Emotion Recognition among Persons on the Autism Spectrum: An Examination of Contributing Factors and Strengths-Based Approaches

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June 3, 2022

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy in School/Applied Child Psychology

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Abstract

Differences in emotion recognition (ER) skills have been thought to contribute to the socialization patterns characteristic of persons on the Autism Spectrum (AS). Yet, discrepancies in the findings concerning ER accuracy by persons on the AS compared to typically-developing (TD) persons lead to questions regarding the specificity and universality of ER differences between the groups. Mixed ER findings may be due to the considerable heterogeneity in individual traits among persons on the AS, such as variability in verbal cognitive abilities (VCA) and alexithymia (a difficulty describing emotions). The way that studies are designed to measure ER may also contribute to mixed findings. For example, ER processing tasks have frequently involved socially explicit facial and vocal emotional stimuli, but not alternate types of emotional stimuli such as music, a domain on which persons on the AS often demonstrate unique strengths. Additional consideration is needed to understand the impact of these factors on ER in childhood.

Thus, the goal of this dissertation was to investigate contributing factors and strengths-based approaches to ER among persons on the AS. Study 1 was designed to examine the relative influence of VCA and alexithymia on ER among persons on the AS. Through a systematic review of ER task performance, I found that differences between AS and TD groups often disappeared when VCA and alexithymia were considered; controlling for VCA appeared to impact group differences on behavioural ER tasks, whereas alexithymia was more likely to contribute to group differences relevant to neurophysiological responses. These findings suggested that both characteristics should be considered in understanding ER among persons on the AS.

Studies 2 and 3 were designed to evaluate potential differences in ER between children on the AS and TD children (6-13 years) from faces, voices, and music, while accounting for

VCA and alexithymia. I also considered the impact of categorical versus dimensional (valence, arousal) response options. In Study 2, with VCA controlled, the analyses revealed that the groups performed comparably in recognizing facial and vocal emotions. However, the AS group outperformed the TD group when recognizing emotions from music. Both groups also performed comparably using dimensional ratings, except for slightly higher valence ratings for happy emotions among the AS group. Thus, reduced ER accuracy was not observed among children on the AS while accounting for VCA. Rather, children on the AS displayed an ER strength when emotions were conveyed in music.

In Study 3, the impact of alexithymia on ER was explored among a subset of the participants from Study 2. With VCA controlled, alexithymia was not associated with reduced facial or vocal ER accuracy, nor with dimensional valence and arousal ratings. However, higher levels of alexithymia and autism traits were associated with increased recognition of emotions from music. Consistent with Study 1, these findings suggest that behavioural measures of facial and vocal ER may not be strongly impacted by alexithymia when VCA and task demands are considered, nor does co-occurring alexithymia among children on the AS negatively impact musical ER strengths, extending the findings from Study 2.

Overall, the findings of comparable and enhanced ER among children on the AS relative to TD children, when emotions are presented via different types of stimuli and when considering contributing factors such as VCA and alexithymia, suggest that social differences characteristic of persons on the AS may not be attributed to underlying ER differences. These findings highlight a need to reconsider our study of how persons on the AS process emotions, and how incorporating diverse and strengths-based approaches to ER, including using music to convey emotions, can help to re-shape our thinking about and support for persons on the AS.

Résumé

Les différences de reconnaissance des émotions (RE) contribueraient aux schémas de socialisation caractéristiques des personnes sur le spectre de l'autisme (PSA). Pourtant, les divergences des résultats concernant la RE des PSA par rapport aux personnes dont le développement est typique (PDT) engendrent un questionnement sur la spécificité et l'universalité des différences intergroupe quant à la RE. Les résultats mitigés concernant la RE peuvent être dus à l'hétérogénéité des traits individuels des PSA, incluant les capacités cognitives verbales (CCV) et l'alexithymie (une difficulté à décrire les émotions). La méthodologie des études peut contribuer à ces résultats mitigés. Les tâches de RE incluent souvent des stimuli faciaux et vocaux socialement explicites. Par contre, ces tâches incluent rarement des stimuli émotionnels alternatifs tels que la musique, souvent considérée une forces des PSA. La compréhension de ces facteurs sur la RE pendant l'enfance est importante.

