there are studies investigating gender differences in the core features of ASD. Take the restricted and repetitive behaviours and interests as an example; a recent paper by Sutherland, Hodge, Bruck, Costley, and Klieve (2017) examined gender-related differences in topics of interest to girls and boys, and found that these topics were divided along gender lines. Girls engaged in the types of interests typically expected of their gender, such as animals, reading, art and music, whilst boys were typically described as preferring activities typical of boys of this age group, such as to do with numbers. Similarly, as suggested by Hiller, Young, and Weber (2015) in classroom settings, boys tend to be hyperactive and more aggressive, while girls tend to mimic elements of social environment in order to fit in. Hence it is possible that teachers might pay more attention to boys than girls due to their disruptive behaviour, which in turn may impact on the referral and detection rate for girls. Potentially, girls who are not hyperactive could be overlooked for assessment and educational support in mainstream classrooms despite having largely similar cognitive, academic and behavioural profiles to boys. In short, these differences may suggest that girls may be less likely to receive a diagnosis, even when they show similar levels of autistic traits to boys. Given this, parents, teachers and clinicians should consider these possibilities when assessing and creating management plans for girls with ASD and it is even more important for parents and teachers to be able to identify the traits in girls in order to find a doctor who will listen and refer their child to appropriate specialists for diagnosis Clinicians and educators may need to expect the core symptoms of autism to be also common and severe in high-functioning elementary school-aged girls with ASD. Perhaps this understanding of ASD as a condition which can affect males and females in different ways, rather than viewing ASD as a male condition, will contribute to more accurate identification of females with ASD.

It needs to be noted that the participant profile might also limit the present work from making robust conclusions. As indicated from the participant profile, fewer males were involved in the present work, which limited the comparison between genders for emotion processing. In addition, given that participants in the present work were contacted through emails and screened through online questionnaires, it is likely that the sample is over-representative of individuals with preference for using computer-based technology or social media. Future research could address this question, by considering the use of different recruitment strategies for a larger-scale sample, and making comparisons between autistic females and autistic males, autistic females and typical females, and autistic males and typical females.

In addition to the female-biased participant profile, individuals with high levels of autistic traits were also found to show significant levels of anxiety traits. This result is consistent with the previous claim that autistic individuals with higher levels of functioning are at much greater risk of having high levels of anxiety symptoms than other individuals of the same age and demographic (Bellini, 2004; 2006).

8.5 The use of AQ to assess autistic traits

In the present thesis, the AQ was employed to assess autistic traits in a general population. The AQ was designed for adults with average IQ or above (Baron-Cohen et al., 2001). The full AQ has been shown to have good test-retest reliability as well as good internal consistency (Baron-Cohen et al., 2001). Moreover, the AQ has been reported to have suitably high sensitivity and specificity in individuals referred for diagnosis (Woodbury-smith et al., 2005), making it a sensitive and widely used measure in research and clinical practice to quantify autistic traits in the general population. In addition to the general population, the AQ has shown heritability within families, which is consistent to the genetic evidence suggesting the heritability of ASD (Hoekstra, Bartels, & Boomsma, 2007).

The AQ scores were a relatively reliable indicator of a diagnosis in combination with clinician reports. However, it needs to be mentioned that the AQ is not the only measure of autistic traits. Other measures that are frequently used include the Broad Autism Phenotype Questionnaire (BAPQ, Hurley, Losh, Parlier, Reznick, & Piven, 2007), and the adult Social Responsiveness Scale (SRS) (Constantino & Todd, 2005) 2005). Ingersoll, Hopwood, Wainer, and Donnellan (2011) compared these three self-report measures of autistic traits and found that the BAPQ and SRS demonstrated better internal consistency than the AQ. Future investigations may be benefit from using more than one measure to provide better reliability.

8.6 Limitations of the thesis and future research

In each chapter of this work, the studies have been described alongside their intended aims. However, the findings from the present studies must also be considered in the light of their limitations. In this section, some ideas are also presented for possible improvements to these studies.

Due to time constraints and difficulties recruiting participants, the sample size in the present thesis was relatively small, given the heterogeneous nature of ASD, especially for the fMRI experiments. This reduced the statistical power and decreased the chance of statistically significant results being detected. Relatively small sample sizes (which are a common problem in studies in this field) prevented us from comparing behavioural and neural differences that might relate to gender. In addition, it is possible that the limited sample size might have contributed to the fact that we did not find a significant correlation between anxiety and brain activity in the processing of emotional expressions. Given that the severity of anxiety in the HAQ group was not well distributed (more people in the HAQ group had high levels of anxiety), this may have limited the detection of anxiety impact in the performance for this group. Using a large and well-distributed participant profile within the high levels of autistic traits group with two levels of anxiety (high levels of anxiety and low levels of anxiety) would enable the specific effects of the anxiety to be measured and would allow us to draw further conclusions. The findings from the present work would also benefit from additional data from a larger sample size that are more representative of ASD population in order to further strengthen significant findings and explanations arising from the analysis.

In the behavioural experiment, there was no trend found for impaired performance in recognising emotions, and this was particularly clear in the probability of correct emotion recognition. As mentioned previously (Chapter 4), this may reflect the fact that individuals with considerable autistic traits have similar abilities in recognising emotions to those with low levels of autistic traits. However, there are some alternative explanations for these reported findings. For example, the lack of group differences in the probability of success in the emotion recognition may have been because participants were at or near ceiling level in labelling basic emotions, or because they tended to use their analytic abilities to develop alternative strategies to label the emotion in the stimuli, despite their impairments in emotion processing. In order to avoid ceiling effects for emotion identification, it may be useful to employ a more demanding competing task with a high attention and cognitive load, enabling a direct comparison of the performance under both the present paradigm and the high task demanding paradigm. One such control task might include subtle emotional expressions, or might involve modifying the experiment design by requiring rapid responses within a limited time.

Similarly to the previous literature, the experiments in the present thesis were based on a basic emotion account that assumes a distinct and individual neural system underlying each category of emotions. In the published research on emotions, most studies have tended to use neutral stimuli as a baseline, to contrast with the emotion stimuli, and this is also the case for the present work. However, the use of "neutral" faces/voices as control stimuli could be an inherent confound in emotion research, because of the difficulties in creating truly "neutral" stimuli, especially when different participant groups are considered (Klein, Iffland, Schindler, Wabnitz, & Neuner, 2015; Posner & Rothbart, 2005). This could therefore represent another limitation when interpreting these results.

Despite the high frequency of comorbid anxiety in ASD, very few studies have controlled the level of anxiety traits when examining the performance of people with ASD in emotion perception. The present study may shed light on the patterns of performance when processing emotions in such a population. In addition, results from the present work corroborate the occurrence of heighted anxiety symptoms in individuals with high levels of autistic traits, which warrant further investigation in terms of how these symptoms impact assessment, diagnosis, and neuropathology in this diverse neurological condition. However, anxiety is not the only condition that occurs along with ASD. In light of these findings, further consideration could be given to other potential confounding variables such as depression and ADHD, which also co-occur with ASD, though they are not within the realms of the present work.

Last but not least, by focusing on the emotion processing from others, the present work has overlooked the other cognitive processes that comprise other facets of emotional intelligence abilities, such as the emotion regulation, self-emotion awareness (e.g., Mayer, Salovey, & Caruso, 2000). More efforts can be made on these areas in the future.

8.7 General conclusion

Prior studies on emotion perception in ASD have focused primarily on the perception of unimodality information presented in visual (e.g., facial expression) and auditory (e.g., prosodic sentences) modalities separately, particularly static faces, with little of them on multisensory or audiovisual integration, which is closer to everyday multisensory experiences. Moreover, over the past decade, many investigations for mental health problems in individual with ASD have documented the co-occurrence of anxiety problems. However, little research has been done to explore how this comorbid anxiety affects their social functions (e.g., emotion processing).

In order to achieve this understanding, both behavioural and functional magnetic resonance imaging (fMRI) were employed. This research consistend of three empirical studies. In study One, the effects of autistic traits on emotion processing in unimodal (faces, voices) and crossmodal (emotionally congruent face-voice pairs) presentations were explored. In addition, the question whether the effect of autistic traits on emotion perception is mediated by the degree of anxiety is also examined. Results suggested that, regardless of anxiety, individuals high in autistic traits were able to perform emotion recognition tasks, suggesting a lack of general deficit in emotion perception in individuals with HAQ, compared to individuals with LAQ. In addition, the presence of comorbid anxiety appeared to counteract the effects of autistic traits in the processing of emotions, and this effect tend to be different for two groups. Specifically, with greater anxiety, individuals with HAQ were found to be less accurate in recognizing the emotion of fear. In contrast, individuals with LAQ showed greater probability of correct response in recognizing fear expressions. For response time, anxiety symptoms tend to be significantly associated with greater response latency in the HAQ group but less response latency in the LAQ group in the recognition of emotional expressions, negative emotions in particular (e.g., anger, fear, and sadness); and this effect of anxiety was not restricted to specific modalities. In study Two, the neural correlates engaged in processing of emotional expressions were explored. Analysis of the fMRI data suggested that compared to individuals with LAQ, individuals with HAQ tend to show a hypo-activation of brain areas dedicated to multimodal integration (happy and disgust in particular). However, both the HAQ group and LAQ group showed similar patterns of brain response in response to face-voice combination, mainly in temporal regions. While both groups activated a number of frontal and temporal regions (e.g., STG, MFG, IFG) in response to unimodal emotional expressions (face, voice), different brain network activation were observed between the two groups, which may suggest a more effortful and less automatic processing in individual with HAQ. Following this, using fMRI, study Three examined the neural circuity in responding to incongruence effect (incongruence vs. congruence) in a group of individuals with considerable autistic traits. In addition, whether different patterns of brain activation in the context of instructions of attending to the face or attending to the voice can be found was also explored. Results suggested that there was no significant incongruence effect between groups, given that individuals with a high level of autistic traits are able to recruit more normative neural networks for processing incongruence as individuals with a low level of autistic traits, regardless of instructions. Though no between group differences, individuals with HAQ showed negative activation in regions involved in the default-mode network, indicating a lack of behaviour adjustment, more effortful processing or higher attentional demands in responding to incongruence in this population. When changes of instructions were taken into account, a stronger incongruence effect was seen in the voice-attend condition for individuals with HAQ, and in the face-attend condition for individuals with LAQ. The use of different brain networks for processing emotional incongruence in individuals with high levels of autistic traits does not necessarily imply the presence of deficits. Instead, it may be a result of the combined effect of attentional demands and information processing propensity. In addition to the above results, demographic data from all three studies suggested that individuals with HAQ were more likely to have higher levels of anxiety than individuals with LAQs.

The contribution of this research lies in confirming that individuals high in autistic traits are more vulnerable to anxiety, which also has an impact in the recognition of emotions presented in different modalities. Hence, futher efforts should be made to assess and cope with co-ocurring anxiety in individuals with high level of autistic traits to support their mental health and social and emotional skills. This result also highlighs the importance to consider the effects of individual characterstics (e.g., serveity of anxiety symptoms, severity of depression symtpms, age, gender, language ability, cognitive ability) in social functions. In addition, the research demonstrated that co-morbid anxiety did moderate the emotion recognition, and this effect tended to be different for individuals with high levels of autistic traits and individuals with low levels of autistic traits. This result is significant in informing the development of appropriate service to support emotional skills of individuals. Another important aspect of this research is to examine the brain networks for processing emotional expressions in autistic traits across different modalities, including the mutlsensory integration. In addition, neural correlates in response to emotional incongruences were also explored. These attempts will help to outline the differences in audiovisual processing between individuals high in autistic traits and individuals low in autistic traits. These results are useful for understanding the theoretical basis of multisensory processing in autism and tend to have potential practical and clinical values.

This research had an exploratory goal of examining the unique patterns of emotion understanding in individuals with considerable autistic traits. The findings and implications of this research make contributions to the knowledge of the role of autistic traits and comorbid anxiety in modulating the abilities of emotion recognition from both uni-modal and bi-modal perspectives. It has also shed light on the neural mechanisms associated with emotion processing and multisensory integration in individuals with high levels of autistic traits. These findings are not intended to be a prescription for classroom behavior, but intead an acknowledgement that classroom settings were embedded with different people with different patterns of learning and communicating approaches (both challenges and advantages) and towards this, practice and research can be more reflective and intentional, thus fosting the development of learners. While the findings may be limited to the small sample size, gender distribution and anxiety symptoms' distributionof the participants in the research, it is hoped that future research will be conducted on a large and well-distributed participant profile to provide well-structured comprasion data. Moreover, future research to observe whether these training and practical strategies are associated with better skill development in individuals would be recommended.

References

Admiraal, W., & Wubbels, T. (2005). Multiple voices, multiple realities, what truth ? Student teachers' learning to reflect in different paradigms. *Teachers and Teaching:Theory and Practice*, *11*(3), 315–329. http://doi.org/10.1080/13450600500105668

Adolphs, R. (2002). Recognizing emotion from facial expressions: Psychological and Neurological Mechanisms. *Behavioral and Cognitive Neuroscience Reviews, 1*(1), 21–62. http://doi.org/10.1177/1534582302001001003

Adolphs, R., Sears, L., & Piven, J. (2001). Abnormal processing of social information from faces in autism. *Journal of Cognitive Neuroscience*, *13*(2), 232–240. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11244548

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature*. http://doi.org/10.1038/372669a0

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1995). Fear and the human amygdala. *The Journal of Neuroscience*, *15*(9), 5879–5891. http://doi.org/10.1093/neucas/3.4.267.

Adolphs, R., Tranel, D., Hamann, S., Young, A. ., Clader, A. J., Lee, G. P., & Damasio, A. R. (1999). Recognition of facial emotion in nine subjects with bilataral amygdala damage. *Neuropsychologia*, *37*, 1111–1117. http://doi.org/10.1016/S0028-3932(99)00039-1.

Al-Gelban, K. S. (2007). Depression , anxiety and stress among Saudi adolescent school boys. *J R Soc Health*, *127*, 33–37. http://doi.org/10.1177/1466424007070492

Albano, A. M., Chorpita, B. F.,&Barlow, D. H. (2003). *Childhood anxiety disorders*. In E. J. Mash & R. A. Barkley (Eds.), Child Psychopathology (pp. 279–329). New York: Guilford Press.

Alba-ferrara, L., Hausmann, M., Mitchell, R. L., & Weis, S. (2011). The Neural Correlates of Emotional Prosody Comprehension : Disentangling Simple from Complex Emotion. *PLoS ONE*, *6*(12), e28701. http://doi.org/10.1371/journal.pone.0028701

Allison, C., Baron-Cohen, S., Wheelwright, S., Charman, T., Richler, J., Pasco, G., & Brayne, C. (2008). The Q-CHAT (Quantitative CHecklist for Autism in Toddlers): A normally distributed quantitative measure of autistic traits at 18-24 months of age: Preliminary report. *Journal of Autism and Developmental Disorders*, *38*(8), 1414–1425. http://doi.org/10.1007/s10803-007-0509-7

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, *4*(7), 267–278. http://doi.org/10.1016/S1364-6613(00)01501-1

Amaral, D. G., Bauman, M. D., & Schumann, C. M. (2003). The amygdala and autism: implications from non-human primate studies. *Genes, Brain, and Behavior*, *2*(5), 295–302. http://doi.org/10.1046/j.1601-183X.2003.00043.x

Anderson, A. K., & Phelps, E. A. (2000). Expression Without Recognition: Contributions of the Human Amygdala to Emotional Communication. *Psychological Science*, *11*(2), 106–111. http://doi.org/10.1111/1467-9280.00224

Anderson, A.K. and Phelps, E.A. (1998) Intact recognition of vocal expressions of fear following bilateral lesion of the human amygdala. *Neuroreport*, 9: 3607–3613. http://doi.org/10.1093/neucas/6.6.442

Anderson, M. L. (2016). Précis of After Phrenology: Neural Reuse and the Interactive Brain. *Behavioral and Brain Sciences*, *39*(2016), e120. http://doi.org/10.1017/S0140525X15000631

Arthur-kelly, M., Sigafoos, J., Green, V., Mathisen, B., Arthur-kelly, R., Mathisen, B., & Arthur-kelly, R. (2009). Issues in the use of visual supports to promote communication in individuals with autism spectrum disorder individuals with autism spectrum disorder. *Disability and Rehabilitation*, *31*(18), 1474–1486. http://doi.org/10.1080/09638280802590629

Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., & Bullmore, E. T. (2007). Differential activation of the amygdala and the "social brain" during fearful face-processing in Asperger Syndrome. *Neuropsychologia*, *45*(1), 2–14. http://doi.org/10.1016/j.neuropsychologia.2006.04.014

Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of negative basic emotions in autism: A test of the amygdala theory. *Social Neuroscience*, *1*(3–4), 349–363. http://doi.org/10.1080/17470910601040772

Atkinson, A. P., & Adolphs, R. (2011). The neuropsychology of face perception: Beyond simple dissociations and functional selectivity. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *366*(1571), 1726–1738. http://doi.org/10.1098/rstb.2010.0349

Attwood, T. (1998) *Asperger's Syndrome – A guide for parents and professionals.* London: Jessica Kingsley Publishers Ltd.

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: Children's version (AQ-Child). *Journal of Autism and Developmental Disorders*, *38*(7), 1230–1240. http://doi.org/10.1007/s10803-007-0504-z

Ayduk, Ö., Gyurak, A., & Luerssen, A. (2010). Individual differences in the rejection-aggression link in the hot sauce paradigm: The case of Rejection Sensitivity. *Journal of Experimental Social Psychology*, *44*(3), 775–782. http://doi.org/10.1016/j.jesp.2007.07.004.Individual

Ayoko, O. B., Callan, V. J., & Härtel, C. E. J. (2008). The influence of team emotional intelligence cimate on conflict and team members' reactions to conflict. *Small Group Research*, *39*(2), 121–149. http://doi.org/10.1177/1046496407304921

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–412. http://doi.org/10.1016/j.jml.2007.12.005

Bajgar, J., Ciarrochi, J., Lane, R., & Deane, F. P. (2005). Development of the levels of emotional awareness scale for children (LEAS-C). *British Journal of Developmental Psychology*, *23*, 569–586.

Baker, K. F., Montgomery, A. A., & Abramson, R. (2010). Brief report: Perception and lateralization of spoken emotion by youths with high-functioning forms of autism. *Journal of Autism and Developmental Disorders*, *40*(1), 123–129. http://doi.org/10.1007/s10803-009-0841-1

Baker, M. J., Koegel, R. L. & Koegel, L. K. (1998). Increasing the social behaviour of young children with autism using their obsessive behaviours. *Journal of the Association for Persons with Severe Handicaps*, 23, 300-308. http://doi.org/10.2511/rpsd.23.4.300

Bal, E., Harden, E., Lamb, D., Van Hecke, A. V., Denver, J. W., & Porges, S. W. (2010). Emotion recognition in children with autism spectrum disorders: relations to eye gaze and autonomic state. *Journal of Autism and Developmental Disorders*, *40*, 358–370. http://doi.org/10.1007/s10803-009-0884-3

Bandura, A. (1977). *Social learning theory*. Prentice Hall, Englewood Cliffs, New Jersey, USA.

Bandura, A., Caprara, G. V., Barbaranelli, C., Gerbino, M., & Pastorelli, C. (2003). Role of affective self-regulatory efficacy in diverse spheres of psychosocial functioning. *Child Development*, *74*(3), 769–782.

Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of Personality and Social Psychology*, *70*(3), 614–636. http://doi.org/10.1037/0022-3514.70.3.614

Barlow, D.H. & Cerny, J.A. (1988). *Psychological treatment of panic*. Guilford Press: New York.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. http://doi.org/10.1037/0033-2909.133.1.1

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and Theory of Mind*. Cambridge: MIT Press

Baron-Cohen, S. (1997). Another advanced test of theory of mind: evidence from very high functioning adults with autism or asperger syndrome. *Journal of Child Psychology & Psychiatry*, *38*(7), 813–822. Retrieved from http://docs.autismresearchcentre.com/papers/1997_BCetal_Anotheradvancedtest.pdf

Baron-Cohen, S. (2010). Empathizing, systemizing, and the extreme male brain theory of autism. *Progress in Brain Research*, *186*, 167–175. http://doi.org/10.1016/B978-0-444-53630-3.00011-7

Baron-Cohen, S. (2008). Autism, hypersystemizing, and truth. *Quarterly Journal of Experimental Psychology (2006)*, *61*(1), 64–75. http://doi.org/10.1080/17470210701508749

Baron-Cohen, S., Baldwin, D. A., & Crowson, M. (1997). Do children with autism use the speaker's direction of gaze strategy to crack the code of language ? *Child Development*, *68*(1), 48–57. http://doi.org/10.1111/j.1467-8624.1997.tb01924.x

Baron-Cohen, S., Golan, O., & Ashwin, E. (2009). Can emotion recognition be taught to children with autism spectrum conditions? *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1535), 3567–74. http://doi.org/10.1098/rstb.2009.0191

Baron-Cohen, S., Hoekstra, R. A., Knickmeyer, R., & Wheelwright, S. (2006). The Autism-Spectrum Quotient (AQ) - Adolescent version. *Journal of Autism and Developmental Disorders*, *36*(3), 343–350. http://doi.org/10.1007/s10803-006-0073-6

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind" ? *Cognition*, *21*(1), 37–46. http://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. R. (2000). The amygdala theory of autism. *Neuroscience and Biobehavioral Reviews*, *24*(3), 355–364. http://doi.org/10.1016/S0149-7634(00)00011-7

Baron-Cohen, S., Spitz, A., & Cross, P. (1993). Do children with autism recognise surprise ? A research note. *Cognition and Emotion*, *7*(6), 507–516. http://doi.org/10.1080/02699939308409202

Baron-Cohen, S., & Wheelwright, S. (2003). The friendship questionnaire: An investigation of adults with asperger syndrome or high-functioning autism, and Normal Sex Differences. *Journal of Autism and Developmental Disorders*, *33*(5), 509–517. http://doi.org/10.1023/A:1025879411971

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *42*(2), 241–51. http://doi.org/10.1111/1469-7610.00715

Baron-Cohen, S., Wheelwright, S., & Jolliffe, and T. (1997). Is there a "Language of the Eyes"? Evidence from normal adults, and adults with autism or asperger syndrome. *Visual Cognition*, *4*(3), 311–331. http://doi.org/10.1080/713756761

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism spectrum quotient: Evidence from asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. http://doi.org/10.1023/A:1005653411471

Barrett, P. M., Barrett, P., & Turner, C. (2001). Prevention of anxiety symptoms in primary school children: Preliminary results from a universal school-based trial. *British Journal of Clinical Psychology*, *40*, 399–410. http://doi.org/10.1348/014466501163887

Barrett, P. M., & Turner, C. M. (2004). *Prevention strategies*. In T. L. Morris, & J. S. March (Eds.), Anxiety disorders in children and adolescents (pp. 371–387). New York: Guilford.

Bastiaansen, J. A., Thioux, M., Nanetti, L., Van Der Gaag, C., Ketelaars, C., Minderaa, R., & Keysers, C. (2011). Age-related increase in inferior frontal gyrus activity and social functioning in autism spectrum disorder. *Biological Psychiatry*, *69*, 832–838. http://doi.org/10.1016/j.biopsych.2010.11.007

Bates, D. (2005). Fitting linear mixed models in R. *R News*, *5*(1), 27–30. http://doi.org/10.1159/000323281

Bates, D. M., & Sarkar, D. (2007). *lme4: Linear mixed-effects models using S4 classes,* R package version 0.99875-6.

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research*, *17*(3), 613–620. http://doi.org/10.1016/S0926-6410(03)00174-5

Baucom, L. B., Wedell, D. H., Wang, J., Blitzer, D. N., & Shinkareva, S. V. (2012). Decoding the neural representation of affective states. *NeuroImage*, *59*(1), 718–727. http://doi.org/10.1016/j.neuroimage.2011.07.037

Bauminger, N., Solomon, M., & Rogers, S. J. (2010). Predicting friendship quality in autism spectrum disorders and typical development. *Journal of Autism and Developmental Disorders*, *40*(6), 751–761. http://doi.org/10.1007/s10803-009-0928-8

Bayram, N., & Bilgel, N. (2008). The prevalence and socio-demographic correlations of depression , anxiety and stress among a group of university students. *Soc Psychiatry Psychiatr Epidemiol*, (43), 667–672. http://doi.org/10.1007/s00127-008-0345-x

Beauchamp, M., Lee, K., Argall, B., & Martin, a. (2004). Integration of auditory and visual information about objects in superior temporal sulcus. *Neuron*, *41*, 809–823. http://doi.org/10.1016/S0896-6273(04)00070-4

Beauchamp, M. S. (2005a). See me, hear me, touch me: Multisensory integration in lateral occipital-temporal cortex. *Current Opinion in Neurobiology*, *15*(2), 145–153. http://doi.org/10.1016/j.conb.2005.03.011

Beauchamp, M. S. (2005b). Statistical criteria in fMRI studies of multisensory integration. *Neuroinformatics*, *3*(2), 93–113. http://doi.org/10.1385/NI

Beaumont, R., & Sofronoff, K. (2008). A multi-component social skills intervention for children with Asperger syndrome: The junior detective training program. *Journal of Child Psychology and Psychiatry*, *49*(7), 743–753. http://doi.org/10.1111/j.1469-7610.2008.01920.x

Beck, A. T. (1976). *Cognitive therapy and the emotional disorders*. New York: International Universities Press.

Beck, A.T., Emery, G., Greenberg, R.L., (1985). *Anxiety disorders and phobias: A cognitive perspective.* Basic Books, New York.

Beddington, J., Cooper, C. L., Field, J., Goswami, U., Huppert, F. a, Jenkins, R., … Thomas, S. M. (2008). The mental wealth of nations. *Nature*, *455*(7216), 1057–1060. http://doi.org/10.1038/4551057a

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia*, *44*(1), 110–129. http://doi.org/10.1016/j.neuropsychologia.2005.04.002

Belin, P., Fecteau, S., & Bédard, C. (2004). Thinking the voice: neural correlates of voice perception. *Trends in Cognitive Sciences*, *8*(3), 129–35. http://doi.org/10.1016/j.tics.2004.01.008

Belin, P., Fillion-Bilodeau, S., & Gosselin, F. (2008). The montreal affective voices: a validated set of nonverbal affect bursts for research on auditory affective processing. *Behavior Research Methods*, *40*(2), 531–539. http://doi.org/10.3758/BRM.40.2.531

Belin, P., Zatorre, R. J., Lafaille, P., Ahad, P., & Pike, B. (2000). Voice-selective areas in human auditory cortex. *Nature*, *403*(6767), 309–312. http://doi.org/10.1038/35002078

Bellini, S. (2004). Social skill deficits and anxiety in high-functioning adolescents with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *19*(2), 78–86. http://doi.org/10.1177/10883576040190020201

Bellini, S. (2006). The development of social anxiety in adolescents with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *21*(3), 138–145. http://doi.org/10.1177/10883576060210030201

Bernstein, M. A., King, K. F. & Joe Zhou, X.-h. (2004). *Handbook of MRI Pulse Sequences*. Amsterdam, Elsevier Academic Press.

Best, C. S., Moffat, V. J., Power, M. J., Owens, D. G. C., & Johnstone, E. C. (2008). The boundaries of the cognitive phenotype of autism: theory of mind, central coherence and ambiguous figure perception in young people with autistic traits. *Journal of Autism and Developmental Disorders*, *38*(5), 840–7. http://doi.org/10.1007/s10803-007-0451-8

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex*, *19*(12), 2767–2796. http://doi.org/10.1093/cercor/bhp055

Bird, G., Leighton, J., Press, C., & Heyes, C. (2007). Intact automatic imitation of human and robot actions in autism spectrum disorders. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1628), 3027–3031. http://doi.org/10.1098/rspb.2007.1019

Blair, C., & Peters Razza, R. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Source: Child Development Child Development*, *78*(2), 647–663. Retrieved from http://www.jstor.org/stable/4139250%250Ahttp://www.jstor.org/stable/4139250?seq=1&cid=pdf-reference#references_tab_contents%250Ahttp://about.jstor.org/terms

Blair, R. J. R. (2005). Responding to the emotions of others : Dissociating forms of empathy through the study of typical and psychiatric populations. *Consciousness and Cognition*, *14*, 698–718. http://doi.org/10.1016/j.concog.2005.06.004

Blair, R. J. R., Morris, J. S., Frith, C. D., Perrett, D. I., & Dolan, R. J. (1999). Dissociable neural responses to facial expressions of sadness and anger. *Brain*, *122*(5), 883–893. http://doi.org/10.1093/brain/122.5.883

Blasi, A., Lloyd-Fox, S., Sethna, V., Brammer, M. J., Mercure, E., Murray, L., … Johnson, M. H. (2015). Atypical processing of voice sounds in infants at risk for autism spectrum Disorder. *Cortex*, *71*, 122–133. http://doi.org/10.1016/j.cortex.2015.06.015

Blasi, A., Mercure, E., Lloyd-Fox, S., Thomson, A., Brammer, M., Sauter, D., … Murphy, D. G. M. (2011). Early specialization for voice and emotion processing in the infant brain. *Current Biology*, *21*(14), 1220–1224. http://doi.org/10.1016/j.cub.2011.06.009

Blasi, G., Goldberg, T. E., Weickert, T., Das, S., Kohn, P., Zoltick, B., … Mattay, V. S. (2006). Brain regions underlying response inhibition and interference monitoring and suppression. *European Journal of Neuroscience*, *23*, 1658–1664. http://doi.org/10.1111/j.1460-9568.2006.04680.x

Bölte, S., Hubl, D., Feineis-Matthews, S., Prvulovic, D., Dierks, T., & Poustka, F. (2006). Facial affect recognition training in autism: can we animate the fusiform gyrus? *Behavioral Neuroscience*, *120*(1), 211–216. http://doi.org/10.1037/0735-7044.120.1.211

Bogdan, R. y Biklen, S., (2003) *Qualitative Research for Education.* An introduction to theories and methods. Pearson.

Bookheimer, S. Y., Wang, A. T., Scott, A., Sigman, M., & Dapretto, M. (2008). Frontal contributions to face processing differences in autism : evidence from fMRI of inverted face processing. *Journal of the International Neuropsychological Society*, *14*, 922–932.

Boraston, Z. L., Corden, B., Miles, L. K., Skuse, D. H., & Blakemore, S. J. (2008). Brief report: Perception of genuine and posed smiles by individuals with autism. *Journal of Autism and Developmental Disorders*, *38*(3), 574–580. http://doi.org/10.1007/s10803-007-0421-1

Bornstein, M. H., & Arterberry, M. E. (2003). Recognition, discrimination and categorization of smiling by 5-month-old infants, Developmental Science, *5*, 585–599. http://doi.org/10.1111/1467-7687.00314

Boucher, J., Lewis, V., & Collis, G. M. (2000). Voice processing abilities in children with autism, children with specific language impairments, and young typically developing children. *Journal of Child Psychology & Psychiatry & Allied Disciplines*, *41*(7), 847–857. http://doi.org/10.1111/1469-7610.00672

Bower, G. H. (1981). Mood and memory. *Behaviour Research and Therapy*, *25*(6), 443–455. http://doi.org/10.1016/0005-7967(87)90052-0

Bower, G. H. (1987). Commentary on mood and memory. *Behaviour Research and Therapy*, *25*(6), 443–455. http://doi.org/10.1016/0005-7967(87)90052-0

Bowman-perrott, L., Burke, M. D., Zhang, N., & Zaini, S. (2014). Direct and collateral effects of peer tutoring on social and behavioral outcomes: a meta-analysis of single-case research. *School Psychology Rreview*, *43*(3), 260–285.

Boyatzis, C. J., Chazan, E., & Ting, C. Z. (1993). Preschool children's decoding of facial emotions. *The Journal of Genetic Psychology*, *154*(3), 375–382. http://doi.org/10.1080/00221325.1993.10532190

Bozikas, V. P., Kosmidis, M. H., Anezoulaki, D., Giannakou, M., Andreou, C., & Karavatos, A. (2006). Impaired perception of affective prosody in schizophrenia. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *18*(1), 81–85. http://doi.org/10.1176/appi.neuropsych.18.1.81

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision*, (10), 433–436.

Brackett, M. A., & Salovey, P. (2004). *Measuring emotional intelligence with the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT).* In G. Geher (Ed.), Measuring emotional intelligence: Common ground and controversy (pp. 181-196). Hauppauge, NY: Nova Science.

Breiter, H. C., Etcoff n, L., Whalen p, J., Kennedy w, a, Rauch s, L., Buckner r, L., … Rosen b, R. (1996). Response and habituation of the human amygdala during visual processing offacial expression. *Neuron*, *17*, 875–887. http://doi.org/10.1016/S0896-6273(00)80219-6

Brereton, A. V., Tonge, B. J., & Einfeld, S. L. (2006). Psychopathology in children and adolescents with autism compared to young people with intellectual disability. *Journal of Autism and Developmental Disorders*, *36*(7), 863–870. http://doi.org/10.1007/s10803-006-0125-y

Bristol, M. M., & Schopler, E. (1983). *Stress and coping in families of autistic adolescents.* In E. Schopler & G. Mesibov (Eds.), Autism in adolescents and adults (pp. 251–278). New York: Plenum Press

Brock, J., Brown, C. C., Boucher, J., & Rippon, G. (2002). The temporal binding deficit hypothesis of autism. *Development and Psychopathology*, *14*(2), 209–224. http://doi.org/10.1017/S0954579402002018

Broks, P., Young, A. W., Maratos, E. J., Coffey, P. J., Calder, A. J., Isaac, C. L., … Hadley, D. (1998). Face processing impairments after encephalitis : amygdala damage and recognition of fear. *Neuropsychologia*, *36*(1), 59–70. http://dx.doi.org/10.1016/S0028-3932(97)00105-X

Brown, TA. Chorpita, BF. Korotitsch, W. Barlow, D. (1997). Psychometric properties of the Depression Anxiety Stress Scales (DASS) in Clinical Samples*. *Behav. Res. Ther.*, *35*(I), 79–89. http://doi.org/10.1016/S0005-7967(96)00068-X

Brown, E. L., Kanny, M. A., & Johnson, B. (2013). "I Am Who I Am Because of Here!": School settings as a mechanism of change in establishing high-risk adolescents academic identities. *Journal of Early Adolescence*, *34*, 178–205. http://doi.org/10.1177/0272431613480271

Brown, T. A., & Barlow, D. H. (1992). Comorbidity among anxiety disorders: Implications for treatment and DSM-IV. *Journal of Consulting and Clinical Psychology*, *60*(6), 835–844. http://doi.org/0022-006X/92/S3.00

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Import, A., Langton, S., McAuley, S., & Wright, R. (2000). Testing face processing skills in children. *British Journal of Developmental Psychology*, *18*(3), 319–333. http://doi.org/10.1348/026151000165715

Bruce, B. & Hansson, K. (2010). *Promoting peer interaction*. Retrieved September 3, 2013 from http://cdn.intechopen.com/pdfs/19210/InTech- Promoting_peer_interaction.pdf

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77*(3), 305–327. http://doi.org/10.1111/j.2044-8295.1986.tb02199.x

Bruffee, K. A. (1999). *Collaborative learning: higher education, interdependence, and the authority of knowledge (2nd ed.)*. Baltimore, MD: The John Hopkins University Press.

Brunsdon, V. E. a., Colvert, E., Ames, C., Garnett, T., Gillan, N., Hallett, V., … Happé, F. (2014). Exploring the cognitive features in children with autism spectrum disorder, their co-twins, and typically developing children within a population-based sample. *Journal of Child Psychology and Psychiatry*, *56*(8), 893–902. http://doi.org/10.1111/jcpp.12362

Bryman, A. (2004). *Social Research Methods (2nd Edition),* Oxford: Oxford University Press.

Buccino, G., Vogt, S., Ritzl, Fink, G. R., Zilles, K., & Freund, H. J. (2004). Neural Circuits underlying imitation learning of hand actions: an event related fMRI study. *Neuron*, *42*, 323–334. http://doi.org/10.1016/S0896-6273(04)00181-3

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, *1124*, 1–38. http://doi.org/10.1196/annals.1440.011

Burns, R. B. (2000). *Introduction to research methods.* London: Sage Publications.

Cabeza, R., & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience*, 12, 1-47. http://doi.org/10.1162/08989290051137585

Calder, A. J. (1996). Facial emotion recognition after bilateral amygdala damage: differentially severe impairment of fear. *Cognitive Neuropsychology*, *13*(5), 699–745. http://doi.org/10.1080/026432996381890

Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, *3*(11), 1077–1078. http://doi.org/10.1038/80586

Calder, A. J., Lawrence, A. D., & Young, A. W. (2001). Neuropsychology of fear and loathing. *Nature Reviews Neuroscience*, *2*(5), 352–363. http://doi.org/10.1038/35072584

Calder, L., Hill, V., & Pellicano, E. (2012). "Sometimes I want to play by myself": Understanding what friendship means to children with autism in mainstream primary schools. *Autism*, *17*(3), 296–316. http://doi.org/10.1177/1362361312467866

Calvert, G. A. (2001). Crossmodal processing in the human brain: insights from functional neuroimaging studies. *Cereb Cortex*, *11*(12), 1110–1123. http://doi.org/10.1093/cercor/11.12.1110

Calvert, G. A. A., Campbell, R., & Brammer, M. J. J. (2000). Evidence from functional magnetic resonance imaging of crossmodal binding in the human heteromodal cortex. *Current Biology*, *10*(11), 649–657. http://doi.org/10.1016/S0960-9822(00)00513-3

Calvert, G. A., Hansen, P. C., Iversen, S. D., & Brammer, M. J. (2001). Detection of audio-visual integration sites in humans by application of electrophysiological criteria to the BOLD effect. *NeuroImage*, *14*(2), 427–438. http://doi.org/10.1006/nimg.2001.0812

Calvert, G. A., & Thesen, T. (2004). Multisensory integration: Methodological approaches and emerging principles in the human brain. *Journal of Physiology Paris*, *98*, 191–205. http://doi.org/10.1016/j.jphysparis.2004.03.018

Calvert, G. a, Brammer, M. J., Bullmore, E. T., Campbell, R., Iversen, S. D., & David, a S. (1999). Response amplification in sensory-specific cortices during crossmodal binding. *Neuroreport*, *10*(12), 2619–2623. http://doi.org/10.1097/00001756-199908200-00033

Campanella, S., & Belin, P. (2007). Integrating face and voice in person perception. *Trends in Cognitive Sciences*. http://doi.org/10.1016/j.tics.2007.10.001

Canavan, S., Sun, Y., Zhang, X., & Yin, L. (2012). A dynamic curvature based approach for facial activity analysis in 3D space. *IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*, 14–19. http://doi.org/10.1109/CVPRW.2012.6239350

Capps, L., Yirmiyat, N., & Sigmant, M. (1992). Understanding of simple and complex emotions in non-retarded children with autism. *Journal of Child Psychial*, *33*(7), 1169–1182. http://doi.org/10.1111/j.1469-7610.1992.tb00936.x

Carbo, M., Dunn R., Dunn K., (1986). *Teaching Students to read through their individual learning styles.*

Carothers, D. E., & Taylor, R. L. (2004). Social cognitive processing in elementary school children with asperger syndrome. *Education and Training in Developmental Disabilities*, *39*(2), 177–187.