Le but de cette thèse est d'examiner les facteurs contribuants à la RE en tenant compte des forces des PSA. L'étude 1 examine l'influence des CCV et de l'alexithymie sur la RE des PSA. Une revue systématique de la performance aux tâches de RE confirme que les différences de performance entre les groupes SA et DT s'estompe lorsque les CCV et l'alexithymie considérées. Les différences de groupe seraient liées au CCV lors de tâches comportementales et à l'alexithimie lors de réponses neurophysiologiques. Ces deux caractéristiques seraient donc pertinentes à la compréhension de la RE chez les PSA.

Les études 2 et 3 évaluent les différences de la RE via des visages, des voix et de la musique entre les enfants sur le SA et les enfants au DT (6-13 ans), en tenant compte des CCV et de l'alexithymie. Nous considérons aussi l'impact de choix de réponses par catégorie versus sur un continum dimensionnel (valence, énergie). Dans l'étude 2, les analyses révèlent une

performance comparable entres les groupes dans la RE faciales et vocales quand les CCV sont controlées. Cependant, la performance du groupe SA a surpassé celle du groupe DT lors de la RE à travers la musique. Les deux groupes ont obtenu des résultats comparables lors de l'utilisation d'évaluation dimensionnelle, à l'exception des évaluations de valence légèrement plus élevées pour la joie dans le groupe SA. Ainsi, une réduction de la RE n'a pas été observée chez les enfants sur le SA lorsque les CCV sont considérées. Les enfants sur le SA démontrent plutôt une force pour la RE à travers la musique.

L'étude 3 explore l'impact de l'alexithymie sur la RE parmi un sous-groupe de l'étude 2. L'alexithymie n'est pas associée à une réduction de la RE faciale ou vocale, ni à la valence et aux niveau d'énergie, quand les CCV sont prises en compte. Cependant, un niveau d'alexithymie et de traits autistiques plus élevés sont associés à une meilleure RE à travers la musique. Conformément à l'étude 1, ces résultats suggèrent que les mesures comportementales de la RE faciale et vocale ne seraient pas influencées par l'alexithymie lorsque les CCV sont prises en compte. De plus, l'alexithymie concomitante chez les enfants sur le SA n'aurait pas d'impact négatif sur la RE à travers la musique, ce qui appuie les résultats de l'étude 2.

Les résultats comparables et parfois meilleurs de la RE chez les PSA , lorsque les émotions sont présentées via différents types de stimuli et lors de la prise en compte de facteurs tels que les CCV et l'alexithymie, suggèrent que les différences sociales caractéristiques du SA ne sont pas nécessairement attribuables à la RE. Ces résultats démontrent le besoin de reconsidérer notre approche sur l'étude du traitement des émotions par les PSA. L'intégration d'approches diverses et basées sur les forces des PSA, y compris l'utilisation de la musique comme véhicule émotionel, pourrait ré-orienter notre compréhension de cette population et notre approche thérapeutique.

Acknowledgements

What a journey these past seven years have been. I have immense gratitude for my supervisors and the faculty, administrative, and support staff at McGill (ECP, SACP, Graphos) for always being there in a pinch, for making the dissertation writing process easier, and for being communities of support on and off campus. I am also indebted to the Social Sciences and Humanities Research Council of Canada, the Organization for Autism Research, and the Canadian Autism Research Training Program, for their generous support in facilitating my training and funding my projects.

Jake, thank you for always pushing me to strive for excellence, while modelling sensitivity and humility for the communities we serve through research and clinic. I'll forever be grateful to you for welcoming me into the MYST lab family with open arms. Armando and Steve, thank you for always being willing to chat, teach, and offer all amounts of program and personal support possible (usually when I would pop into your offices unannounced). It was always truly appreciated, and your caring about all of us students did not go unnoticed.

Gwen, Tania, Hadas, Charlotte, Dianne, and all of the BAND lab students and research assistants that I've had the pleasure of knowing over the years. There is no one else I would want to go on data collection trips to Gatineau with, and no one more fun to commiserate and celebrate with at Thomson House. I could not have been luckier than to be part of the BAND with you all. Greg, Matt, and Justin – thank you for indulging me in an excessive number of study sessions – and countless coffees and meals! I'll always cherish my time living in Montreal because of all of you.

To my family and loved ones from all of the places I've been fortunate to end up over the years. Thank you for putting up with my unrelenting academic pursuits, and for being there unwaveringly during the good times and the bad. I would never have dreamed of getting to this point without your support and cheerleading over the years. Amma, Appa, Shalika, Sarah, Alan, Mariya, Niro, Steph, Cinntha, Sam, Kirsten, Summer, Beth, Evan. Thank you.

Finally, to Eve-Marie. You will never know what it has meant to me being mentored by you all these (seven!) years. Thank you guiding me through each and every project in this dissertation, for supporting and encouraging me when I needed it (especially cross-borders over Zoom), for nerding out with me on science and statistics chats, for making me take breaks, and for all of your professional and personal advice over the years, as I followed in your footsteps in more ways than I can count. Above all, thank you for believing in me.

Contribution to Original Knowledge

This dissertation aimed to challenge existing notions of core "deficits" in emotion recognition (ER) among persons on the autism spectrum (AS), relative to (TD) persons, given mixed findings highlighting comparable performance between AS and TD groups, as well as relative strengths among persons on the AS in the recognition of emotions from music. As such, the overarching goal of this dissertation was to systematically re-examine contributing participant characteristics and task-specific factors relevant to ER, and to offer nuanced perspectives to facilitate our thinking about and support for persons on the AS, with a focus on strengths-based and process-focused approaches.

The first aim of this dissertation was to elucidate the nature of relevant participant characteristics to ER and emotion processing broadly, among persons on the AS. Relative to TD persons, greater variability in verbal cognitive ability (VCA) and alexithymia traits among persons on the AS have both been identified as relevant to performance on basic emotion processing tasks, yet these participant characteristics have often been studied separately. As such, Study 1 (Chapter 3) provides an original contribution to the field as the first systematic review to evaluate the relative and specific impacts of VCA and alexithymia on emotion processing task performance, between AS and TD groups. Findings from Study 1 suggested that VCA may have a greater impact on behavioural responses to emotion processing tasks regardless of whether alexithymia is considered, whereas the impact of alexithymia is more readily observed among neurophysiological correlates of emotion processing. Study 1 thus contributed to the field by highlighting the importance of considering both VCA and alexithymia in group comparisons, as well as identifying consistent and broad gaps in the literature involving the types of ER stimuli used and response options offered, as well as a dearth of research on the interaction of these factors in emotion processing skills among children on the AS.

The second aim of this dissertation was to evaluate the recognition of basic emotions from strengths-based approaches using music, compared with conventional socially explicit facial and vocal stimuli, among children on the AS relative to TD children. I also considered the impact of task demands associated with categorical and dimensional response options. Studies 2 and 3 (Chapters 4 and 5, respectively) provided original contributions to the literature by being the first studies to directly compare basic ER skills using multiple stimulus types and response options, while also considering the impact of VCA and alexithymia. In a newly developed multi-stimulus behavioural ER paradigm, children on the AS and TD children rated musical, facial, and vocal emotions using categorical verbal labels and dimensional ratings of emotional valence and arousal, for happy, sad, and fear emotions. Findings revealed that compared to TD children, children on the AS demonstrated comparable ER skills from faces and voices, and enhanced processing of musical emotions, while accounting for VCA (Study 2 and 3). Alexithymia (Study 3) did not appear to impact ER performance overall, though I did find positive associations with alexithymia and autism traits and musical ER performance, after VCA was taken into account. Overall, the empirical findings from Studies 2 and 3 challenged the notion that social differences between children on the AS and TD children are due to underlying differences in basic ER and offered an alternate framework for thinking about ER and the ways in which children on the AS process emotions.

Additional contributions of these studies to ER research among persons on the AS, including the effectiveness of tailored, strengths-based clinical and educational approaches using music to support socioemotional learning, are considered within the dissertation discussion (Chapter 6).

Contribution of Authors

Chapter 1 (Introduction) was written and edited by Shalini Sivathasan (SS), with feedback from Jacob A. Burack (JAB) and Eve-Marie Quintin (EMQ).

Chapter 2 (Literature Review) was written and edited by SS, with feedback from JAB and EMQ.

Chapter 3 (Study 1) is an exact reproduction of the article entitled, "Emotion processing and autism spectrum disorder: A review of the relative contribution of alexithymia and verbal IQ", published in the peer-reviewed journal *Research in Autism Spectrum Disorders* in June 2020. It was authored by SS, Tania Palma Fernandes (TPF), JAB, and EMQ. SS conceived of the study, and planned and determined scope of the systematic review with EMQ. SS completed the systematic review. TPF independently completed a second review for verification. SS compiled and interpreted the studies included in the review, with input from EMQ, TPF, and JAB. SS wrote and edited the article, with feedback from EMQ and JAB. All authors read and approved the final manuscript.