Carter, C. S., & Van Veen, V. (2007). Anterior cingulate cortex and conflict detection: an update of theory and data. *Cognitive, Affective & Behavioral Neuroscience*, *7*(4), 367–379. http://doi.org/10.3758/cabn.7.4.367

Casile, A., Dayan, E., Caggiano, V., Hendler, T., Flash, T., & Giese, M. A. (2010). *Neuronal encoding of human kinematic invariants during action observation*. *Cerebral Cortex* (Vol. 20). http://doi.org/10.1093/cercor/bhp229

Carson, R.L., Templin, T.J. (2007). *Emotion regulation and teacher burnout: Who says that the management of emotional expression doesn't matter?* Paper presented at the American Education Research Association Annual Convention, Chicago.

Carver, C. S. (2004). *Self-regulation of action and affect. In R. F. Baumeister & K. D. Vohs (Eds.),* Handbook of self-regulation: Research, theory, and applications (pp. 13–39). New York, NY: Guilford Press.

Castelli, F. (2005). Understanding emotions from standardized facial expressions in autism and normal development. *Autism*, *9*(4), 428–449. http://doi.org/10.1177/1362361305056082

Cattell, R. B, Sheier, I. H. (1963). *Handbook for the IPAT anxiety scale. 2nd ed.* Champaign (IL): Institute for Personality and Ability Testing;

Celeghin, A., Diano, M., Bagnis, A., Viola, M., & Tamietto, M. (2017). Basic emotions in human neuroscience: Neuroimaging and beyond. *Frontiers in Psychology*, *8*(AUG), 1–13. http://doi.org/10.3389/fpsyg.2017.01432

Chakrabarti, S., & Fombonne, E. (2001). Pervasive developmental disorders in preschool children. *Jama*, *285*(24), 3093–3099. http://doi.org/joc10065 [pii]

Chalfant, A. M., Rapee, R., & Carroll, L. (2007). Treating anxiety disorders in children with high functioning autism spectrum disorders: A controlled trial. *Journal of Autism and Developmental Disorders*, *37*(10), 1842–1857. http://doi.org/10.1007/s10803-006-0318-4

Chatwin, I., & Harley, V. (2007). *Implementing TEACCH in support of a 24-hour curriculum*. In B. Carpenter & J. Egerton (Eds.), New horizons in special education: Evidence-based practice in action (pp. 171-180). Worcester: Sunfield Publications.

Chan, J. M. ., & O'Reilly, M. F. (2008). A social storiesTM intervention package for students with autism in inclusive classroom settings. *Journal of Applied Behavior Analysis*, *41*(405–409). http://doi.org/10.1901/jaba.2008.41-405

Charbonneau, G., Bertone, A., Lepore, F., Nassim, M., Lassonde, M., Mottron, L., & Collignon, O. (2013). Multilevel alterations in the processing of audio-visual emotion expressions in autism spectrum disorders. *Neuropsychologia*, *51*(5), 1002–10. http://doi.org/10.1016/j.neuropsychologia.2013.02.009

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, *16*(4), 231–9. http://doi.org/10.1016/j.tics.2012.02.007

Chevallier, C., Noveck, I., Happé, F., & Wilson, D. (2011). What's in a voice? Prosody as a test case for the Theory of Mind account of autism. *Neuropsychologia*, *49*(3), 507–517. http://doi.org/10.1016/j.neuropsychologia.2010.11.042

Cisler, Josh, M., & Koster, Ernst. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorder: An integrative review. *Clinical Psychology Review*, *30*(2), 203–216. http://doi.org/10.1016/j.cpr.2009.11.003.Mechanisms

Cohen, M. X., van Gaal, S., Ridderinkhof, K. R., & Lamme, V. a F. (2009). Unconscious errors enhance prefrontal-occipital oscillatory synchrony. *Frontiers in Human Neuroscience*, *3*(November), 54. http://doi.org/10.3389/neuro.09.054.2009

Cohen, L., Manion, L., and Morrison, K. (2011) *Research methods in education.* 7th ed. London: Routledge Falmer.

Collignon, O., Girard, S., Gosselin, F., Roy, S., Saint-Amour, D., Lassonde, M., & Lepore, F. (2008). Audio-visual integration of emotion expression. *Brain Research*, *1242*, 126–135. http://doi.org/10.1016/j.brainres.2008.04.023

Collins, M., & Nowicki, S. J. (2001). African American children's ability to identify emotion in facial expressions and tones of voice of European Americans. *The Journal of Genetic Psychology*, *162*(3), 334–346. http://doi.org/10.1080/00221320109597487

Colwell, M. J., & Hart, S. (2006). Emotion framing: does it relate to children's emotion knowledge and social behavior? *Early Child Development and Care*, *176*(6), 591–603. http://doi.org/10.1080/03004430500147367

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: A twin study. *Archives of General Psychiatry*, *60*, 524–530. http://doi.org/10.1001/archpsyc.60.5.524

Constantino, J. N., & Todd, R. D. (2005). Intergenerational transmission of subthreshold autistic traits in the general population. *Biological Psychiatry*, *57*(6), 655–660. http://doi.org/10.1016/j.biopsych.2004.12.014

Cooray, S. E., & Bakala, A. (2005). Anxiety disorders in people with learning disabilities. *Advances in Psychiatric Treatment*, *11*(5), 355–361. http://doi.org/10.1192/apt.11.5.355

Corbett, B., Carmean, V., Ravizza, S., Wendelken, C., Henry, M. L., Carter, C., … Rivera, S. M. (2009). A functional and structural study of emotion and face processing in children with autism. *Psychiatry Research*, *173*(3), 196–205. http://doi.org/10.1016/j.pscychresns.2008.08.005

Corden, B., Chilvers, R., & Skuse, D. (2008). Avoidance of emotionally arousing stimuli predicts social – perceptual impairment in Asperger's syndrome. *Neuropsychologia*, *46*, 137–147. http://doi.org/10.1016/j.neuropsychologia.2007.08.005

Coupland, N. J. (2001). Social phobia: etiology, neurobiology, and treatment. *J Clin Psychiatry*, *62*(suppl 1), 25–35.

Courchesne, E., & Pierce, K. (2005). Why the frontal cortex in autism might be talking only to itself: Local over-connectivity but long-distance disconnection. *Current Opinion in Neurobiology*, *15*(2), 225–230. http://doi.org/10.1016/j.conb.2005.03.001

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches (2nd ed.).* Thousand Oaks, CA: Sage.

Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C., Van Amelsvoort, T., Robertson, D. M., … Murphy, D. G. (2000). The functional neuroanatomy of social behaviour: changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain : A Journal of Neurology*, (11), 2203–12. http://doi.org/10.1093/brain/123.11.2203

Critchley, H., Daly, E., Phillips, M., Brammer, M., Bullmore, E., Williams, S., … Murphy, D. (2000). Explicit and implicit neural mechanisms for processing of social information from facial expressions: a functional magnetic resonance imaging study. *Human Brain Mapping*, *9*(2), 93–105. http://doi.org/10.1002/(SICI)1097-0193(200002)9:2<93::AID-HBM4>3.0.CO;2-Z

Crooke, P. J., Hendrix, R. E., & Rachman, J. Y. (2008). Brief report: Measuring the effectiveness of teaching social thinking to children with Asperger syndrome (AS) and High Functioning Autism (HFA). *Journal of Autism and Developmental Disorders*, *38*(3), 581–591. http://doi.org/10.1007/s10803-007-0466-1

Cutting, A. L., & Dunn, J. (2002). The cost of understanding other people : social cognition predicts young children ' s sensitivity to criticism. *Journal of Child Psychology & Psychiatry*, *43*(7), 849–860.

Dale, A. M., & Buckner, R. L. (1997). Selective averaging of rapidly presented individual trials using fMRI. *Human Brain Mapping*, *5*(5), 329–340. http://doi.org/10.1002/(SICI)1097-0193(1997)5:5<329::AID-HBM1>3.0.CO;2-5

Daleiden, E. L., & Vasey, M. W. (1997). An information-processing perspective on childhood anxiety. *Clinical Psychology Review*, *17*(4), 407–429.

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., Goldsmith, H. H., … Davidson, R. J. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, *8*(4), 519–526. http://doi.org/10.1038/nn1421

Dalton, P., Doolittle, N., Nagata, H., & Breslin, P. A. S. (2000). The merging of the senses: Integration of subthreshold taste and smell. *Nature Neuroscience*, *3*(5), 431–432. http://doi.org/10.1038/74797

Damasio, A. R. (1994). *Descartes' error: emotion, reason, and the human brain*. New York, NY: G.P. Putnam's Sons.

Darwin, C. (1872/1965). *The expression of the emotions in man and animals.* Chicago: University of Chicago Press.

Dapretto, M., Davies, M. S., Pfeifer, J. H., Scott, A. A., Sigman, M., Bookheimer, S. Y., … Iacoboni, M. (2006). Understanding emotions in others: mirror neuron dysfunction in children with autism spectrum disorders. *Nat.Neurosci*, *9*(1), 28–30. http://doi.org/10.1038/nn1611

Davidson, R. J. (2003). *Parsing the subcomponents of emotion and disorders of emotion: Perspectives from affective neuroscience.* In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), Handbook of affective sciences (pp. 8-24). New York: Oxford University Press.

Davidson, R. J., Goldsmith, H. H., & Scherer, K. (2003). *Handbook of affective sciences.* New York: Oxford University Press.

Davis, T. E., Moree, B. N., Dempsey, T., Reuther, E. T., Fodstad, J. C., Hess, J. a., … Matson, J. L. (2011). The relationship between autism spectrum disorders and anxiety: The moderating effect of communication. *Research in Autism Spectrum Disorders*, *5*(1), 324–329. http://doi.org/10.1016/j.rasd.2010.04.015

Dawson, G., Meltzoff, A., Osterling, J. ., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occuring social stimuli.

de Gelder, B., & Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cognition & Emotion*, *14*(3), 289–311. http://doi.org/10.1080/026999300378824

Deeley, Q., Daly, E. M., Surguladze, S., Page, L., Toal, F., Robertson, D., … Murphy, D. G. M. (2007). An event related functional magnetic resonance imaging study of facial emotion processing in asperger syndrome. *Biological Psychiatry*, *62*(3), 207–217. http://doi.org/10.1016/j.biopsych.2006.09.037

Deetz, S. (1996). Crossroads - Describing differences in approaches to organization science : rethinking burrell and morgan and their legacy. *Organization Science*, *7*(2), 191–207.

Della-Maggiore, V., Chau, W., Peres-Neto, P. R., & McIntosh, A. R. (2002). An empirical comparison of SPM preprocessing parameters to the analysis of fMRI Data. *NeuroImage*, *17*(1), 19–28. http://doi.org/10.1006/nimg.2002.1113

Dematte, M. L. (2006). Cross-modal interactions between olfaction and touch. *Chemical Senses*, *31*(4), 291–300. http://doi.org/10.1093/chemse/bjj031

Demirbatir, R. E. (2012). Undergraduate music students' depression, anxiety and stress levels: a study from Turkey. *Procedia - Social and Behavioral Sciences*, *46*, 2995–2999. http://doi.org/10.1016/j.sbspro.2012.05.603

Denscombe, M. (2002). *Ground rules for good research*, Buckingham: Open University Press.

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, *111*(2), 225–236. http://doi.org/10.1037//0021-843X.111.2.225

Dewey, J. (1938). *Experience and Education*. New York, NY: Touchstone.

DiTomasso, R.A. & Gosch, E.A. (2002). *Anxiety disorders: A practitioner's guide to comparative treatments.* Springer Publishing Company: New York.

Dolan, R. J., Morris, J. S., & de Gelder, B. (2001). Crossmodal binding of fear in voice and face. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(17), 10006–10010. http://doi.org/10.1073/pnas.171288598

Dolcos, F., & Mccarthy, G. (2006). Brain systems mediating cognitive interference by emotional distraction, *26*(7), 2072–2079. http://doi.org/10.1523/JNEUROSCI.5042-05.2006

Donohue, S. E., Darling, E. F., & Mitroff, S. R. (2012). Links between multisensory processing and autism. *Exp Brain Res*, *222*(4), 377–387. http://doi.org/10.1007/s00221-012-3223-4

Downer, J. T., Booren, L. M., Lima, O. K., Luckner, A. E., & Pianta, R. C. (2010). The individualized classroom assessment scoring system (inCLASS): Preliminary reliability and validity of a system for observing preschoolers' competence in classroom interactions. *Early Childhood Research Quarterly*, *25*(1), 1–16. http://doi.org/10.1002/ana.22528.Toll-like

Doyle-Thomas, K. a R., Goldberg, J., Szatmari, P., & Hall, G. B. C. (2013). Neurofunctional underpinnings of audiovisual emotion processing in teens with autism spectrum disorders. *Frontiers in Psychiatry*, *4*(48), 1–9. http://doi.org/10.3389/fpsyt.2013.00048

Durand, K., Gallay, M., Seigneuric, A., Robichon, F., & Baudouin, J.-Y. (2007). The development of facial emotion recognition: the role of configural information. *Journal of Experimental Child Psychology*, *97*(1), 14–27. http://doi.org/10.1016/j.jecp.2006.12.001

Dyck, M. J. ., Piek, J. P. ., Hay, D., Smith, L., & Hallmayer, J. (2006). Are abilities abnormally interdependent in children with autism? *Journal of Clinical Child and Adolescent Psychology*, *35*(20–33).

Edwards, J., Jackson, H. J., & Pattison, P. E. (2002). Emotion recognition via facial expression and affective prosody in schizophrenia: A methodological review. *Clinical Psychology Review*, *22*(6), 789–832. http://www.ncbi.nlm.nih.gov/pubmed/12214327

Efklides, A., & Petkaki, C. (2005). Effects of mood on students' metacognitive experiences. *Learning and Instruction, 15,* 415–431. http://doi.org/10.1016/j.learninstruc.2005.07.010

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex*, *18*(6), 1475–1484. http://doi.org/10.1093/cercor/bhm179

Eichelberger, R.T. (1989). Disciplined inquiry: Understanding and doing educational research. New York: Longman.

Eigsti, I.-M., Schuh, J., Mencl, E., Schultz, R. T., & Paul, R. (2012). The neural underpinnings of prosody in autism. *Child Neuropsychology : A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *18*(6), 600–617. http://doi.org/10.1080/09297049.2011.639757

Ekman, P. (1999). *Basic emotions.* In T. Dalgleish & M. Power (Eds.), Handbook of cognition and emotion (pp. 45–60). New York, NY: Wiley.

Ekman, P., & Davidson, R. J. (1994). *The nature of emotion: fundamental questions*. New York: Oxford University Press.

Ekman, P. & Friesen, W. (1976). *Pictures of facial affect.* Consulting Psychologists Press,

Estrada, C. A., Isen, A. M., & Young, M. J. (1994). Positive affect improves creative problem solving and influences reported source of practice satisfaction in physicians. *Motivation and Emotion*, *18*(4), 285–299.

Ethofer, T., Anders, S., Erb, M., Herbert, C., Wiethoff, S., Kissler, J., … Wildgruber, D. (2006). Cerebral pathways in processing of affective prosody: A dynamic causal modeling study. *NeuroImage, 30*(2), 580–587. http://doi.org/10.1016/j.neuroimage.2005.09.059

Ethofer, T., Bretscher, J., Gschwind, M., Kreifelts, B., Wildgruber, D., & Vuilleumier, P. (2012). Emotional voice areas: anatomic location, functional properties, and structural connections revealed by combined fMRI/DTI. *Cerebral Cortex*, *22*, 191–200. http://doi.org/10.1093/cercor/bhr113

Evans, A., Collins, D., Mills, S., Brown, E., Kelly, R., & Peter, T. (1993). 3D statistical neuroanatomical models from 305 MRI volumes. *Nuclear Sci Symp Med Imaging Confc Vols*, (1–3), 1813–1817.

Evers, K., Steyaert, J., Noens, I., & Wagemans, J. (2015). Reduced recognition of dynamic facial emotional expressions and emotion-specific response bias in children with an Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *45*, 1774–1784. http://doi.org/10.1007/s10803-014-2337-x

Eysenck, M. W. (1992). *Anxiety: The cognitive perspective*. Hove, England: Erlbaum.

Eysenck, M.W. (1997). *Anxiety and cognition: A unified theory.* Hove, England: Psychology Press.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336–53. http://doi.org/10.1037/1528-3542.7.2.336

Fabri, M. (2006). *Emotionally expressive avatars for collaborative virtual environment.* thesis(PhD). Leeds Metropolitan University.

Farley, M. A., McMahon, W. M., Fombonne, E., Jenson, W. R., Miller, J., Gardner, M., … Coon, H. (2009). Twenty-year outcome for individuals with autism and average or near-average cognitive abilities. *Autism Research*, *2*(2), 109–118. http://doi.org/10.1002/aur.69

Fecteau, S., Belin, P., Joanette, Y., & Armony, J. L. (2007). Amygdala responses to nonlinguistic emotional vocalizations. *NeuroImage*, *36*(2), 480–487. http://doi.org/10.1016/j.neuroimage.2007.02.043

Fernald, A., & Morikawa, H. (1993). Infants articles common themes and cultural variations in Japanese and American mothers' speech to infants. *Child Development*, *64*(3), 637–656.

Foley, E., Rippon, G., Thai, N. J., Longe, O., & Senior, C. (2012). Dynamic facial expressions evoke distinct activation in the face perception network: a connectivity analysis study. *Journal of Cognitive Neuroscience*, *24*(2), 507–20. http://doi.org/10.1162/jocn_a_00120

Fombonne, E. (2002). Epidemiological trends in rates of autism. *Molecular Psychiatry*, *7*, S4–S6. http://doi.org/10.1038/sj.mp.4001162

Fombonne, E., Quirke, S., & Hagen, A. (2011). *Epidemiology of pervasive developmental disorders*. In D. G. Amaral, G. Dawson, & D. H. Geschwind (Eds.), Autism Spectrum disorders. Oxford: Oxford University Press.

Forster, B., Cavina-Pratesi, C., Aglioti, S. M., & Berlucchi, G. (2002). Redundant target effect and intersensory facilitation from visual-tactile interactions in simple reaction time. *Experimental Brain Research*, *143*(4), 480–487. http://doi.org/10.1007/s00221-002-1017-9

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, *130*(4), 681–700. http://doi.org/10.1037//0096-3445.130.4.681

Frazier, J. A., Biederman, J., Bellordre, C. A., Garfield, S. B., Geller, D. A., Coffey, B. J., & Faraone, S. V. (2001). Should the diagnosis of attention-deficit/hyperactivity disorder be considered in children with pervasive developmental disorder? *Journal of Attention Disorders*, *4*(4), 203–211. http://doi.org/10.1177/108705470100400402

Friedhoff, S., Meier zu Verl, C., Pietsch, C., Meyer, C., Vompras, J., & Liebig, S. (2013). Social research data: Documentation, management, and technical implementation within the SFB 882, (16). Retrieved from http://pub.uni-bielefeld.de/publication/2560035%5Cnhttp://pub.uni-bielefeld.de/download/2560035/2560036

Friston, K. J., Jezzard, P. ., & Turner, R. (1994). Analysis of functional MRI time-series. *Human Brain Mapping*, *1*, 153–171.