Chapter 4 (Study 2) is an exact reproduction of the article entitled, "Basic emotion recognition of children on the autism spectrum is enhanced in music and typical for faces and voices," to be submitted for publication. It is authored by SS, Hadas Dahary (HD), JAB, and EMQ. SS conceived of the study, and planned and developed the experimental methodology with EMQ. SS and HD recruited the participants and collected data. SS conducted data analyses. HD aided in verifying data analyses. All authors contributed to the interpretation of data and findings. SS wrote and edited the article, with feedback from EMQ and JAB. All authors read and approved the final manuscript.

Chapter 5 (Study 3) is an exact replication of the brief report article entitled, "Examining the impact of alexithymia and autism traits on emotion recognition skills among children on the autism spectrum and typically-developing children," to be submitted for publication. It is authored by SS, JAB, and EMQ. SS conceived of the study, and planned and developed the experimental methodology with EMQ. SS conducted data analyses from a subset of data collected for Study 2. All authors contributed to the interpretation of data and findings. SS wrote and edited the article, with feedback from EMQ and JAB. All authors read and approved the final manuscript.

Chapter 6 (Discussion) was written and edited by SS, with feedback from JAB and EMQ.

Chapter 7 (Final Conclusion and Summary) was written and edited by SS, with feedback from JAB and EMQ.

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List of Abbreviations

ACC	Anterior cingulate cortex
ACM	Affect Circumplex Model
ADI-R	Autism Diagnostic Interview, Revised
ADOS	Autism Diagnostic Observation Schedule
AIC	Anterior insula cortex
ALX	Alexithymia
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
AQ	Autism-Spectrum Quotient
AS	Autism Spectrum (also ‘Asperger Syndrome’ in Chapter 3-Table 2 only)
ASD	Autism Spectrum Disorder
BPVS	British Picture Vocabulary Scale
BVAQ	Bermond-Vorst Autism Questionnaire
CA	Chronological age
CAM	Children’s Alexithymia Measure
CAM-PR	Children’s Alexithymia Measure - Parent-Report
Con	Control group
Corr	Correlated
DDF	Difficulty Describing Feelings
DIF	Difficulty Identifying Feelings
Diff	Differences
DSM	Diagnostic and Statistical Manual of Mental Disorders
EMG	Electromyography
EOT	Externally-Oriented Thinking
EP	Emotion processing
EPF	Enhanced Perceptual Functioning
ER	Emotion recognition
FACET	Facial recognition software
FG	Fusiform gyrus
fMRI	functional magnetic resonance imaging
FSIQ	Full Scale IQ
GSR	Galvanic skin response
HC	Healthy control
HLM	Hierarchical linear modelling
ICD	International Classification of Diseases
IQ	Intelligence Quotient
IMT	Improvisational music therapy
M	Mean
MA	Mental age
MAV	Montreal Affective Voices
MEB	Musical Emotional Bursts
mFG	Medial frontal gyrus
MWT	Mehrfachwahl-Wortschatz-Intelligenztest
N.s.	Not significant

NT	Neurotypical
NVCA	Non-verbal cognitive ability
NVIQ	Non-verbal IQ
OFC	Orbitofrontal cortex
PAG	Periaqueductal gray
PMC	Primary motor cortex
PFC	Prefrontal cortex
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
Rel'n	Relationship
RMET	Reading the Mind in the Eyes Test
ROI	Region of interest
SD	Standard deviation
SE	Standard error
SRS	Social Responsiveness Scale
STG	Superior temporal gyrus
STS	Superior temporal sulcus
TAS	Toronto Alexthymia Scale
TASIT-P1	Awareness of Social Inference Test-Emotion Recognition subsection
TD	Typically-developing
TMS	Transmagnetic cranial stimulation
VCA	Verbal cognitive ability
VCI	Verbal Comprehension Index
VIQ	Verbal IQ
VMA	Verbal Mental Age
WAIS	Wechsler Adult Intellectual Scale
WASI	Wechsler Abbreviated Scale of Intelligence
WCC	Weak Central Coherence
WISC	Wechsler Intellectual Scale for Children
WST	Wortschatztest

Chapter 1: Introduction

Autism spectrum disorder (ASD) is one of the most common neurodevelopmental conditions among children, characterized by differences in social communication and interaction, and restricted or repetitive behaviours and interests (American Psychiatric Association, 2013). Though widely heterogeneous in presentation and degree, social differences have long been associated with differences in the processing of basic emotions (e.g., Hobson, 1986a; Hobson, 1986b), with divergences in emotion recognition (ER) skills beginning early in development (Shultz et al., 2018). Much of the support for this notion comes from behavioural studies measuring how accurate persons on the autism spectrum (AS) are at identifying emotions, compared to typically-developing (TD) persons. However, despite conclusions from large-scale systematic reviews and meta-analyses citing overall reduced ER task performance by persons on the AS (Harms et al., 2010; Lozier et al., 2014; Uljarevic & Hamilton, 2012; Velikonja et al., 2019), several individual studies have found comparable ER performance between AS and TD groups (e.g., Castelli, 2005; Heaton et al., 2008; Jones et al., 2010; Quintin et al., 2011).