Friston, K. J., Harrison, L., & Penny, W. (2003). Dynamic causal modelling. *NeuroImage*, *19*(4), 1273–1302. http://doi.org/10.1016/S1053-8119(03)00202-7

Friston, K. J., Holmes, A. P., Price, C. J., Büchel, C., & Worsley, K. J. (1999). Multisubject fMRI studies and conjunction analyses. *NeuroImage*, *10*(4), 385–396. http://doi.org/10.1006/nimg.1999.0484

Friston, K. J., Lawson, R., & Frith, C. D. (2013). On hyperpriors and hypopriors: Comment on Pellicano and Burr. *Trends in Cognitive Sciences*, *17*(1), 1. http://doi.org/10.1016/j.tics.2012.11.003

Friston, K., Thornton, C., and Clark, A. (2012). Free-energy minimization and the dark-room problem. *Front. Psychol*. 3:130. doi: 10.3389/fpsyg.2012. 00130.

Frith, U. (1989). *Autism: Explaining the enigma.* Oxford: Blackwell publishing.

Frith, U. (2003). *Autism: Explaining the Enigma.* (2nd Edition) Oxford: Blackwell Publishing.

Frith, U., & Happé, F. (1994). Autism: beyond "theory of mind". *Cognition*, *50*, 115–132. http://doi.org/10.1016/0010-0277(94)90024-8

Frühholz, S., Ceravolo, L., & Grandjean, D. (2012). Specific brain networks during explicit and implicit decoding of emotional prosody. *Cerebral Cortex*, *22*(5), 1107–1117. http://doi.org/10.1093/cercor/bhr184

Frühholz, S., & Grandjean, D. (2012). Towards a fronto-temporal neural network for the decoding of angry vocal expressions. *NeuroImage*, *62*(3), 1658–1666. http://doi.org/10.1016/j.neuroimage.2012.06.015

Frühholz, S., & Grandjean, D. (2013). Processing of emotional vocalizations in bilateral inferior frontal cortex. *Neuroscience and Biobehavioral Reviews*, *37*(10), 2847–2855. http://doi.org/10.1016/j.neubiorev.2013.10.007

Frühholz, S., Gschwind, M., & Grandjean, D. (2015). Bilateral dorsal and ventral fiber pathways for the processing of affective prosody identified by probabilistic fiber tracking. *NeuroImage*, *109*, 27–34. http://doi.org/10.1016/j.neuroimage.2015.01.016

Frühholz, S., Trost, W., & Grandjean, D. (2014). The role of the medial temporal limbic system in processing emotions in voice and music. *Progress in Neurobiology*, *123*, 1–17. http://doi.org/10.1016/j.pneurobio.2014.09.003

Frühholz, S., Trost, W., & Grandjean, D. (2016). Whispering - The hidden side of auditory communication. *NeuroImage*, *142*, 602–612. http://doi.org/10.1016/j.neuroimage.2016.08.023

Gaigg, S. B., & Bowler, D. M. (2008). Free recall and forgetting of emotionally arousing words in autism spectrum disorder. *Neuropsychologia*, *46*(9), 2336–2343. http://doi.org/10.1016/j.neuropsychologia.2008.03.008

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain* 119 (119), 593–609.

Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. *Journal of Experimental Child Psychology*, *102*(4), 503–521. http://doi.org/10.1016/j.jecp.2008.11.002

Gebauer, L., Skewes, J., Westphael, G., Heaton, P., & Vuust, P. (2014). Intact brain processing of musical emotions in autism spectrum disorder, but more cognitive load and arousal in happy vs. sad music. *Frontiers in Neuroscience, 8* (Article 192). http://doi.org/10.3389/fnins.2014.00192

George, M. S., Parekh, P. I., Rosinsky, N., Ketter, T. A., Kimbrell, T.A., Heilman, K. M., Herscovitch, P., & Post, R.M. (1996). Understanding emotional prosody activates right hemisphere regions, *Archives of Neurology,* 53, 665-670.

Gepner, B., Deruelle, C., & Grynfeltt, S. (2001). Motion and emotion: a novel approach to the study of face processing by young autistic children. *Journal of Autism and Developmental Disorders*, *31*(1), 37–45. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11439752

Gervais, H., Belin, P., Boddaert, N., Leboyer, M., Coez, A., Sfaello, I., … Zilbovicius, M. (2004). Abnormal cortical voice processing in autism. *Nature Neuroscience*, *7*(8), 801–802. http://doi.org/10.1038/nn1291

Getzel, E. E., & Wehman, P. (2005). *Going to college: Expanding opportunities for people with disabilities*. Baltimore, MD: P.H. Brookes.

Gillberg, C. (1998). Asperger syndrome and high-functioning autism. *British Journal of Psychiatry*, *172*, 200–209. Retrieved from http://www.biomednet.com/db/medline/98276652

Gillott, A., Furniss, F., & Walter, A. (2001). Anxiety in high-functioning children with autism. *Autism*, *5*(3), 277–286. http://doi.org/10.1177/1362361301005003005

Glenn, A. L., Raine, A., & Schug, R. A. (2009). The neural correlates of moral decision-making in psychopathy. *Molecular Psychiatry*, *14*, 5–6. http://doi.org/10.1038/mp.2008.104

Glover, V. (2011). Annual Research Review: Prenatal stress and the origins of psychopathology:an evolutionary perspective. *Journal of Child Psychology and Psychiatry*, *52*(4), 356–367. http://doi.org/10.1111/j.1469-7610.2011.02371.x

Gobrial, E., & Raghavan, R. (2012). Prevalence of anxiety disorder in children and young people with intellectual disabilities and autism. *Advances in Mental Health and Intellectual Disabilities*, *6*(3), 130–140. http://doi.org/http://dx.doi.org/10.1108/20441281211227193

Golan, O., Baron-Cohen, S., & Golan Y. (2008). The “Reading the Mind in Films” task [child version]:complex emotion and mental state recognition in children with and without autism spectrum conditions. *Journal of Autism and Developmental Disorders*, *38*, 1534–1541. http://doi.org/10.1007/s10803-007-0533-7

Golan, O., Baron-Cohen, S., & Hill, J. (2006). The Cambridge Mindreading (CAM) face-voice battery: testing complex emotion recognition in adults with and without Asperger syndrome. *Journal of Autism and Developmental Disorders*, *36*, 169–183. http://doi.org/10.1007/s10803-005-0057-y

Golan, O., Baron-Cohen, S., Hill, J. J., & Rutherford, M. D. (2007). The “Reading the Mind in the Voice” test-revised: a study of complex emotion recognition in adults with and without autism spectrum conditions. *Journal of Autism and Developmental Disorders*, *37*(6), 1096–1106. http://doi.org/10.1007/s10803-006-0252-5

Gomot, M., & Wicker, B. (2012). A challenging, unpredictable world for people with Autism Spectrum Disorder. *International Journal of Psychophysiology*, *83*(2), 240–247. http://doi.org/10.1016/j.ijpsycho.2011.09.017

Grafman, J., Schwab, K., Warden, D., Pridgen, A., Brown, H. R., & Salazar, A. M. (1996). Frontal lobe injuries, violence, and aggression: a report of the vietnam head injury study. *Neurology*, *46*(5), 1231–1231. http://doi.org/10.1212/WNL.46.5.1231

Grandin, T., (1995). *Thinking in Pictures: and other reports from my life with autism*. New York: Vintage.

Grandjean, D., Sander, D., Pourtois, G., Schwartz, S., Seghier, M. L., Scherer, K. R., & Vuilleumier, P. (2005). The voices of wrath: brain responses to angry prosody in meaningless speech. *Nature Neuroscience, 8*(2), 145–146. http://doi.org/10.1038/nn1392

Gray, J. M., Young, A. W., Barker, W. A., Curtis, A., & Gibson, D. (1997). Impaired recognition of disgust in Huntington' s disease gene carriers. *Brain*, *120*, 2029–2038.

Greenberg, M. T., Kusche, C. A., Cook, E. T., & Quamma, J. P. (1995). Promoting emotional competence in school-aged children: The effects of the PATHS curriculum. *Development and Psychopathology, 7*, 117–136.

Greenwood, C. R., Carta, J. J., Hart, B., Thurston, L. P., & Hal, R. V. (1989). A behavioural approach to research on psychosocial retardation. *Education and Treatment of Children*, *12*(4), 330–346.

Greimel, E., Schulte-rüther, M., Kircher, T., Kamp-becker, I., Remschmidt, H., Fink, G. R., … Konrad, K. (2010). NeuroImage Neural mechanisms of empathy in adolescents with autism spectrum disorder and their fathers. *NeuroImage*, *49*(1), 1055–1065. http://doi.org/10.1016/j.neuroimage.2009.07.057

Grill-Spector, K., Knouf, N., & Kanwisher, N. (2004). The fusiform face area subserves face perception, not generic within-category identification. *Nature Neuroscience*, *7*(5), 555–562. http://doi.org/10.1038/nn1224

Gross, T. F. (2004). The perception of four basic emotions in human and nonhuman faces by children with autism and other developmental disabilities. *Journal of Abnormal Child Psychology*, *32*(5), 469–480. http://doi.org/10.1111/j.1469-7610.1992.tb00936.x

Grossman, J. B., Klin, A, Carter, A. S., & Volkmar, F. R. (2000). Verbal bias in recognition of facial emotions in children with Asperger syndrome. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *41*(3), 369–79. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10784084

Grossman, R. B., & Tager-Flusberg, H. (2012). "who said that?" matching of low- and high-intensity emotional prosody to facial expressions by adolescents with ASD. *Journal of Autism and Developmental Disorders*, *42*(12), 2546–2557. http://doi.org/10.1007/s10803-012-1511-2

Guba, E.G. & Lincoln, Y.S. (2004). *Competing paradigms in qualitative research: Theories and issues*. in S.N. Hesse-Biber and P. Leavy (Eds.) Approaches to qualitative research: A reader on theory and practice. Oxford: Oxford University Press.

Haas, B. W., Omura, K., Constable, R. T., & Canli, T. (2006). Interference produced by emotional conflict associated with anterior cingulate activation. *Cognitive, Affective, & Behavioral Neuroscience*, *6*(2), 152–156. http://doi.org/10.3758/CABN.6.2.152

Hadjikhani, N., Joseph, R. M. ., Snyder, J., & Tager-Flusberg, H. (2007). Abnormal activation of the social brain during face perception in. *Human Brain Mapping*, *28*(5), 441–449. http://doi.org/10.1002/hbm.20283

Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology*, *25*(4), 379–393. http://doi.org/10.1080/01443410500041607

Haith, M., Bergman, T., & Moore, M. (1977). Eye contact and face scanning in early infancy. *Science*, *198*(4319), 853–855. Retrieved from doi: 10.1126/science.918670

Hall, G. B. C., Szechtman, H., & Nahmias, C. (2003). Enhanced salience and emotion recognition in Autism: a PET study. *The American Journal of Psychiatry*, *160*(8), 1439–1441. http://doi.org/10.1176/appi.ajp.160.8.1439

Hamilton, A. F., Brindley, R. M., & Frith, U. (2007). Imitation and action understanding in autistic spectrum disorders: how valid is the hypothesis of a deficit in the mirror neuron system? *Neuropsychologia*, *45*(8), 1859–1868. http://doi.org/10.1016/j.neuropsychologia.2006.11.022

Happé, F., Ehlers, S., Fletcher, P., Frith, U., Johansson, M., Gillberg, C., … Frith, C. (1996). “Theory of mind” in the brain. Evidence from a PET scan study of asperger syndrome. *NeuroReport*, *8*(1), 197–201. http://doi.org/10.1097/00001756-199612200-00040

Happé, F., & Frith, U. (2006). The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *36*(1), 5–25. http://doi.org/10.1007/s10803-005-0039-0

Happé, F. (1994). An advanced test of theory of mind: Understanding of story characters’ thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*(2), 129–154. http://doi.org/10.1007/BF02172093

Harenski, C. L., Antonenko, O., Shane, M. S., & Kiehl, K. A. (2010). A functional imaging investigation of moral deliberation and moral intuition. *NeuroImage*, *49*(3), 2707–2716. http://doi.org/10.1016/j.neuroimage.2009.10.062

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: a review of behavioral and neuroimaging studies. *Neuropsychology Review*, *20*, 290–322. http://doi.org/10.1007/s11065-010-9138-6

Haxby, J. V, Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biol Psychiatry*, *51*(1), 59–67. http://doi.org/10.1016/S0006-3223(01)01330-0

Hayes, S., Macleod, C., & Hammond, G. (2009). Anxiety-linked task performance : Dissociating the influence of restricted working memory capacity and increased investment of effort. *Cognition and Emotion*, *23*(4), 753–781. http://doi.org/10.1080/02699930802131078

Hesling, I., Dilharreguy, B., Peppé, S., Amirault, M., Bouvard, M., & Allard, M. (2010). The integration of prosodic speech in high functioning autism: a preliminary fMRI study. *PloS One*, *5*(7), e11571. http://doi.org/10.1371/journal.pone.0011571

Hiller, R. M., Young, R. L., & Weber, N. (2016). Sex differences in pre-diagnosis concerns for children later-diagnosed with autism spectrum disorder Corresponding: *Autism*, 20 (1), 75-84. http://doi.org/10.1177/1362361314568899

Hobson, R. P. (1986). The autistic child's appraisal of expressions of emotion: a future study. *Journal of Child Psychology and Psychiatry*, *27*, 321–342.

Hobson, R. P., Ouston, J., & Lee, A. (1988). Emotion recognition in autism: Coordinating faces and voices. *Psychological Medicine*, *18*(4), 911–923. http://doi.org/10.1017/S0033291700009843

Hobson, R. P., Oustont, J., & Lee, A. (1989). Naming emotion in faces and voices : Abilities and disabilities in autism and mental retardation. *British Journal of Developmental Psychology*, *7*, 237–250. http://doi.org/10.1111/j.2044-835X.1989.tb00803.x

Hoekstra, R. A., Bartels, M., & Boomsma, D. (2007). Heritability of autistic traits in the general population. *Archives of Pediatrics and Adolescent Medicine*, *161*, 372–377. http://doi.org/10.1001/archpedi.161.4.372

Hoffman, E.A, & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84. http://doi.org/10.1038/71152

Homer, M., & Rutherford, M. D. (2008). Individuals with autism can categorize facial expressions. *Child Neuropsychology*, *14*(5), 419–437. http://doi.org/10.1080/09297040802291715

Hooker, C. I., Verosky, S. C., Germine, L. T., Knight, R. T., & D'Esposito, M. (2008). Mentalizing about emotion and its relationship to empathy. *Social Cognitive and Affective Neuroscience*, *3*(3), 204–217. http://doi.org/10.1093/scan/nsn019

Hornak, J., Bramham, J., Roll, E. T., Morris, R. G., O'Doherty, J., Bullock, P. R., & Polkey, C. E. (2003). Changes in emotion after circumscribed surgical lesions of the orbitofrontal and cingulate cortices. *Brain*, *126*(7), 1691–1712. http://doi.org/10.1093/brain/awg168

Howard, M. A. ., Cowell, P. E. ., Boucher, J., Broks, P., Mayes, A., Farrant, A., & Roberts, N. (2000). Convergent neuroanatomical and behavioural evidence of an amygdala hypothesis of autism. *Brain Imaging*, *11*(13), 2931–2935. http://doi.org/10.1097/00001756-200009110-00020

Hsiao, M.-N., Tseng, W.-L., Huang, H.-Y., & Gau, S. S.-F. (2013). Effects of autistic traits on social and school adjustment in children and adolescents: the moderating roles of age and gender. *Research in Developmental Disabilities*, *34*(1), 254–65. http://doi.org/10.1016/j.ridd.2012.08.001

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonséca, D., & Deruelle, C. (2007). Brief report: recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, *37*, 1386–1392. http://doi.org/10.1007/s10803-006-0275-y

Hubl, D., B, S., Matthews, S. F., Lanfermann, H., Federspiel, A., Strik, W., … Dierks, T. (2003). Functional imbalance of visual pathways indicates alternative face processing strategies in autism. *Neurology*, 61, 1232-1237.http:// doi: http://dx.doi.org/10.1212/01.WNL. 0000091862.22033.1A

Huettel, S. A., Song, A. W., & McCarthy, G. (2004). *Functional magnetic resonance imaging*. Sunderland: Sinauer Associates.

Hughlings-Jackson, J. (1915). On affectations of speech from diseases of the brain. *Brain*, 38, 107–74.

Huijbers, W., Pennartz, C. M. A., Cabeza, R., & Daselaar, S. M. (2011). The hippocampus is coupled with the default network during memory retrieval but not during memory encoding. *PLoS ONE*, *6*(4), 1–9. http://doi.org/10.1371/journal.pone.0017463

Humphreys, K., Hasson, U., Avidan, G., Minshew, N., & Behrmann, M. (2008). Cortical patterns of category-selective activation for faces, places and objects in adults with autism. *Autism Research*, *1*(1), 52–63. http://doi.org/10.1002/aur.1.Cortical

Humphreys, K., Minshew, N., Leonard, G. L., & Behrmann, M. (2007). A fine-grained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia*, *45*(4), 685–695. http://doi.org/10.1016/j.neuropsychologia.2006.08.003

Humphreys, W., Donnelly, N., & Riddoch, M. J. (1993). Expression is computed separately from facial identity, and it is computed separately for moving and static faces: Neuropsychological evidence: *Neuropsychologia*, *31*(2), 173–181. https://doi.org/10.1016/0028-3932(93)90045-2

Hungler, B. P, Polit, D. F. (1999). *Nursing Research Principles and Method.* 6th Edition. New York: J. B. Lippincott Company.

Hurley, R. S. E., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The broad autism phenotype questionnaire. *Journal of Autism and Developmental Disorders*, *37*(9), 1679–1690. http://doi.org/10.1007/s10803-006-0299-3

Iacoboni, M., & Dapretto, M. (2006). The mirror neuron system and the consequences of its dysfunction. *Nature Reviews Neuroscience*, *7*(12), 942–951. http://doi.org/10.1038/nrn2024

Iarocci, G., & McDonald, J. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders*, *36*(1), 77–90. http://doi.org/10.1007/s10803-005-0044-3

Ingersoll, B. (2008). The effect of context on imitation skills in children with autism. *Research in Autism Spectrum Disorders*, *2*(2), 332–340. http://doi.org/10.1016/j.rasd.2007.08.003

Ingersoll, B., Hopwood, C. J., Wainer, A., & Donnellan, M. B. (2011). A comparison of three self-report measures of the broader autism phenotype in a non-clinical sample. *J. Autism Dev. Disord.*, *41*, 1646–1657. http://doi.org/10.1007/s10803-011-1192-2

Ishai, A. (2008). Let's face it: It's a cortical network. *NeuroImage*, *40*(2), 415–419. http://doi.org/10.1016/j.neuroimage.2007.10.040

Izard, C., Fine, S., Schultz, D., Mostow, A., Ackerman, B., & Youngstrom, E. (2001). Emotion knowledge as a predictor of social behavior and academic competence in children at risk. *Psychological Science*, *12*(1), 18–23. http://doi.org/10.1111/1467-9280.00304

Jameel, L., Vyas, K., Bellesi, G., Roberts, V., & Channon, S. (2014). Going "above and beyond": Are those high in autistic traits less pro-social? *Journal of Autism and Developmental Disorders*, *44*(8), 1846–1858. http://doi.org/10.1007/s10803-014-2056-3

James, W. (1884). What is an emotion? *Mind*, 9, 188-205.