These studies and others (e.g., Bird & Cook, 2013; Ozonoff et al., 1990) have prompted questions about the specificity and universality of differences in ER associated with autism, noting two essential areas for consideration. Mixed findings may stem from variability of relevant cognitive and dispositional traits (i.e., participant characteristics) among persons on the AS, as well as from differences in consideration of how emotions are presented (task stimuli) and processed (task demands) in experimental tasks. Historically, much of the ER research among persons on the AS has involved a deficit-focused lens; yet, like TD persons, persons on the AS demonstrate many strengths and preferences that should be further explored and fostered. In re-examining our thinking about persons on the AS, further conceptual and methodological evaluation of ER of persons on the AS is needed to offer alternate perspectives and tailored approaches to ER that capitalize on their strengths and preferences.

As such, the current dissertation aims to comprehensively evaluate the question of specificity and universality of basic ER differences among persons on the AS relative to TD persons, by investigating relevant participant characteristics and task-specific factors that may contribute to ER, and by utilizing musical stimuli as an alternate, strengths-based approach to studying ER. Following this first introductory chapter, Chapter 2 constitutes a general review of the ER literature among persons on the AS.

In Chapter 3 I investigated the impact of participant characteristics on basic emotion processing task performance broadly, between persons on the AS and TD persons. Verbal cognitive ability (VCA) and alexithymia (a difficulty with identifying and verbalizing emotions) may contribute to differences in emotion processing by persons on the AS due to more significant variability in these characteristics relative to TD persons (Kinnaird et al., 2019; Maenner et al., 2021). However, despite calls for greater consideration of VCA (Harms et al., 2010), and more recently, alexithymia, in group comparisons (e.g., Bird & Cook, 2013), these characteristics have not been consistently accounted for in emotion processing studies (statistically or by group matching), making it difficult to be specific about the nature of emotion processing differences where and for whom they exist. Further, the relative influence of VCA and alexithymia on emotion processing broadly, and ER specifically, among persons on the AS is not well understood. Thus, Study 1 presents the findings from a systematic review of the contributions of VCA and alexithymia–two distinct but related participant characteristics–to emotion processing task performance among persons on the AS. This systematic review, entitled "Emotion processing and autism spectrum disorder: A review of the relative contribution of alexithymia and verbal IQ," was published in the peer-reviewed journal *Research in Autism Spectrum Disorders* (Sivathasan et al., 2020).

In Chapter 4, I considered the impact ER task stimuli and demands may also contribute to mixed findings, and address gaps in the literature identified by Study 1. ER tasks have predominately utilized socially explicit stimuli (i.e., facial and vocal expressions), which persons on the AS may perceive and process differently than TD persons (Velkonjia et al., 2019). However, music is a unique and powerful stimulus that can also effectively portray emotions. Research in the domains of music cognition and recognition of music-evoked emotions (also referred to as musical ER) have found comparable or enhanced processing among adults and children on the AS relative to their TD peers (Quintin, 2019). While music education and interventions are often sought out among persons on the AS, how ER skills from music directly compare with ER from faces and voices, is not yet known. This comparison is presented in Chapter 4. ER tasks have also traditionally used categorical response options (e.g., verbal labels), success with which may also be influenced by VCA. To assess whether task demands contribute to group differences in ER performance, in Chapter 4 I explored the use of alternate response options to capture ER skills, through dimensional ratings of emotional valence and arousal.

Thus, Chapter 4 presents the findings from Study 2, an experimental study designed to directly test basic ER skills among 48 participants comprising of children on the AS and TD children. Participant characteristics, task stimuli, and task demands were directly compared through a newly-developed multi-stimulus behavioural ER paradigm, in which children were asked to identify happy, sad, and fear emotions in quickly presented musical, facial, and vocal task stimuli. The participants responded in two ways, using a traditional categorical response option (i.e., to select a verbal label) and using dimensional Likert scale ratings of emotional valence and arousal. Additionally, in this study, I also considered the impact of VCA among AS and TD groups. The findings from Study 2 will be submitted for publication in an article entitled, "Basic emotion recognition of children on the autism spectrum is enhanced in music and typical for faces and voices."