Jang, J.-S., & Kanade, T. (2008). Robust 3D head tracking by online feature registration. *IEEE International Conference on Automatic Face & Gesture Recognition*. http://doi.org/10.1109/AFGR.2008.4813307

Jantz, K. M. (2011). Support groups for adults with asperger syndrome. *Focus on Autism and Other Developmental Disabilities*, *26*(2), 119–128. http://doi.org/10.1177/1088357611406903

Järvinen-pasley, A., Wallace, G. L., Ramus, F., Happé, F., & Heaton, P. (2008). Enhanced perceptual processing of speech in Enhanced perceptual processing of speech in autism. *Developmental Science*, *11*(1), 109–121. http://doi.org/10.1111/j.1467-7687.2007.00644.x

Joassin, F., Maurage, P., & Campanella, S. (2011). The neural network sustaining the crossmodal processing of human gender from faces and voices: An fMRI study. *NeuroImage*, *54*(2), 1654–1661. http://doi.org/10.1016/j.neuroimage.2010.08.073

Joassin, F., Pesenti, M., Maurage, P., Verreckt, E., Bruyer, R., & Campanella, S. (2011). Cross-modal interactions between human faces and voices involved in person recognition. *Cortex*, *47*(3), 367–376. http://doi.org/10.1016/j.cortex.2010.03.003

Johnstone, T., van Reekum, C. M., Oakes, T. R., & Davidson, R. J. (2006). The voice of emotion: an fMRI study of neural responses to angry and happy vocal expressions. *Social Cognitive and Affective Neuroscience*, *1*, 242–249. http://doi.org/10.1093/scan/nsl027

Jones, C. R. G., Pickles, A., Falcaro, M., Marsden, A. J. S., Happé, F., Scott, S. K., … Charman, T. (2011). A multimodal approach to emotion recognition ability in autism spectrum disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *52*(3), 275–285. http://doi.org/10.1111/j.1469-7610.2010.02328.x

Jones, E. G., & Powell, T. P. S. (1970). An anatomical study of converging sensory pathways within the cerebral cortex of the monkey. *Brain*, *93*(4), 793–820. http://doi.org/10.1093/brain/93.4.793

Julian, L. J. (2011). Measures of anxiety: State-trait anxiety inventory (STAI), beck anxiety inventory (BAI), and hospital anxiety and depression scale-anxiety (HADS-A). *Arthritis Care and Research*, *63*, 467–472. http://doi.org/10.1002/acr.20561

Kagohara, D. M., Meer, L. Van Der, Ramdoss, S., Reilly, M. F. O., Lancioni, G. E., Davis, T. N., … Sigafoos, J. (2013). Using iPods (R) and iPads (R) in teaching programs for individuals with developmental disabilities : A systematic review, A systematic review. *Research in Developmental Disabilities*, *34*(1), 147–156. http://doi.org/10.1016/j.ridd.2012.07.027

Kamps, D., Kamps, D. M., Leonard, B. R., Vernon, S. U. E., Dugan, E. P., & Delquadri, J. C. (1992). Teaching social skills to students with autism to increase peer interactions in an integrated first-grade classroom. *Journal of Applied Behavior Analysis*, *25*, 281–288. http://doi.org/10.1901/jaba.1992.25-281

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*. http://doi.org/10.1105/tpc.11.5.949

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *17*(11), 4302–11. http://doi.org/10.1098/Rstb.2006.1934

Kashihara, K. (2014). A brain-computer interface for potential non-verbal facial communication based on EEG signals related to specific emotions. *Frontiers in Neuroscience*, (8), 244. http://doi.org/10.3389/fnins.2014.00244

Kassuba, T., Klinge, C., Hölig, C., Menz, M. M., Ptito, M., Röder, B., & Siebner, H. R. (2011). The left fusiform gyrus hosts trisensory representations of manipulable objects. *NeuroImage, 56*(3), 1566–1577. http://doi.org/10.1016/j.neuroimage.2011.02.032

Karpf, A. (2006). *The human voice.* London: Bloomsbury.

Kendall, P. C., Krain, A., & Treadwell, K. R. H. (1999). *Generalized anxiety disorders.* In R. T. Ammerman, M. Hersen, & C. G. Last (Eds.), Handbook of prescriptive treatments for children and adolescents (pp. 155–171). Needham Heights: Allyn & Bacon.

Klusmann, U., Richter, D., & Lüdtke, O. (2016). Teachers' emotional exhaustion is negatively related to students' achievement: Evidence from a large-scale assessment study. *Journal of Educational Psychology*, 108(8), 1193-1203. http://dx.doi.org/10.1037/edu0000125

Knapp, M. L., & Hall, J. A. (2005). *Nonverbal communication in human interaction (6th ed.)*. Belmont, CA: Wadsworth.

Knapp, M. L., & Hall, J. A. (2009). *Nonverbal communication in human interaction (7th ed.).* Boston, MA: Wadsworth.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. International Encyclopedia of Unified Science, 2(2); second edition, enlarged. Chicago: U. of Chicago Press.

Loveland, K. A., Bachevalier, J., Pearson, D. A., and Lane, D. M. (2008). Fronto-limbic functioning in children and adolescens with and without autism. *Neuropsychologia*, *46*(1), 49–62. http://doi.org/10.1016/j.neuropsychologia.2007.08.017.Fronto-limbic

Love, S. A., Pollick, F. E., & Latinus, M. (2011). Cerebral correlates and statistical criteria of cross-modal face and voice integration. *Seeing and Perceiving*, 24(4), 351-367.doi:10.1371/journal.pone.0019165

Lyneham, H. J., Abbott, M. J., Wignall, A., & Rapee, R. M. (2003). *The Cool Kids family program—therapist manual*. Sydney: Macquarie University.

Kätsyri, J., Saalasti, S., Tiippana, K., von Wendt, L., & Sams, M. (2008). Impaired recognition of facial emotions from low-spatial frequencies in asperger syndrome. *Neuropsychologia*, *46*(7), 1888–97. http://doi.org/10.1016/j.neuropsychologia.2008.01.005

Keltner, D., Capps, L., Kring, A. M., Young, R. C., & Heerey, E. A. (2001). Just teasing : A conceptual analysis and empirical review. *Psychological Bullettinulletin*, *127*(2), 229–248. http://doi.org/10.1037//0033-2909.127.2.229

Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science (New York, N.Y.)*, *303*(5660), 1023–6. http://doi.org/10.1126/science.1089910

Kerr, S., & Durkin, K. (2004). Understanding of thought bubbles as mental representations in children with autism : Implications for theory of mind. *Journal of Autism and Developmental Disorders*, *34*(6), 637–648.

Killgore, W. D. S., & Yurgelun-Todd, D. A. (2004). Activation of the amygdala and anterior cingulate during nonconscious processing of sad versus happy faces. *NeuroImage*, *21*(4), 1215–1223. http://doi.org/10.1016/j.neuroimage.2003.12.033

Kim, J., Szatmari, P., Bryson, S., Streiner, D., & Wilson, F. (2000). The prevalence of anxiety and mood problems among children with autism and asperger syndrome. *Autism*, *4*(2), 117–132. http://doi.org/10.1177/1362361300004002002

Kim, J., Wang, J., Wedell, D. H., & Shinkareva, S. V. (2016). Identifying core affect in Individuals from fMRI Responses to Dynamic Naturalistic Audiovisual Stimuli. *PLoS ONE*, *11*(9), e0161589. http://doi.org/10.1371/journal.pone.0161589

Kirby, L. A. J., & Robinson, J. L. (2015). Affective mapping: An activation likelihood estimation (ALE) meta-analysis. *Brain and Cognition*, *118*, 137–148. http://doi.org/10.1016/j.bandc.2015.04.006

Kirchner, J. C., Hatri, A., Heekeren, H. R., & Dziobek, I. (2011). Autistic symptomatology, face processing abilities, and eye fixation patterns. *Journal of Autism and Developmental Disorders*, 41, 158–167. http://doi.org/10.1007/s10803-010-1032-9

Klasen, M., Kenworthy, C. A., Mathiak, K. K. A., Kircher, T. T. J., & Mathiak, K. K. A. (2011). Supramodal representation of emotions. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *31*(38), 13635–13643. http://doi.org/10.1523/JNEUROSCI.2833-11.2011

Klein, F., Iffland, B., Schindler, S., Wabnitz, P., & Neuner, F. (2015). This person is saying bad things about you : The influence of physically and socially threatening context information on the processing of inherently neutral faces. *Cognitive Affective Behavioral Neuroscience*, *15*, 736–748. http://doi.org/10.3758/s13415-015-0361-8

Kleinhans, N. M., Richards, T., Sterling, L., Stegbauer, K. C., Mahurin, R., Johnson, L. C., … Aylward, E. (2008). Abnormal functional connectivity in autism spectrum disorders during face processing. *Brain*, *131*, 1000–1012. http://doi.org/10.1093/brain/awm334

Kleinhans, N. M., Richards, T., Weaver, K., Johnson, L. C., Greenson, J., Dawson, G., & Aylward, E. (2010). Association between amygdala response to emotional faces and social anxiety in autism spectrum disorders. *Neuropsychologia*, *48*(12), 3665–3670. http://doi.org/10.1016/j.neuropsychologia.2010.07.022

Klin, A. (1991). Young autistic children's listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. *Journal of Autism and Developmental Disorders*, *21*(1), 29–42. http://doi.org/10.1007/BF02206995

Klin, A. (2000). Attributing social meaning to ambiguous visual stimuli in higher-functioning autism and asperger syndrome: The social attribution task. *Journal of Child Psychology and Psychiatry*, *41*(7), 831–846. http://doi.org/10.1017/S0021963099006101

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, *59*(9), 809–816. http://doi.org/10.1001/archpsyc.59.9.809

Knapp, M. L., & Hall, J. A. (2009). *Nonverbal communication in human interaction (7th ed.)*.

Koegel, L. K., Ashbaugh, K., Koegel, R. L., Detar, W. J., & Regester, A. (2013). Increasing socialization in adults with asperger's syndrome. *Psychology in the Schools*, *50*(9), 899–909. http://doi.org/10.1002/pits.21715

Koegel, R. L. ., Bimbela, A., & Schreibman, L. (1996). Collateral effects of parent training on family interactions. *Journal of Autism and Developmental Disorders*, *26*(3), 347–359. http://doi.org/10.1007/BF02172479

Koelewijn, T., Bronkhorst, A., & Theeuwes, J. (2010). Attention and the multiple stages of multisensory integration: A review of audiovisual studies. *Acta Psychologica*, *134*(3), 372–84. http://doi.org/10.1016/j.actpsy.2010.03.010

Koizumi, A., Tanaka, A., Imai, H., Hiramatsu, S., Hiramoto, E., Sato, T., & de Gelder, B. (2011). The effects of anxiety on the interpretation of emotion in the face-voice pairs. *Experimental Brain Research*, *213*, 275–282. http://doi.org/10.1007/s00221-011-2668-1

Korb, S., Frühholz, S., & Grandjean, D. (2015). Reappraising the voices of wrath. *Social Cognitive and Affective Neuroscience*, *10*(12), 1644–1660. http://doi.org/10.1093/scan/nsv051

Kreifelts, B., Ethofer, T., Grodd, W., Erb, M., & Wildgruber, D. (2007). Audiovisual integration of emotional signals in voice and face: An event-related fMRI study. *NeuroImage*, *37*(4), 1445–1456. http://doi.org/10.1016/j.neuroimage.2007.06.020

Kreifelts, B., Ethofer, T., Huberle, E., Grodd, W., & Wildgruber, D. (2010). Association of trait emotional intelligence and individual fMRI-activation patterns during the perception of social signals from voice and face. *Human Brain Mapping*, *31*, 979–991. http://doi.org/10.1002/hbm.20913

Kreslins, A., Robertson, A. E., & Melville, C. (2015). The effectiveness of psychosocial interventions for anxiety in children and adolescents with autism spectrum disorder: a systematic review and meta-analysis. *Child and Adolescent Psychiatry and Mental Health*, *9*(1), 22. http://doi.org/10.1186/s13034-015-0054-7

Kumar, S., von Kriegstein, K., Friston, K., & Griffiths, T. D. (2012). Features versus feelings: dissociable representations of the acoustic features and valence of aversive Sounds. *Journal of Neuroscience*, *32*(41), 14184–14192. http://doi.org/10.1523/JNEUROSCI.1759-12.2012

Kuusikko, S., Haapsamo, H., Jansson-Verkasalo, E., Hurtig, T., Mattila, M.-L., Ebeling, H., … Moilanen, I. (2009). Emotion recognition in children and adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, (39), 938–945. http://doi.org/10.1007/s10803-009-0700-0

Lacroix, A., Guidetti, M., Rogé, B., & Reilly, J. (2009). Recognition of emotional and nonemotional facial expressions: A comparison between Williams syndrome and autism. *Research in Developmental Disabilities*, *30*(5), 976–985. http://doi.org/10.1016/j.ridd.2009.02.002

Lai, G., Schneider, H. D., Schwarzenberger, J. C., & Hirsch, J. (2011). Speech stimulation during functional MR imaging as a potential indicator of autism. *Radiology*, *260*(2), 521–530. http://doi.org/10.1148/radiol.11101576

Lainhart, J. E. (1999). Psychiatric problems in individuals with autism, their parents and siblings. *International Review of Psychiatry*, *11*(4), 278–298. http://doi.org/10.1080/09540269974177

Lawson, R. P., Rees, G., & Friston, K. J. (2014). An aberrant precision account of autism. *Frontiers in Human Neuroscience*, *8*(302), 1–10. http://doi.org/10.3389/fnhum.2014.00302

Leopold, D. A. ., Toole, A. J. O., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience*, (4), 89–94. http://doi:10.1038/82947

Leyfer, O. T., Folstein, S. E., Bacalman, S., Davis, N. O., Dinh, E., Morgan, J., … Lainhart, J. E. (2006). Comorbid psychiatric disorders in children with autism: interview development and rates of disorders. *Journal of Autism and Developmental Disorders*, *36*(7), 849–61. http://doi.org/10.1007/s10803-006-0123-0

Lindner, J. L., & Rosén, L. a. (2006). Decoding of emotion through facial expression, prosody and verbal content in children and adolescents with Asperger's syndrome. *Journal of Autism and Developmental Disorders*, *36*(6), 769–77. http://doi.org/10.1007/s10803-006-0105-2

Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of emotion: A meta-analytic review. *Behavioral and Brain Sciences*, *35*(3), 121–143. http://doi.org/10.1017/S0140525X11000446

Linnenbrink, E. A., & Pintrich, P. R. (2002). Achievement goal theory and affect : An asymmetrical bidirectional model. *Educational Psychologist*, *37*(2), 69–78. http://doi.org/10.1207/S15326985EP3702

Liu, T., Slotnick, S. D., Serences, J. T., & Yantis, S. (2003). Cortical mechanisms of feature-based attentional control. *Cerebral Cortex*, *13*(12), 1334–1343. http://doi.org/10.1093/cercor/bhg080

Lopata, C., Volker, M. A., Putnam, S. K., Thomeer, M. L., & Nida, R. E. (2008). Effect of social familiarity on salivary cortisol and self-reports of social anxiety and stress in children with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *38*(10), 1866–1877. http://doi.org/10.1007/s10803-008-0575-5

Lotter, V. (1966). Epidemiology of autistic conditions in young children: Prevalence. *Social Psychiatry, 1*, 124–127. http://doi.org/10.1007/BF00584048

Love, S.A., Pollick, F.E., and Latinus, M., (2011). Cerebral correlates and statistical criteria of cross-modal face and voice integration. *Seeing and Perceiving*, *24*(4), 351–367. http://doi.org/10.1163/187847511X584452

Loveland, K. A., Steinberg, J. L., Pearson, D. A., Mansour, R., Reddoch, S. (2008). Judgments of auditory-visual affective congruence in adolescents with and without autism: A pilot study of a new task using fMRI. *Perceptual and Motor Skills, 107,* 557–575. http://doi.org/10.2466/pms.107.2.557-575

Loveland, K. A., Tunali-kotoski, B., Chen, R., Brelsford, K. A., Ortegon, J., & Pearson, D. A. (1995). Intermodal perception of affect in persons with autism or Down syndrome. *Development and Psychopathology*, *7,* 409–418. https://doi.org/10.1017/S095457940000660X

Loveland, K. A., Tunali-Kotoski, B., Chen, Y. R., Ortegon, J., Pearson, D. A., Brelsford, K. A., & Gibbs, M. C. (1997). Emotion recognition in autism: verbal and nonverbal information. *Development and Psychopathology*, *9*, 579–593. http://doi.org/10.1017/S0954579497001351

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour Research and Therapy*, *33*(3), 335–343. http://doi.org/10.1016/0005-7967(94)00075-U

Lugnegård, T., Hallerbäck, M. U., & Gillberg, C. (2011). Psychiatric comorbidity in young adults with a clinical diagnosis of asperger syndrome. *Research in Developmental Disabilities*, *32*(5), 1910–1917. http://doi.org/10.1016/j.ridd.2011.03.025

Macdonald, H., Rutter, M., Howlin, P., Rios, P., Le Conteur, A., Evered, C., & Folstein, S. (1989). Recognition and expression of emotional cues by autistic and normal adults. *Journal of Child Neurology*, *30*(6), 865–877. http://dx.doi.org/10.1111/j.1469-7610.1989.tb00288.x

MacLeod, C. (1999). *Anxiety and anxiety disorders.* In T. Dalgleish & M. Power (Eds.), Handbook of cognition and emotion (pp. 447–477). Chichester, UK: Wiley.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15–20. http://doi.org/10.1037/0021-843X.95.1.15

Maenner, M. J., Rice, C. E., Arneson, C. L., Cunniff, C., Schieve, L. A., Carpenter, L. A., … Durkin, M. S. (2014). Potential impact of DSM-5 criteria on autism spectrum disorder prevalence estimates. *JAMA Psychiatry*, *71*(3), 292–300. http://doi.org/10.1001/jamapsychiatry.2013.3893

Mahmoud, J., Staten, R., Hall, L., & Lennie, T. (2012). The relationship among young adult college students' depression, anxiety, stress, demographics, life satisfaction, and coping styles. *Issues in Mental Health Nursing*, *33*, 149–156. http://doi.org/10.3109/01612840.2011.632708

Mantini, D., & Vanduffel, W. (2013). Emerging roles of the brain's default network. *The Neuroscientist : A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, *19*(1), 76–87. http://doi.org/10.1177/1073858412446202

Marsh, L. E., & Hamilton, A. F. d. C. (2011). Dissociation of mirroring and mentalising systems in autism. *NeuroImage*, *56*(3), 1511–1519. http://doi.org/10.1016/j.neuroimage.2011.02.003

Massaro, D. W., & Egan, P. B. (1996). Perceiving affect from the voice and the face. *Psychonomic Bulletin & Review*, *3*(2), 215–221. http://doi.org/10.3758/BF03212421

Materna, S., Dicke, P. W., & Thier, P. (2008). The posterior superior temporal sulcus is involved in social communication not specific for the eyes. *Neuropsychologia*, *46*, 2759–2765. http://doi.org/10.1016/j.neuropsychologia.2008.05.016

Mathews, A. (1990). Why worry? The cognitive function of anxiety. *Behaviour Research and Therapy*, *28*(6), 455–468. http://doi.org/10.1016/0005-7967(90)90132-3

Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition & Emotion*, *16*(3), 331–354. http://doi.org/10.1080/02699930143000518

Mattavelli, G., Sormaz, M., Flack, T., Asghar, A. U. R., Fan, S., Frey, J., … Andrews, T. J. (2014). Neural responses to facial expressions support the role of the amygdala in processing threat. *Social Cognitive and Affective Neuroscience*, *9*(11), 1684–1689. http://doi.org/10.1093/scan/nst162

Mattila, M.-L., Hurtig, T., Haapsamo, H., Jussila, K., Kuusikko-Gauffin, S., Kielinen, M., … Moilanen, I. (2010). Comorbid psychiatric disorders associated with asperger syndrome/high-functioning autism: a community- and clinic-based study. *Journal of Autism and Developmental Disorders*, *40*(9), 1080–93. http://doi.org/10.1007/s10803-010-0958-2

Maurage, P., & Campanella, S. (2013). Experimental and clinical usefulness of crossmodal paradigms in psychiatry: an illustration from emotional processing in alcohol-dependence. *Frontiers in Human Neuroscience*, *7*, 394. http://doi.org/10.3389/fnhum.2013.00394

Mayer, J. D., Salovey, P., & Caruso, D. R. (2000). *Emotional intelligence as zeitgeist, as personality, and as a standard intelligence.* In R. Bar-On & J. D. A. Parker (Eds.), Handbook of emotional intelligence (pp. 92–117). New York, NY: Jossey-Bass

Mazefsky, C. a., Kao, J., & Oswald, D. P. (2011). Preliminary evidence suggesting caution in the use of psychiatric self-report measures with adolescents with high-functioning autism spectrum disorders. *Research in Autism Spectrum Disorders*, *5*(1), 164–174. http://doi.org/10.1016/j.rasd.2010.03.006

Mazefsky, C. A., & Oswald, D. P. (2007). Emotion perception in Asperger's syndrome and high-functioning autism: The importance of diagnostic criteria and cue intensity. *Journal of Autism and Developmental Disorders*, *37*(6), 1086–1095. http://doi.org/10.1007/s10803-006-0251-6

McCarthy, G., Puce, A., Gore, J. C., & Allison, T. (1997). Face-Specific Processing in the human fusiform gyrus. *Journal of Cognitive Neuroscience*, *9*(5), 605–610. http://doi.org/10.1162/jocn.1997.9.5.605

Mcdonnell, J., Mathot-buckner, C., Thorson, N., & Fister, S. (2001). Supporting the inclusion of students with moderate and severe disabilities in junior high school general education classes: The effects of classwide peer tutoring, multi-element curriculum, and accommodations. *Education and Treatment of Children*, *24*(2), 141–160.