Chapter 5 presents the findings of Study 3, in which I collected parent-reported measures of alexithymia in a subgroup of 36 of the 48 AS and TD children who participated in Study 2, to explore the impact of alexithymia on ER task performance across the multiple stimulus types and response options. These data allowed me to assess the relative contributions of alexithymia and autism traits to ER, while also considering VCA. Study 3 will be submitted for publication as a brief report entitled, "Examining the impact of alexithymia and autism traits on emotion recognition skills among children on the autism spectrum and typically-developing children."

Finally, Chapter 6 presents the discussion, contributions, future directions, and implications of the research presented in this dissertation. Clinical and educational implications for utilizing music as a strengths-based approach for persons on the AS, in order to facilitate socioemotional learning through music-based interventions, are discussed. Chapter 7 offers a final conclusion and summary of this dissertation.

Chapter 2: Literature Review

Emotion Processing and Autism

Autism spectrum disorder (ASD)[1] is one of the most common neurodevelopmental conditions in North America (Maenner et al., 2021; Ofner et al., 2018). While broadly characterized by differences in patterns of social communication and interaction, behaviours, and interests (American Psychiatric Association, 2013), persons on the autism spectrum (AS) demonstrate significant heterogeneity across these primary domains, as well as in patterns of cognitive, language, sensory, and other learning differences that contribute to developmental differences in social engagement (Jones & Klin, 2009; Pelphrey et al., 2011). Given increasing prevalence estimates among school-aged children on the AS, currently ranging between 1 in 44 (Maenner et al., 2021) and 1 in 66 (Ofner et al., 2018), continued and intentional efforts are needed to understand and support the diversity of socialization patterns and socioemotional learning needs of persons on the AS throughout the lifespan.

A domain that has received a great deal of research attention in considering the socialization patterns displayed by persons on the AS involves emotion processing. The ability to process and utilize emotional information from an early age has long since been thought to have a strong evolutionary component for humans, beginning with the recognition of basic emotions. According to the theory of basic emotions (Ekman & Friesen, 1969, 1971), humans are universally neurologically and physiologically endowed with the ability to recognize a discrete set of basic emotions (i.e., happy, sad, fear, anger, disgust, surprise) that are pertinent to survival (Ekman, 1992) and to ensuring the viability of offspring (Keltner et al., 2006). Moreover,

[1]In an effort to use inclusive and non-ableist language to discuss individuals with a wide range of abilities and preferences of both self-advocates and of caregivers, identify-first terms such as “autistic community” and “autistic persons” as well as children or persons “on the autism spectrum” are used interchangeably. In a similar vein, “typically-developing” and “non-autistic” persons are used interchangeably. (Bottema-Beutel et al., 2021; CASDA, 2020).

emotion recognition (ER) abilities are thought to be fundamental precursors to the development of social skills (Leppanen & Nelson, 2006), including emotional self-regulation (Izard, 2001; Mayer et al., 2001), effective perspective-taking (Hoffman, 1975), and pro-social behaviour (Findlay et al., 2006).

Several researchers over the past four decades have suggested, via various hypotheses, that developmental differences in the ability to accurately recognize basic emotions, relative to typically-developing (TD) persons, underlie social differences characteristic of persons on the AS (e.g., Hobson, 1986b; Baron-Cohen, 2005; Yeung, 2021). Yet, these hypotheses are contradicted by numerous findings of comparable ER abilities between AS and TD groups (e.g., Heaton et al., 2008; Jones et al., 2010; Ozonoff et al., 1990; Quintin et al., 2011). Such findings have prompted calls to consider factors that may contribute to mixed findings in the ER literature beyond an autism diagnosis, such as verbal cognitive ability (e.g., Harms et al., 2010). Additionally, consideration of alternate process-focused theoretical frameworks may inform and shape our views and study of the unique socialization profiles and diverse learning needs of autistic persons (e.g., Burack et al., 2016). As such, in order to make sense of mixed ER findings and ultimately to re-consider our thinking of and support for persons on the AS, a systematic approach toward accurately assessing and comparing the emotional skills of persons on the AS relative to TD persons, beginning in childhood, is needed.