McKay, L. S., Simmons, D. R., McAleer, P., Marjoram, D., Piggot, J., & Pollick, F. E. (2012). Do distinct atypical cortical networks process biological motion information in adults with autism spectrum disorders? *NeuroImage*, *59*(2), 1524–33. http://doi.org/10.1016/j.neuroimage.2011.08.033

Mckiernan, K. A., Kaufman, J. N., Kucera-thompson, J., & Binder, J. R. (2003). A parametric manipulation of factors affecting task-induced deactivation in functional neuroimaging. *Journal of Cognitive Neuroscience*, *15*(3), 394–408. http://doi.org/10.1162/089892903321593117

Mesulam, M. (1998). From sensation to cognition. *Brain : A Journal of Neurology*, *121*(6), 1013–1052. http://doi.org/10.1093/brain/121.6.1013

Mesulam, M. M., & Mufson, E. J. (1982). Insula of the old world monkey. III: Efferent cortical output and comments on function. *The Journal of Comparative Neurology*, *212*(1), 38–52. http://doi.org/10.1002/cne.902120104

Mertens, D. (2009). *Transformative research and evaluation*. New York: The Guilford Press.

Meyer, D. K., & Turner, J. C. (2002). Discovering emotion in classroom motivation research. *Educational Psychologist*, *37*(2), 107–114. http://doi.org/10.1207/S15326985EP3702

Meyer, D. K., & Turner, J. C. (2006). Re-conceptualizing emotion and motivation to learn in classroom contexts. *Educational Psychology Review*, *18*(4), 377–390. http://doi.org/10.1007/s10648-006-9032-1

Mitchell, I. J., Phil, D., Heims, H., Sc, B., Neville, E. A., Sc, B., & Rickards, H. (2005). Huntington's disease patients show impaired perception of disgust in the gustatory and olfactory modalities. *Journal of Neuropsychiatry Clin Neurosci*, *17*(1), 119–121.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, *36*, 809–848. https://doi.org/10.1016/S0005-7967(98)00063-1

Monk, C. S., Weng, S., Wiggins, J. L., Kurapati, N., Louro, H. M. C., Carrasco, M., … Lord, C. (2010). Neural circuitry of emotional face processing in autism spectrum disorders. *Journal of Psychiatry and Neuroscience*, *35*(2), 105–114. http://doi.org/10.1503/jpn.090085

Moore, D. G., Hobson, R. P., & Lee, A. (1997). Components of person perception: An investigation with autistic, non-autistic retarded and typically developing children and adolescents. *British Journal of Developmental Psychology*, *15*(4), 401–423. http://doi.org/10.1111/j.2044-835X.1997.tb00738.x

Morris, J. S., Friston, K. J., Büchel, C., Frith, C. D., Young, A. W., Calder, A. J., & Dolan, R. J. (1998). A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain: A Journal of Neurology*, *121 (Pt 1*, 47–57. http://doi.org/10.1093/brain/121.1.47

Morris, J. S., Scott, S. K., & Dolan, R. J. (1999). Saying it with feeling: Neural responses to emotional vocalizations. *Neuropsychologia*, *37*(10), 1155–1163. http://doi.org/10.1016/S0028-3932(99)00015-9

Moseley, D. S., Tonge, B. J., Brereton, A. V, & Einfeld, S. L. (2011). Psychiatric comorbidity in adolescents and young adults with autism. *Journal of Mental Health Research in Intellectual Disabilities*, *4*(4), 229–243. http://doi.org/10.1080/19315864.2011.595535

Mottron, L., Burack, J. a. J., Dawson, M., Soulières, I., & Hubert, B. (2001). Enhanced perceptual functioning in the development of autism. *The Development of Autism: Perspectives from Theory and Research*, *36*, 27–43. http://doi.org/10.1007/s10803-005-0040-7

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, *36*(1), 27–43. http://doi.org/10.1007/s10803-005-0040-7

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, *36*(1), 27–43. http://doi.org/10.1007/s10803-005-0040-7

Mufson, E. J., & Mesulam, M. M. (1984). Thalamic connections of the insula in the rhesus monkey and comments on the paralimbic connectivity of the medial pulvinar nucleus. *The Journal of Comparative Neurology*, *227*(1), 109–20. http://doi.org/10.1002/cne.902270112

Müller, E., Schuler, A., & Yates, G. B. (2008). Social challenges and supports from the perspective of individuals with Asperger syndrome and other autism spectrum disabilities. *Autism*, *12*(2), 173–190. http://doi.org/10.1177/1362361307086664

Mumme, D. L., Fernald, A., & Herrera, C. (1996). Infants' responses to facial and vocal emotional signals in a social referencing paradigm. *Child Development*, *67*(6), 3219–3237. http://doi.org/10.1111/j.1467-8624.1996.tb01910.x

Muris, P., Steerneman, P., Merckelbach, H., Holdrinet, I., & Meesters, C. (1998). Comorbid anxiety symptoms in children with pervasive developmental disorders. *Journal of Anxiety Disorders*, *12*(4), 387–393. http://doi.org/10.1016/s0887-6185(98)00022-x

Nadeau, J., Sulkowski, M., Ung, D., Wood, J., Lewin, A., Murphy, T., … Storch, E. (2011). Treatment of comorbid anxiety and autism spectrum disorders. *Neuropsychiatry*, *1*(6), 567–578. http://doi.org/10.2217/npy.11.62

Näykki, P., Järvelä, S., Kirschner, P. A., & Järvenoja, H. (2014). Socio-emotional conflict in collaborative learning-A process-oriented case study in a higher education context. *International Journal of Educational Research*, *68*, 1–14. https://doi.org/10.1016/j.ijer.2014.07.001

Nelson, B. N., Martin, R. P. ., Havill, V. ., & Kamphaus, R. (1999). Modeling the prediction of elementary school adjustment from preschool temperament. *Personality and Individual Differences*, *26*, 687–700. https://doi.org/10.1016/S0191-8869(98)00174-3

Nesse, R. M., & Ellsworth, P. C. (2009). Evolution, emotions, and emotional disorders, *64*(2), 129–139. http://doi.org/10.1037/a0013503

Neumann, D., Spezio, M. L., Piven, J., & Adolphs, R. (2006). Looking you in the mouth : abnormal gaze in autism resulting from impaired top-down modulation of visual attention. *Scan*, *1*, 194–202. http://doi.org/10.1093/scan/nsl030

Ng, E., & Lee, K. (2015). Effects of trait test anxiety and state anxiety on children’ s working memory task performance. *Learning and Individual Differences*, *40*, 141–148. http://doi.org/10.1016/j.lindif.2015.04.007

O’Connor, K. (2007). Brief Report: Impaired identification of discrepancies between expressive faces and voices in adults with asperger’s syndrome. *Journal of Autism and Developmental Disorders*, *37*(10), 2008–2013. http://doi.org/10.1007/s10803-006-0345-1

Ochsner, K. N., Hughes, B., Robertson, E. R., Cooper, J. C., & Gabrieli, J. D. E. (2009). Neural systems supporting the control of affective and cognitive conflicts. *Journal of Cognitive Neuroscience*, *21*(9), 1842–1855. http://doi.org/10.1162/jocn.2009.21129

Ogai, M., Matsumoto, H., Suzuki, K., Ozawa, F., Fukuda, R., Uchiyama, I., … Takei, N. (2003). fMRI study of recognition of facial expressions in high-functioning autistic patients. *Brain Imaging*, *14*(4), 59–63. http://doi.org/10.1097/01.wnr.0000061019.47393.71

Ogawa, S., Lee, T. M., Kay, A. R., & Tank, D. W. (1990). Brain magnetic resonance imaging with contrast dependent on blood oxygenation. *Proceedings of the National Academy of Sciences of the United States of America*, *87*(24), 9868–9872. http://doi.org/10.1073/pnas.87.24.9868

O¨hman, A. (1993). *Fear and anxiety as emotional phenomena: Clinical phenomenology, evolutionary perspectives and information processing mechanisms*. In M. Lewis & J. M. Haviland (Eds.), Handbook of emotions. New York: Guilford.

Ojanen, V., Möttönen, R., Pekkola, J., Jääskeläinen, I. P., Joensuu, R., Autti, T., & Sams, M. (2005). Processing of audiovisual speech in Broca’s area. *NeuroImage*, *25*(2), 333–338. http://doi.org/10.1016/j.neuroimage.2004.12.001

Oldfield, R. C. (1971). The assessment and analysis of handedness: The edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. http://doi.org/10.1016/0028-3932(71)90067-4

Orsmond, G. I., Krauss, M. W., & Seltzer, M. M. (2004). Peer relationships and social and recreational activities among adolescents and adults with autism. *J. Autism Dev. Disord.*, *34*(3), 245–256. http://doi.org/10.1023/B:JADD.0000029547.96610.df

Ortony, A., & Turner, T. J. (1990). What’s basic about basic emotions? *Psychological Review*, *97*(3), 315–331. http://doi.org/10.1037/0033-295X.97.3.315

Owens, M., Stevenson, J., Hadwin, J. A., & Norgate, R. (2012). Anxiety and depression in academic performance: An exploration of the mediating factors of worry and working memory. *School Psychology International*, *33*(4), 433–449. http://doi.org/10.1177/0143034311427433

Ozonoff, S., Pennington, B. F. ., & Rogers, S. J. (1990). Are there emotion perception deficits in young autistic children? *Journal of Child Psychial*, *31*(3), 343–361.

Panerai, S., Zingale, M., Trubia, G., Finocchiaro, M., Zuccarello, R., Ferri, R., & Elia, M. (2009). Special education versus inclusive education: the role of the TEACCH program. *Journal of Autism and Developmental Disorders*, *39*(6), 874–82. http://doi.org/10.1007/s10803-009-0696-5

Pannese, A., Grandjean, D., & Fru¨hholz, S. (2016). Amygdala and auditory cortex exhibit distinct sensitivity to relevant acoustic features of auditory emotions. *Cortex*, *85*, 116–125. http://doi.org/10.1016/j.cortex.2016.10.013

Pannese, A., Grandjean, D., & Frühholz, S. (2015). Subcortical processing in auditory communication. *Hearing Resear Ch*, *328*, 67–77.

Parise, E., Cleveland, A., Costabile, A., & Striano, T. (2007). Influence of vocal cues on learning about objects in joint attention contexts. *Infant Behavior and Development*, *30*(2), 380–384. http://doi.org/10.1016/j.infbeh.2006.10.006

Park, J.-Y., Gu, B.-M., Kang, D.-H., Shin, Y.-W., Choi, C.-H., Lee, J.-M., & Kwon, J. S. (2010). Integration of cross-modal emotional information in the human brain: An fMRI study. *Cortex*, *46*(2), 161–169. http://doi.org/10.1016/j.cortex.2008.06.008

Parry, F. M., Young, A. W., Shona, J., Saul, M., Moss, A., Parry, F. M., … Moss, A. (1991). Dissociable face processing impairments after brain injury. *Journal of Clinical and Experimental Neuropsychology*, *13*(4), 545–558. http://doi.org/10.1080/01688639108401070

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. R. (2005). Perception and Production of Prosody by Speakers with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *35*(2), 205–220. http://doi.org/10.1007/s10803-004-1999-1

Pauling, L., & Coryell, C. D. (1936). The magnetic properties and structure of hemoglobin, oxyhemoglobin and carbonmonoxyhemoglobin. *Proceedings of the National Academy of Sciences*, *22*(4), 210–216. http://doi.org/10.1073/pnas.22.4.210

Paynter, J., & Peterson, C. (2010). Language and ToM development in autism versus asperger syndrome: Contrasting influences of syntactic versus lexical/semantic maturity. *Research in Autism Spectrum Disorders*, *4*, 377–385. http://doi.org/10.1016/j.rasd.2009.10.005

Pearson, R. C. A., Brodal, P., Gatter, K. C., & Powell, T. P. S. (1982). The organization of the connections between the cortex and the claustrum in the monkey. *Brain Research*, *234*(2), 435–441. http://doi.org/10.1016/0006-8993(82)90883-6

Pekrun, R. (1990). *Emotion and motivation in educational psychology: General and European perspectives.* In P. Drenth, J. Sergeant, & R. Takens (Eds.). European perspectives in psychology, Vol. 1 (pp. 265–295). Chichester, UK: Wiley

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in stuents' self-regulated learning and achievement: A program of qualitative and quantitative research304. *Educational Psychologist*, *37*(2), 95–105. http://doi.org/10.1207/S15326985EP3702

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision*, *10*(4), 437–442. http://doi.org/10.1163/156856897X00366

Pellicano, E., & Burr, D. (2012). When the world becomes "too real": A Bayesian explanation of autistic perception. *Trends in Cognitive Sciences*, *16*(10), 504–510. http://doi.org/10.1016/j.tics.2012.08.009

Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2004). Grasping the intentions of others: the perceived intentionality of an action influences activity in the superior temporal sulcus during social perception. *Journal of Cognitive Neuroscience*, *16*(10), 1706–16. http://doi.org/10.1162/0898929042947900

Pelphrey, K. A., Morris, J. P., McCarthy, G., & LaBar, K. S. (2007). Perception of dynamic changes in facial affect and identity in autism. *Social Cognitive and Affective Neuroscience*, *2*(2), 140–149. http://doi.org/10.1093/scan/nsm010

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, *32*(4), 249–261. http://doi.org/10.1023/A:1016374617369

Peltola, M. J., Leppänen, J. M., Palokangas, T., & Hietanen, J. K. (2008). Fearful faces modulate looking duration and attention disengagement in 7-month-old infants. *Developmental Science*, *11*(1), 60–68. http://doi.org/10.1111/j.1467-7687.2007.00659.x

Petrovica, S., Anohina-naumeca, A., & Ekenel, H. K. (2017). Emotion Recognition in Affective Tutoring Systems : Collection of Ground-Truth Data. Procedia Computer Science, *104*, 437–444. http://doi.org/10.1016/j.procs.2017.01.157

Pfeifer, J. H., Iacoboni, M., & Mazziottaa, J. C. (2008). Mirroring others' emotions relates to empathy and interpersonal competence in children. *NeuroImage*, *39*(4), 3279–3288. http://doi.org/10.1007/s11103-011-9767-z.Plastid

Philip, R. C. M., Dauvermann, M. R., Whalley, H. C., Baynham, K., Lawrie, S. M., & Stanfield, A. C. (2012). A systematic review and meta-analysis of the fMRI investigation of autism spectrum disorders. *Neuroscience and Biobehavioral Reviews*, *36*(2), 901–942. http://doi.org/10.1016/j.neubiorev.2011.10.008

Philip, R. C. M., Whalley, H. C., Stanfield, a C., Sprengelmeyer, R., Santos, I. M., Young, a W., … Hall, J. (2010). Deficits in facial, body movement and vocal emotional processing in autism spectrum disorders. *Psychological Medicine*, *40*(11), 1919–29. http://doi.org/10.1017/S0033291709992364

Phillips, M. L., Bullmore, E. T., Howard, R., Peter, W. R., Wright, I. C., Williams, S. C. R., … David, A. S. (1998). Investigation of facial recognition memory and happy and sad facial expression perception: an fMRI study. *Psychiatry Research - Neuroimaging*, (83), 127–138.

Phillips, M. L., Young, A. W., Scott, S. K., Calder, A. J., Andrew, C., Giampietro, V., … Gray, J. A. (1998). Neural responses to facial and vocal expressions of fear and disgust. *Proceedings of the Royal Society Series B-Biological Sciences*, *265*, 1809–1817. http://doi.org/10.1098/rspb.1998.0506

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., … David, A. S. (1997). A specific neural substrate for perceiving facial expressions of disgust. *Nature, 389*(October), 495–498. http://doi.org/10.1038/39051

Plutchik, R. (1980). *Emotion: A psychoevolutionary synthesis*. New York: Harper and Row.

Pierce, K., Müller, R. a, Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform "face area" in autism: evidence from functional MRI. *Brain : A Journal of Neurology*, *124* (10), 2059–2073. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11571222

Piggot, J., Kwon, H., Mobbs, D., Blasey, C., Lotspeich, L., Menon, V., … Reiss, A. L. (2004). Emotional attribution in high-functioning individuals with autistic spectrum disorder : A functional imaging study. *J Am Acad Child Adolesc Psychiatry*, *43*(4), 473–480. http://doi.org/10.1097/00004583-200404000-00014

Pine, D. S., Mogg, K., Bradley, B. P., Montgomery, L. A., Monk, C. S., McClure, E., … Kaufman, J. (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. *American Journal of Psychiatry*, *162*(2), 291–296. http://doi.org/10.1176/appi.ajp.162.2.291

Pizzamiglio, L., Zoccolotti, P., Mammucari, A., & Cesaroni, R. (1983). The independence of face identity and facial expression recognition mechanisms: Relationship to sex and cognitive style. *Brain and Cognition*, *2*, 176–188.

Plaisted, K., Saksida, L., Alcántara, J., & Weisblatt, E. (2003). Towards an understanding of the mechanisms of weak central coherence effects: experiments in visual configural learning and auditory perception. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *358*(1430), 375–386. http://doi.org/10.1098/rstb.2002.1211

Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *40*(5), 733–42. http://doi.org/10.1111/1469-7610.00489

Ponterotto, J. G. (2005). Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of Counseling Psychology*, *52*(2), 126–136. http://doi.org/10.1037/0022-0167.52.2.126

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. http://doi.org/10.1080/00335558008248231

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25–42. http://doi.org/10.1146/annurev.neuro.13.1.25

Posner, M. I., & Rothbart, M. K. (2005). Influencing brain networks: implications for education. *Trends in Cognitive Sciences*, *9*(3), 99–103. http://doi.org/10.1016/j.tics.2005.01.007

Pourtois, G., de Gelder, B., Bol, A., & Crommelinck, M. (2005). Perception of facial expressions and voices and of their combination in the human brain. *Cortex*, *41*(1), 49–59. http://doi.org/10.1016/S0010-9452(08)70177-1

Premack, D., & Woodruff, G. (1978). Premack and woodruff : Chimpanzee theory of mind. *Behavioral and Brain Sciences*, *4*(1978), 515–526. https://doi.org/10.1017/S0140525X00076512

Preston, L.D., (1998), Multisensory approaches to reading, http://www.med.ufl.edu/mdtp/resources/MultisensoryReading.htm.

Prior, M., Dahlstrom, B., & Squires, T. (1990). Autistic children's knowledge of thinking and feeling states in other people. *Journal of Child Psychial*, *31*(4), 587–601. http://doi.org/10.1111/j.1469-7610.1990.tb00799.x

Puce, A., Allison, T., Asgari, M., Gore, J. C., & McCarthy, G. (1996). Differential sensitivity of human visual cortex to faces, letterstrings, and textures: a functional magnetic resonance imaging study. *The Journal of Neuroscience*, *16*(16), 5205–5215. http://doi.org/10.1016/S1053-8119(96)80364-8

Purdue O, Spielberger C. *Anxiety and the perception of punishment*. Ment Hyg. 1966;50:39.

Qualter, P., Whiteley, H. E., Hutchinson, J. M., & Pope, D. J. (2007). Supporting the development of emotional intelligence competencies to ease the transition from primary to High School. *Educational Psychology in Practice*, *23*(1), 79–95. http://doi.org/10.1080/02667360601154584

R Development Core Team. 2008. *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing,

Rachman, S. (2004). *Anxiety (2nd ed.).* New York: Taylor & Francis.

Raghunathan, R., & Pham, M. (1999). All negative moods are not equal: motivational influences of anxiety and sadness on decision making. *Organizational Behavior and Human Decision Processes*, *79*(1), 56–77. http://doi.org/10.1006/obhd.1999.2838

Raine, A., Lencz, T., Bihrle, S., LaCasse, L., & Colletti, P. (2000). Reduced prefrontal gray matter volume and reduced autonomic activity in antisocial personality disorder. *Archives of General Psychiatry*, *57*(2), 119. http://doi.org/10.1001/archpsyc.57.2.119

Reaven, J. (2011). The treatment of anxiety symptoms in youth with high-functioning autism spectrum disorders: Developmental considerations for parents. *Brain Research*, *1380*, 255–63. http://doi.org/10.1016/j.brainres.2010.09.075

Redcay, E. (2008). The superior temporal sulcus performs a common function for social and speech perception: Implications for the emergence of autism. *Neuroscience and Biobehavioral Reviews*, *32*(1), 123–142. http://doi.org/10.1016/j.neubiorev.2007.06.004

Reeves, B., Nass, C. (1996). *The media equation*. Cambridge University Press.

Rhodes, G., Michie, P. T., Hughes, M. E., & Byatt, G. (2009). The fusiform face area and occipital face area show sensitivity to spatial relations in faces. *European Journal of Neuroscience*, *30*(4), 721–733. http://doi.org/10.1111/j.1460-9568.2009.06861.x

Rivers, S. E., Brackett, M. A., Salovey, P., & Mayer, J. D. (2007). *Measuring emotional intelligence as a set of mental abilities*. In G. Matthews, M. Zeidner, & R. D. Roberts (Eds.), The science of emotional intelligence: Knowns and unknowns (pp. 230–257). New York, NY: Oxford University Press

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*(1), 169–192. http://doi.org/10.1146/annurev.neuro.27.070203.144230

Robins, D. L. ., Hunyadi, E., & Schultz, R. T. (2009). Superior temporal activation in response to dynamic audio-visual emotional cues. *Brain Cogn*, *69*(2), 269–278. http://doi.org/10.1016/j.bandc.2008.08.007.Superior

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013). The impact of anxiety upon cognition: Perspectives from human threat of shock studies. *Frontiers in Human Neuroscience*, *7*, 203. http://doi.org/10.3389/fnhum.2013.00203

Rogers, S. J. (2000). *Diagnosis of autism before the age of 3*. In International Review of Research in Mental Retardation (Vol. 23, pp. 1-31).

Rogers, S. J., Hepburn, S., & Wehner, E. (2003). Parent reports of sensory functioning in toddlers with autism and those with other developmental disorders. *Journal of Autism and Developmental Disorders*, *33*(6), 631–642. http://doi.org/10.1023/B:JADD.0000006000.38991.a7

Rombouts, S. a, Barkhof, F., Hoogenraad, F. G., Sprenger, M., Valk, J., & Scheltens, P. (1997). Test-retest analysis with functional MR of the activated area in the human visual cortex. *AJNR. American Journal of Neuroradiology*, *18*(7), 1317–1322. http://doi.org/10.1097/00041327-199906000-00012

Rothman, A. D., & Nowicki, S. (2004). A measure of the ability to identify emotion in children's tone of voice. *Journal of Nonverbal Behavior*, *28*(2), 67–92. http://doi.org/10.1023/B:JONB.0000023653.13943.31

Roy, P. P., Seilesh, K., & Doshi, M. A. (2015). Depression, anxiety and stress among first year undergraduate medical students. *Asian Journal of Biomedical and Pharmaceutical Sciences*, *5*(45), 37–38. http://doi.org/10.15272/ajbps.v5i45.716

Rump, K. M. ., Giovannelli, J. L., Minshew, N. J. ., & Strauss, M. S. (2009). The development of emotion recognition in individuals with autism. *Child Development*, *80*(5), 1434–1447. http://doi.org/10.1111/j.1467-8624.2009.01343.x.The

Russell, J. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*. http://doi.org/10.1037/h0077714

Russell, J. (1997).*How executive disorders can bring about an inadequate theory of mind.* In J. Russell (Ed.), Autism as an Executive Disorder. Oxford: Oxford University Press.

Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus prototype matching: Strategies of perception of emotional facial expressions in the autism spectrum. *Journal of Autism and Developmental Disorders, 37*, 187–196. http://doi.org/10.1007/s10803-006-0151-9

Rutherford, M. D., & Towns, A. M. (2008). Scan path differences and similarities during emotion perception in those with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38*, 1371–1381. http://doi.org/10.1007/s10803-007-0525-7

Rutherford, M. D., Baron-Cohen, S., & Wheelwright, S. (2002). Reading the mind in the voice: a study with normal adults and adults with asperger syndrome and high functioning autism. *Journal of Autism and Developmental Disorders*, *32*(3), 189–94. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12108620

Rutherford, M. D., Clements, K. A., & Sekuler, A. B. (2007). Differences in discrimination of eye and mouth displacement in autism spectrum disorders. *Vision Research*, *47*, 2099–2110. http://doi.org/10.1016/j.visres.2007.01.029

Ryan, C., & Nı´Charraga´in, C. (2010). Teaching emotion recognition skills to children with autism teaching emotion recognition skills to children with autism. *Journal of Autism and Developmental Disorders*, *40*, 1505–1511. http://doi.org/10.1007/s10803-010-1009-8

Saarela, M. V., Hlushchuk, Y., Williams, A. C. D. C., Schürmann, M., Kalso, E., & Hari, R. (2007). The compassionate brain: Humans detect intensity of pain from another's face. *Cerebral Cortex*, *17*(1), 230–237. http://doi.org/10.1093/cercor/bhj141

Salovey, P., & Mayer, J. (1990). Emotional intelligence. *Imagination, Cognition and Personality*. http://doi.org/10.1016/S0962-1849(05)80058-7

Sato, W., Toichi, M., Uono, S., & Kochiyama, T. (2012). Impaired social brain network for processing dynamic facial expressions in autism spectrum disorders. *BMC Neuroscience*, *13*, 99. http://doi.org/10.1186/1471-2202-13-99

Sauter, D. A., & Eimer, M. (2009). Rapid detection of emotion from human vocalizations. *Journal of Cognitive Neuroscience*, *22*(3), 474–481. http://doi.org/10.1162/jocn.2009.21215

Sauter, D. A., Panattoni, C., & Happ, F. (2013). Children' s recognition of emotions from vocal cues, 97–113. http://doi.org/10.1111/j.2044-835X.2012.02081.x

Scarantino, A., & Griffiths, P. (2011). Don't give up on basic emotions. *Emotion Review*, *3*(4), 444–454. http://doi.org/10.1177/1754073911410745

Schechner, T., Britton, J. C., Pérez-Edgar, K., Bar-Haim, Y., Ernst, M., Fox, N. A., … Pine, D. S. (2012). Attention biases, anxiety, and development: Toward or away from threats or rewards? *Depression and Anxiety*, *29*(4), 282–294. http://doi.org/10.1038/cdd.2010.172.MicroRNAs

Scherer, K. R., Banse, R., & Wallbott, H. G. (2001). Emotion inferences from vocal expression correlate across languages and cultures. *Journal of Cross-Cultural Psychology*, *32*(1), 76–92. http://doi.org/10.1177/0022022101032001009

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., … Gore, J. C. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and asperger syndrome. *Archives of General Psychiatry*, *57*(4), 331–340. http://doi.org/10.1001/archpsyc.57.4.331

Scott, S. K., Young, a W., Calder, a J., Hellawell, D. J., Aggleton, J. P., & Johnson, M. (1997). Impaired auditory recognition of fear and anger following bilateral amygdala lesions. *Nature*. http://doi.org/10.1038/385254a0

Seltzer, M. M., Shattuck, P., Abbeduto, L., & Greenberg, J. S. (2004). Trajectory of development in adolescents and adults with autism. *Mental Retardation and*

Developmental Disabilities Research Reviews, *10*(4), 234–247. http://doi.org/10.1002/mrdd.20038

Sergerie, K., Chochol, C., & Armony, J. L. (2008). The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *32*(4), 811–830. http://doi.org/10.1016/j.neubiorev.2007.12.002

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry*, *24*(4), 613–620. http://doi.org/10.1111/1469-7610.ep11422546.

Shah, A., & Fritht, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *34*(8), 1351–1364. http://doi.org/10.1111/j.1469-7610.1993.tb02095.x

Sharples, M., Taylor, J., & Vavoula, G. N. (2005). Towards a theory of mobile learning. *Proceedings of mLearn 2005*, *1*(1), 1–9.

Siegel, Bryna. (1999). *Autistic learning disabilities and individualizing treatment for autistic spectrum disorders*. Infants & Young Children. 12. . 10.1097/00001163-199910000-00004.

Siegel, D. D. J., Minshew, N. J. N., & Goldstein, G. (1996). Wechsler IQ profiles in diagnosis of high-functioning autism. *Journal of Autism and Developmental Disorders*, *26*(4), 389–406. http://doi.org/10.1007/BF02172825

Silk, T., Vance, A., Rinehart, N., Egan, G., Boyle, M. O., & Br, J. L. (2005). Fronto-parietal activation in attention-deficit hyperactivity disorder, combined type : functional magnetic resonance imaging study. *British Journal Of Psychiatry*, *187*, 282–283.

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Research*, *49*(22), 2705–2739. http://doi.org/10.1016/j.visres.2009.08.005

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity, and associated factors in a population-derived sample. *Journal of the American Academy of Child and Adolescent Psychiatry*, *47*(8), 921–929. http://doi.org/10.1097/CHI.0b013e318179964f

Sincák, P., Loreník, D., Viríkova, M., & Gamec, J. (2015). *Emergent trends in robotics and intelligent systems (pp. 13–30)*. Springer International Publishing.

Skipper, J. I., Nusbaum, H. C., & Small, S. L. (2005). Listening to talking faces: Motor cortical activation during speech perception. *NeuroImage*, *25*(1), 76–89. http://doi.org/10.1016/j.neuroimage.2004.11.006

Slavin, R.E. (1995). *Cooperative Learning: Theory, Research and Practice (2nd ed.)*. Boston.

Smith, C.A., & Ellsworth, P. C. (1985). Patterns of cognitive appraisal in emotion. *Journal of Personality and Social Psychology*, *48*(4), 813–838. http://doi.org/10.1037//0022-3514.48.4.813

Smith, D. G., Jones, P. S., Bullmore, E. T., Robbins, T. W., & Ersche, K. D. (2013). Cognitive control dysfunction and abnormal frontal cortex activation in stimulant drug users and their biological siblings. *Transl Psychiatry*, *3*(5), e257. http://doi.org/10.1038/tp.2013.32

Smoller, J. W., & Tsuang, M. T. (1998). Panic and phobic anxiety: Defining phenotypes for genetic studies. *American Journal of Psychiatry*, *155*(9), 1152–1162. http://doi.org/10.1176/ajp.155.9.1152

Sofronoff, K., & Farbotko, M. (2002). The effectiveness of parent management training to increase self-efficacy in parents of children with asperger syndrome. *Autism*, *6*(3), 271–286.

Somers, J. M., Goldner, E. M., Waraich, P., & Hsu, L. (2006). Prevalence and incidence studies of anxiety disorders: a systematic review of the literature. *Canadian Journal of Psychiatry. Revue Canadienne de Psychiatrie*, *51*(2), 100–113. http://doi.org/10.1177/070674370605100206

South, M., Ozonoff, S., Suchy, Y., Kesner, R. P., McMahon, W. M., & Lainhart, J. E. (2008). Intact emotion facilitation for nonsocial stimuli in autism: is amygdala impairment in autism specific for social information? *Journal of the International Neuropsychological Society*, *14*(1), 42–54. http://doi.org/10.1017/S1355617708080107

Southall, C. M., & Gast, D. L. (2011). Self-management procedures: A comparison across the autism spectrum. *Education and Training in Autism and Developmental Disabilities*, *46*(2), 155–171. http://doi.org/10.1177/0014402914532235

Spreng, R. N., DuPre, E., Selarka, D., Garcia, J., Gojkovic, S., Mildner, J., … Turner, G. R. (2014). Goal-congruent default network activity facilitates cognitive control. *Journal of Neuroscience*, *34*(42), 14108–14114. http://doi.org/10.1523/JNEUROSCI.2815-14.2014

Spielberger, C. D. (1966). *Theory and research on anxiety.* In C. D. Spielberger (Ed.), Anxiety and behavior (pp. 3–20). New York: Academic.

Spielberger, C. D. (1972). *Anxiety as an emotional state*. In C. D. Spielberger (Ed.), Anxiety: Current trends in theory and research (pp. 23–49).NewYork: Academic.

Spielberger, C. D. (1983). *Manual for the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.

Sprengelmeyer, R., Rausch, M., Eysel, U. T., & Przuntek, H. (1998). Neural structures associated with recognition of facial expressions of basic emotions. *Biological Sciences*, *265*, 1927–1931. http://doi.org/10.1098/rspb.1998.0522

Sprengelmeyer, R., Young, A. W., Calder, A. J., Karnat, A., Lange, H., Homberg, V., … Rowland, D. (1996). Loss of disgust perception of faces and emotions in Huntington ' s disease. *Brain*, *119*, 1647–1665.

Stein, B. E., & Meredith, M. A. (1990). Multisensory integration: neural and behavioral solutions for dealing with stimuli from different sensory modalities. *Annals of the New York Academy of Sciences*, *608*(1), 51–70. http://doi.org/10.1111/j.1749-6632.1990.tb48891.x

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: Current issues from the perspective of the single neuron. *Nature Reviews. Neuroscience*, *9*(4), 255–66. http://doi.org/10.1038/nrn2331

Stein, B. E., Wallace, M. T., & Stanford, T. R. (1999). Development of multisensory integration: transforming sensory input into motor output. *Mental Retardation and Developmental Disabilities Research Reviews*, *5*, 72–85.

Stevenson, J. L., & Hart, K. R. (2017). Psychometric properties of the autism-spectrum quotient for assessing low and high levels of autistic traits in college students. *Journal of Autism and Developmental Disorders*, *47*(6), 1838–1853. http://doi.org/10.1007/s10803-017-3109-1

Stichter, J. P., O'Connor, K. V., Herzog, M. J., Lierheimer, K., & McGhee, S. D. (2012). Social competence intervention for elementary students with aspergers syndrome and high functioning autism. *Journal of Autism and Developmental Disorders*, *42*(3), 354–366. http://doi.org/10.1007/s10803-011-1249-2

Stokes, M., Newton, N., & Kaur, A. (2007). Stalking, and social and romantic functioning among adolescents and adults with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *37*(10), 1969–1986. http://doi.org/10.1007/s10803-006-0344-2

Sucksmith, E., Allison, C., Baron-Cohen, S., Chakrabarti, B., & Hoekstra, R. A. (2013). Empathy and emotion recognition in people with autism, first-degree relatives, and controls. *Neuropsychologia*, *51*(1), 98–105. http://doi.org/10.1016/j.neuropsychologia.2012.11.013

Sukhodolsky, D. G., Scahill, L., Gadow, K. D., Arnold, L. E., Aman, M. G., McDougle, C. J., … Vitiello, B. (2008). Parent-rated anxiety symptoms in children with pervasive developmental disorders: Frequency and association with core autism symptoms and cognitive functioning. *Journal of Abnormal Child Psychology*, *36*(1), 117–128. http://doi.org/10.1007/s10802-007-9165-9

Sutherland, R., Hodge, A., Bruck, S., Costley, D., & Klieve, H. (2017). Parent-reported differences between school-aged girls and boys on the autism spectrum. *Autism*, 136236131666865. http://doi.org/10.1177/1362361316668653

Szameitat, D. P., Kreifelts, B., Alter, K., Szameitat, A. J., Sterr, A., Grodd, W., & Wildgruber, D. (2010). It is not always tickling: Distinct cerebral responses during perception of different laughter types. *NeuroImage*, *53*(4), 1264–1271. http://doi.org/10.1016/j.neuroimage.2010.06.028

Sze, K. M., & Wood, J. J. (2007). Cognitive behavioral treatment of comorbid anxiety disorders and social difficulties in children with high-functioning autism: A case report. *Journal of Contemporary Psychotherapy*, *37*(3), 133–143. http://doi.org/10.1007/s10879-007-9048-y

Sze, K. M., & Wood, J. J. (2008). Enhancing CBT for the treatment of autism spectrum disorders and concurrent anxiety. *Behavioural and Cognitive Psychotherapy*, *36*, 403–409. http://doi.org/10.1017/S1352465808004384

Brugha, T. S., McManus, S., Bankart, J., Scott, F. J., Purdon, S., Smith, J., Bebbington, P., et al. (2011). Epidemiology of autism spectrum disorders in adults in the community in England, *68*(5), 459–466. http://doi.org/10.1001/archgenpsychiatry.2011.38

Talairach J., & Tournoux, P. (1988). Co-planar stereotm'c at-las of the human brain. New York: Thieme.

Tantam, D., Monaghan, L., Nicholson, H., & Stirling, J. (1989). Autistic children's ability to interpret faces: a research note. *Journal of Child Psychial*, *30*(4), 623–630. http://doi.org/10.1111/j.1469-7610.1989.tb00274.x

Tashakkori, A., & Teddlie, C. (1998). *Applied social research methods series: Mixed methodology: Combining qualitative and quantitative approaches* vol. 46, Thousand Oaks, California: Sage.