Emotion Recognition (ER) in Typical Development

Among typically-developing (TD) children, the development of rudimentary ER skills is evident within the first year of life (Rutter, 1983), as infants can discriminate between positively and negatively valenced facial expressions as early as five months of age (Flom & Bahrick, 2007; Leppänen & Nelson, 2009). Facial ER skills continue to improve throughout childhood, approximating adult-like levels by six years old for happy and sad emotions, and later for more complex emotions such as fear, surprise, and disgust (Camras & Allison, 1985; Herba & Phillips, 2004), though age-related improvements in ER accuracy for specific emotions may continue into adolescence (Herba et al., 2006; Lawrence et al., 2015) and adulthood (Thomas et al., 2007).

The development of ER skills conveyed in nonverbal vocal expressions appear to follow a similar trajectory to that for facial ER skills (Morningstar et al., 2018a). Infants and toddlers attend to pre-linguistic vocal expressions of emotion (e.g., laughing, crying, shouting; Blasi et al., 2011) and discriminate between positively and negatively valenced vocalizations by 5 months of age (Flom & Bahrick, 2007; Walker-Andrews, 1997). As with facial ER skills, children demonstrate age-related improvements throughout childhood (Allgood & Heaton, 2015), approximating adult-like levels of vocal ER between six and 10 years of age (Baum & Nowicki, 1998), although continued improvement in vocal ER accuracy is also found through adolescence and adulthood (Chronaki et al., 2015; Morningstar et al., 2018b).

Behavioural findings are bolstered by evidence from neuroimaging studies that map emotion processing to key structures and networks in the brain. Neural structures involved in the processing of facial emotions from what is known as the "social brain," and include the amygdala, prefrontal (PFC) and orbitofrontal (OFC) cortices, the superior temporal sulcus (STS) and gyrus (STG) (Brothers, 1990; Leppänen & Nelson, 2009), as well as the fusiform gyrus (FG) (McCarthy et al., 1997). Similarly, processing of emotions in speech and non-verbal vocalizations are thought to primarily involve the auditory cortex, STS, amygdalae, and OFC and insulae, with speech sounds lateralized to the left hemisphere, and nonverbal vocal emotions lateralized to the right hemisphere (Schirmer & Kotz, 2006). Typical developmental processes including synaptic pruning, as well as reciprocal social experiences and engagement during sensitive periods, continue to shape and refine emotion processing abilities into adolescence and adulthood (for reviews, see Leppänen & Nelson, 2009; Morningstar et al., 2018a, Morningstar et al., 2018b).

ER in Autism: Historical and Prevailing "Deficit-Focused" Approaches

The past nearly four decades have seen great research interest in identifying mechanisms contributing to social differences among persons on the AS, with findings highlighting basic ER differences between AS and non-AS groups giving rise to prominent "deficit-focused" developmental theories of emotion processing. Based on the earliest studies of ER among children on the AS, Hobson (1986a, 1986b) proposed that autistic persons possess an inherent, pervasive, and reduced capacity to identify or accurately 'sense the meaning of emotional expressions,' for which they must compensate with cognitive or perceptual strategies (i.e., 'affective theory'). Expanded theories of social "disability" include Baron-Cohen et al.'s 'meta-representation theory' (also known as the 'cognitive theory' or deficit in 'theory of mind;' Baron-Cohen et al., 1985; Baron-Cohen, 1988), in which they argued that persons on the AS have difficulties in recognizing and empathizing with others' emotions, or understanding others' mental states, thus underlying and contributing to unique social challenges experienced by persons on the AS (Baron-Cohen, 1988; Baron-Cohen et al., 1994) and form the basis of an ASD diagnosis (Baron-Cohen, 2009). Theories of atypical brain connectivity (Belmonte et al., 2004), amygdala dysfunction (the 'amygdala theory of autism;' Baron-Cohen et al., 1999), and atypical mirror neuron activation (Dapretto et al., 2006) and others have been posed in support of the negative impacts on social cognition and behaviour (see Baron-Cohen & Belmonte, 2005, Pelphrey et al., 2011, for reviews).

Historically, these types of conceptualizations have dominated the study of ER and social differences between autistic and non-autistic persons, with considerable evidence in support of notions of reduced ER accuracy among children and adults on the AS. Based on a number of separate but overlapping systematic reviews (Harms et al., 2010) and meta-analyses (Lozier et al., 2014; Uljarevic & Hamilton, 2012; Velikonja et al., 2019; Yeung, 2021) summarizing behavioural study findings between 1986 and 2020, persons on the AS have been found to generally demonstrate reduced ER skills relative to TD persons, with overall mean effect sizes ranging from medium to large in scale. Results from neuroimaging studies have also tended to highlight differences in areas of the social brain between persons on the AS and TD persons, including, for example, hypoactivation of the FG and amygdala (e.g., Baron-Cohen et al., 1999; Corbett et al., 2009) during facial processing, reduced activation in the STS while listening to speech sounds (Gervais et al., 2004), and enlarged amygdala volume in the first years of life (Schumann et al., 2009).