Tell, D., & Davidson, D. (2014). Emotion recognition from congruent and incongruent emotional expressions and situational cues in children with autism spectrum disorder. *Autism: The International Journal of Research and Practice*, *1–5*(3), 1–5. http://doi.org/10.1177/1362361314535676

Teunisse, J.-P., & de Gelder, B. (2001). Impaired categorical perception of facial expressions in high-functioning adolescents with autism. *Child Neuropsychology*, *7*(1), 1–14 http://doi.org/10.1076/chin.7.1.1.3150.

Topping, K. J. (1996). The effectiveness of peer tutoring in further and higher education: A typology and review of the literature. *Higher Education*, *32*, 321–345. http://doi.org/ 10.1007/BF00138870

Topping, K. J., C. Buchs, D. Duran, and H. Van Keer. 2017. Effective peer learning: From principles to practical implementation. London and New York: Routledge.

Touroutoglou, A., Lindquist, K. A., Dickerson, B. C., & Barrett, L. F. (2015). Intrinsic connectivity in the human brain does not reveal networks for "basic" emotions. *Social Cognitive and Affective Neuroscience*, *10*(9), 1257–1265. http://doi.org/10.1093/scan/nsv013

Tracy, J. L., & Randles, D. (2011). Four models of basic emotions: A review of ekman and cordaro, izard, levenson, and panksepp and watt. *Emotion Review*, *3*(4), 397–405. http://doi.org/10.1177/1754073911410747

Trentacosta, C. J. ., Izard, C. E. ., Mostow, A. J. ., & Fine, S. E. (2006). Children' s emotional competence and attentional competence in early elementary competence in early elementary school. *School Psychology Quarterly*, *21*(2), 148–170. http://doi.org/10.1521/scpq.2006.21.2.148

Trevisan, D. A., & Birmingham, E. (2016). Are emotion recognition abilities related to everyday social functioning in ASD? A meta-analysis. *Research in Autism Spectrum Disorders*, *32*, 24–42. http://doi.org/10.1016/j.rasd.2016.08.004

Uljarevic, M., & Hamilton, A. (2013). Recognition of emotions in autism: A formal meta-analysis. *Journal of Autism and Developmental Disorders*, *43*(7), 1517–1526. http://doi.org/10.1007/s10803-012-1695-5

Ursache, A., & Raver, C. C. (2014). Trait and state anxiety: relations to executive functioning in an at risk sample. *Cognition and Emotion*, *28*(5), 845–855. http://doi.org/10.1080/02699931.2013.855173.Trait

Vaidya, P. M., & Mulgaonkar, K. P. (2007). Prevalence of depression anxiety & stress in undergraduate medical students & its co relation with their academic performance. *The Indian Journal of Occupational Therapy*, *39*, 7–10. http://doi.org/0.9734/BJMMR/2015/17193

Van Atteveldt, N., Formisano, E., Goebel, R., & Blomert, L. (2004). Integration of letters and speech sounds in the human brain. *Neuron*, *43*(2), 271–282. http://doi.org/10.1016/j.neuron.2004.06.025

Van Lancker, D., Cornelius, C., & Kreiman, J. (1989). Recognition of emotional-prosodic meanings in speech by autistic, schizophrenic, and normal children. *Developmental Neuropsychology*, *5*(2–3), 207–226. http://doi.org/10.1080/87565648909540433

van Steensel, F. J. A., Bögels, S. M., & Perrin, S. (2011). Anxiety disorders in children and adolescents with autistic spectrum disorders: A meta-analysis. *Clinical Child and Family Psychology Review*, *14*(3), 302–317. http://doi.org/10.1007/s10567-011-0097-0

van Wijngaarden-Cremers, P. J. M. ., van Deurzen, Patricia, A. M. ., & van der Gaag, R. J. (2014). Gender and Age Differences in the Core Triad of Impairments in Autism Spectrum Disorders: A systematic review and meta-analysis. *Journal of Autism and Developmental Disorders*, *44*, 627–635. http://doi.org/10.1007/s10803-013-1913-9

Vannetzel, L., Chaby, L., Cautru, F., Cohen, D., & Plaza, M. (2011). Neutral versus emotional human stimuli processing in children with pervasive developmental disorders not otherwise specified. *Research in Autism Spectrum Disorders*, *5*(2), 775–783. http://doi.org/10.1016/j.rasd.2010.09.005

Vassiou, A., Mouratidis, A., Andreou, E., & Kafetsios, K. (2014). Students' achievement goals, emotion perception ability and affect and performance in the classroom: a multilevel examination. *Educational Psychology*, 1–19. http://doi.org/10.1080/01443410.2014.950192

Vassiou, A., Mouratidis, A., Andreou, E., & Kafetsios, K. (2016). Students' achievement goals, emotion perception ability and affect and performance in the classroom: a multilevel examination. *Educational Psychology*, *36*(5), 869–887. http://doi.org/10.1080/01443410.2014.950192

Vickerstaff, S., Heriot, S., Wong, M., Lopes, A., & Dossetor, D. (2007). Intellectual ability, self-perceived social competence, and depressive symptomatology in children with high-functioning autistic spectrum disorders. *Journal of Autism and Developmental Disorders*, *37*(9), 1647–1664. http://doi.org/10.1007/s10803-006-0292-x

Villalobos, M. E., Mizuno, A., Dahl, B. C., & Kemmotsu, N. (2005). Reduced functional connectivity between V1 and inferior frontal cortex associated with visuomotor performance in autism. *NeuroImage*, *25*(3), 916–925. http://doi.org/10.1016/j.neuroimage.2004.12.022.Reduced

Vitasari, P., Wahab, M. N. A., Othman, A., Herawan, T., & Sinnadurai, S. K. (2010). The relationship between study anxiety and academic performance among engineering students. *Procedia - Social and Behavioral Sciences*, *8*(5), 490–497. http://doi.org/10.1016/j.sbspro.2010.12.067

Vivanti, G., Nadig, A., Ozonoff, S., & Rogers, S. J. (2008). What do children with autism attend to during imitation tasks? *Journal of Experimental Child Psychology*, *101*(3), 186–205. http://doi.org/10.1016/j.jecp.2008.04.008

Vytal, K., & Hamann, S. (2010). Neuroimaging support for discrete neural correlates of basic emotions: A voxel-based meta-analysis. *Journal of Cognitive Neuroscience*, *22*(12), 2864–2885. http://doi.org/10.1162/jocn.2009.21366

Wager, T. D., Kang, J., Johnson, T. D., Nichols, T. E., Satpute, A. B., & Barrett, L. F. (2015). A bayesian model of category-specific emotional brain responses. *PLoS Computational Biology*, *11*(4), 1–27. http://doi.org/10.1371/journal.pcbi.1004066

Walker-Andrews, A. S. (1997). Infants' perception of expressive behaviors: Differentiation of multimodal information. *Psychological Bulletin*, *121*(3), 437–456. http://doi.org/10.1037/0033-2909.121.3.437

Walker-Andrews, A. S., & Lennon, E. (1991). Infants' discrimination of vocal expressions: Contributions of auditory and visual information. *Infant Behavior and Development*, *14*(2), 131–142. http://doi.org/10.1016/0163-6383(91)90001-9

Wallace, M. T., Meredith, M. a, & Stein, B. E. (1998). Multisensory integration in the superior colliculus of the alert cat. *Journal of Neurophysiology*, *80*(2), 1006–1010.

Wallace, S., Coleman, M., & Bailey, A. (2008). An investigation of basic facial expression recognition in autism spectrum disorders. *Cognition and Emotion ISSN:*, *22*(7), 1353–1380. http://doi.org/10.1080/02699930701782153

Walsham, G. (1993). *Interpreting Information Systems in Organizations*.Wiley, Chicheste.

Wang, A., Dapretto, M., Hariri, A., Sigman, M., & Bookheimer, S. Y. (2001). Processing affective and linguistic prosody in autism: An fMRI study. *Neuroimage*, *13*(6), 2001. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Processing+Affective+and+Linguistic+Prosody+in+Autism+:+An+fMRI+Study#0

Wang, A. T., Lee, S. S., Sigman, M., & Dapretto, M. (2006). Neural basis of irony comprehension in children with autism: The role of prosody and context. *Brain*, *129*(4), 932–943. http://doi.org/10.1093/brain/awl032

Wang, a T., Dapretto, M., Hariri, a R., Sigman, M., & Bookheimer, S. Y. (2004). Neural correlates of facial affect processing in children and adolescents with autism spectrum disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *43*(4), 481–490. http://doi.org/10.1097/01.chi.0000111481.76722.66

Wang, a T., Lee, S. S., Sigman, M., & Dapretto, M. (2007). Reading Affect in the Face and Voice. *Archives of General Psychiatry*, *64*(June), 698–708. http://doi.org/10.1001/archpsyc.64.6.698

Watanabe, T., Yahata, N., Abe, O., Kuwabara, H., Inoue, H., Takano, Y., … Yamasue, H. (2012). Diminished medial prefrontal activity behind autistic social judgments of incongruent information. *PLoS ONE*, *7*(6), e39561. http://doi.org/10.1371/journal.pone.0039561

Watson, D., & Friend, R. (1969). Measurement of social-evaluative anxiety. *Journal of Consulting and Clinical Psychology*, *33*(4), 448–457. http://doi.org/10.1037/h0027806

Watson, R., Latinus, M., Noguchi, T., Garrod, O., Crabbe, F., & Belin, P. (2014). Crossmodal adaptation in right posterior superior temporal sulcus during face-voice emotional integration. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *34*(20), 6813–21. http://doi.org/10.1523/JNEUROSCI.4478-13.2014

Weiller, C., May, A., Sach, M., Buhmann, C., & Rijntjes, M. (2006). Role of functional imaging in neurological disorders. *Journal of Magnetic Resonance Imaging*, *23*(6), 840–850. http://doi.org/10.1002/jmri.20591

Wellman, H. M. ., Baron-Cohen, S., Caswell, R., Gomez, J. C., Swettenham, J., Toye, E., & Lagattuta, K. (2002). Thought-bubbles help children with autism acquire an alternative to a theory of mind. *Autism*, *6*(4), 343–363. http://doi.org/10.1177/1362361302006004003

Wells, A., White, J., & Carter, K. (1997). Attention training: Effects on anxiety and beliefs in panic and social phobia. *Clinical Psychology and Psychotherapy*, *4*(February), 226–232. http://doi.org/10.1002/(SICI)1099-0879(199712)4:4<226::AID-CPP129>3.0.CO;2-M

Wendt, T. N. (2003). Changes in cerebral blood flow in Asperger syndrome during theory of mind tasks presented by the auditory route, *189*, 178–189. http://doi.org/10.1007/s00787-003-0337-z

Weng, S.-J., Carrasco, M., Swart, J. R., Wiggins, J. L., Kurapati, N., Liberzon, I., … Monk, C. S. (2011). Neural activation to emotional faces in adolescents with autism spectrum disorde. *Journal of Child Psychology and Psychiatry*, *52*(3), 296–305. http://doi.org/10.1111/j.1469-7610.2010.02317.x.Neural

White, N., & Hastings, R. P. (2004). Social and professional support for parents of adolescents with severe intellectual disabilities. *Journal of Applied Research in Intellectual Disabilities*, *17*(3), 181–190. http://doi.org/10.1111/j.1468-3148.2004.00197.x

White, S. W., Ollendick, T., Scahill, L., Oswald, D., & Albano, A. M. (2009b). Preliminary efficacy of a cognitive-behavioral treatment program for anxious youth with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*(12), 1652–1662. http://doi.org/10.1007/s10803-009-0801-9

White, S. W., & Roberson-Nay, R. (2009). Anxiety, social deficits, and loneliness in youth with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*(7), 1006–1013. http://doi.org/10.1007/s10803-009-0713-8

Wicker, B., Fonlupt, P., Hubert, B., Tardif, C., Gepner, B., & Deruelle, C. (2008). Abnormal cerebral effective connectivity during explicit emotional processing in adults with autism spectrum disorder. *Social Cognitive and Affective Neuroscience*, *3*(2), 135–143. http://doi.org/10.1093/scan/nsn007

Wicker, B., Michel, F., Henaff, M. a, & Decety, J. (1998). Brain regions involved in the perception of gaze: a PET study. *NeuroImage*, *8*(2), 221–7. http://doi.org/10.1006/nimg.1998.0357

Wiethoff, S., Wildgruber, D., Grodd, W., & Ethofer, T. (2009). Response and habituation of the amygdala during processing of emotional prosody. *Neuroreport*, *20*(15), 1356–1360. http://doi.org/10.1097/WNR.0b013e328330eb83

Wigfield, A., Eccles, J.S., Schiefele, U., Roeser, R., Davis-Kean, P. (2006). Development of achievement motivation. In: Damon, W.; Eisenberg, N., editors. Handbook of child psychology. Vol. 3.(pp933-1002). Social, emotional, personality development. 6th ed.. Wiley; New York: Series Ed.

Williams, J. M. G., Watts, F. N., MacLeod, C., A., & Mathews, A. (1997). *Cognitive psychology and emotional disorders (2nd ed.)* Chichester, England: Wiley.

Williams, JMG.; Watts, FN.; MacLeod, C.; Mathews, A.(1988). *Cognitive psychology and emotional disorders*. Wiley; Chichester.

Williams, J. H. G., Whiten, A., & Singh, T. (2004). A systematic review of action imitations in autistic spectrum disorder. *Journal of Autism and Developmental Disorders*, *34*(3), 285–299.

Williams, B. T., & Gray, K. M. (2013). The relationship between emotion recognition ability and social skills in young children with autism. *Autism: The International Journal of Research and Practice*, *17*(6), 762–768. http://doi.org/10.1177/1362361312465355

Williams, J. H. G., Whiten, A., Suddendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience and Biobehavioral Reviews*, *25*(4), 287–295. http://doi.org/10.1016/S0149-7634(01)00014-8

Williams J. Mark G;, & Mathews, A. (1996). The emootional stroop task and psychopathology. *Psychological Bullettin*, *120*(1), 3–24. http://doi.org/10.12989/sem.2006.22.1.053

Wilson, C. E., Brock, J., & Palermo, R. (2010). Attention to social stimuli and facial identity recognition skills in autism spectrum disorder. *Journal of Intellectual Disability Research*, *54*(12), 1104–1115. http://doi.org/10.1111/j.1365-2788.2010.01340.x

Wilt, J., Oehlberg, K., & Revelle, W. (2011). Anxiety in personality. *Personality and Individual Differences*, *50*(7), 987–993. http://doi.org/10.1016/j.paid.2010.11.014

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children’s understanding of deception. *Cognition*, *13*(1), 103–128. http://doi.org/10.1016/0010-0277(83)90004-5

Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of Autism and Developmental Disorders*, *9*(1), 11–29. http://doi.org/10.1007/BF01531288

Wing, L., & Potter, D. (2002). The epidemiology of autistic spectrum disorders: Is the prevalence rising? *Mental Retardation and Developmental Disabilities Research Reviews*, *8*(3), 151–161. http://doi.org/10.1002/mrdd.10029

Winston, J. S., O’Doherty, J., & Dolan, R. J. (2003). Common and distinct neural responses during direct and incidental processing of multiple facial emotions. *NeuroImage*, *20*(1), 84–97. http://doi.org/10.1016/S1053-8119(03)00303-3

Wittfoth, M., Schröder, C., Schardt, D. M., Dengler, R., Heinze, H. J., & Kotz, S. A. (2010). On emotional conflict: Interference resolution of happy and angry prosody reveals valence-specific effects. *Cerebral Cortex*, *20*(2), 383–392. http://doi.org/10.1093/cercor/bhp106

Wolff, S. (1996). The first account of the Asperger Syndrome described? *European Child & Adolescent Psychiatry*, *5*(3), 119–132. http://doi.org/10.1007/BF00571671

Wong, T. K. W., Fung, P. C. W., Chua, S. E., & McAlonan, G. M. (2008). Abnormal spatiotemporal processing of emotional facial expressions in childhood autism: Dipole source analysis of event-related potentials. *European Journal of Neuroscience*, *28*(2), 407–416. http://doi.org/10.1111/j.1460-9568.2008.06328.x

Wood, J. J., & Gadow, K. D. (2010). Exploring the nature and function of anxiety in youth with autism spectrum disorders. *Clinical Psychology: Science and Practice*, *17*(4), 281–292. http://doi.org/10.1111/j.1468-2850.2010.01220.x

Woodbury-smith, M. R., Robinson, J., Baron-cohen, S., Robinson, J., & Wheelwright, S. (2005). Screening adults for Asperger Syndrome using the AQ: A preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders*, *35*(3), 331–335. http://doi.org/10.1007/s10803-005-3300-7

World Health Organization. (1993). *International classification of diseases: Tenth revision.* Geneva: Author.

Wundt, W. (1897). *Outlines of psychology (C. H. Judd, Trans.).* New York: Stechert.

Wright, T. M., Pelphrey, K. A., Allison, T., McKeown, M. J., & McCarthy, G. (2003). Polysensory interactions along lateral temporal regions evoked by audiovisual speech. *Cerebral Cortex*, *13*(10), 1034–1043. http://doi.org/10.1093/cercor/13.10.1034

Xavier, J., Vignaud, V., Ruggiero, R., Bodeau, N., Cohen, D., & Chaby, L. (2015). A multidimensional approach to the study of emotion recognition in autism spectrum disorders. *Frontiers in Psychology*, *6*(DEC), 1–9. http://doi.org/10.3389/fpsyg.2015.01954

Yang, Y., Raine, A., Colletti, P., Toga, A. W., & Narr, K. L. (2009). Abnormal temporal and prefrontal cortical gray matter thinning in psychopaths. *Molecular Psychiatry*, *14*(6), 561–562. http://doi.org/10.1038/mp.2009.12

Yoshida, Y., & Uchiyama, T. (2004). The clinical necessity for assessing Attention Dificit/Hyperactivity Disorder (AD/HD) symptoms in children with high-functioning Pervasive Developmental Disorder (PDD). *European Child and Adolescent Psychiatry*, *13*(5), 307–314. http://doi.org/10.1007/s00787-004-0391-1

Young, A. W., Hellawell, D. J., Van de Wal, C., & Johnson, M. (1996). Facial expression processing after amygdalotomy. *Neuropsychologia*, *34*(I), 31–39. https://doi.org/10.1016/0028-3932(95)00062-3

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron*, *44*(5), 889–898. http://doi.org/10.1016/j.neuron.2004.11.018

Yovel, G., Paller, K. A., & Levy, J. (2005). A whole face is more than the sum of its halves: Interactive processing in face perception. *Visual Cognition*, *12*(2), 337–352. http://doi.org/10.1080/13506280444000210

Zhang, X., Yin, L., Cohn, J. F., Canavan, S., Reale, M., Horowitz, A., … Girard, J. M. (2014). BP4D-Spontaneous: A high-resolution spontaneous 3D dynamic facial expression database. *Image and Vision Computing*, *32*(10), 692–706. http://doi.org/10.1016/j.imavis.2014.06.002

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica*, *67*(6), 361–370. http://doi.org/10.1111/j.1600-0447.1983.tb09716.x

Zilbovicius, M., Meresse, I., Chabane, N., Brunelle, F., Samson, Y., & Boddaert, N. (2006). Autism, the superior temporal sulcus and social perception. *Trends in Neurosciences*, *29*(7), 359–366. http://doi.org/10.1016/j.tins.2006.06.004