Considering Mixed Findings and Contributing Factors to ER in Autism

At face value, ER challenges appear to be ubiquitous among persons on the AS. Yet, despite the evidence broadly supporting the various theories of reduced ER ability among persons on the AS, few or no differences in ER performance between AS and TD groups have been reported in studies, including in some of the earliest (e.g., Braverman et al., 1989; Fein et al., 1992; Ozonoff et al., 1990). Ozonoff et al. (1990), for example, found no differences between AS and TD children on a facial emotion matching task and on a modified version of Hobson's original cross-modal facial-vocal emotion matching task, when the verbal cognitive abilities of the participants were accounted for. Similar findings of no group differences were found in Fein et al. (1992) and Braverman et al. (1989)'s studies, when comparing AS to verbal-ability matched non-AS groups. Since then, comparable performance between AS and non-AS groups on ER tasks have been reported in several studies (e.g., Bird & Cook, 2013; Buitelaar & van der Wees, 1997; Castelli, 2005; Gepner et al., 2001; Grossman et al., 2000; Jones et al., 2010). Thus, while these meta-analyses highlight aggregate findings of reduced ER, they also pose questions about ubiquity of ER differences among persons on the AS. These questions are further emphasized by mixed findings that come from an emerging literature of ER studies not included in these meta-analyses, which have found comparable or better ER performance by persons on the AS when using musical stimuli to convey emotions (e.g., Allen et al., 2013; Caria et al., 2011; Gebauer et al., 2014; Heaton et al., 1999, 2008; Quintin et al., 2011; Stephenson et al., 2016).

What factors might contribute to the range of study findings that report comparable performance between AS and TD groups, despite consistent findings of group differences favouring TD group performance? Contrasting the discrepancies with the prevailing deficit-focused theories, Ozonoff et al. (1990), for example, disputed the notion that social differences stemmed from core ER deficits among persons on the AS, arguing that for a characteristic to be considered a core feature of a particular condition, it must be both specific and universal, or ubiquitous to all persons with that condition. Rather, based on their and others' emerging findings of comparable performance, they emphasized the need to consider the potential impact of additional factors on the development of ER skills and on ER task performance (Ozonoff et al., 1990).

Although numerous factors may have an impact on variability in performance on ER tasks by autistic and non-autistic persons, Harms et al. (2010), Nuske et al. (2012) and others have identified that such factors may be classified across two broad domains: 1) participant characteristics and 2) experimental task stimuli and task demands. Specifically, verbal cognitive ability (VCA) has historically been thought to be a participant characteristic associated with ER (e.g., Ozonoff et al., 1990), though the ways in which varying levels of VCA impact task performance remains unclear. More recently, alexithymia, a difficulty with describing emotions, has become an additional characteristic of great interest, given its higher preponderance among persons on the AS relative to TD persons (Bird & Cook, 2013), though how alexithymia may impact ER separately and relative to VCA is also not well understood.

Experimental task stimuli and demands may also impact ER performance (Harms et al., 2010; Lozier et al., 2014). Specifically, integrating and comparing the use of alternate types of stimuli that can convey emotions, such as musical stimuli, with conventional approaches using facial and vocal stimuli, is essential for answering questions about specificity and universality of ER differences between persons on the AS and TD persons, where they are evident. Additionally, the nature and impact of task demands to ER performance among persons on the AS, including of utilizing different types of response options, is less well elucidated.

Participant Characteristics

Verbal Cognitive Ability

While cognitive abilities are known to play a role in ER development and task performance among TD persons (Lawrence et al., 2015), understanding the specific contribution of cognitive abilities to ER skills of persons on the AS remains a complex issue, due to greater heterogeneity in cognitive profiles relative to TD persons. Whereas just over 2% of TD persons score in the intellectual disability range on cognitive tests (Full Scale IQ score < 70), this represents around 30% of persons on the AS (Christensen et al., 2018). Greater variability in cognitive profiles may also come from differences between verbal and nonverbal abilities, with nearly 30% of persons on the AS displaying stronger non-verbal than verbal IQ profiles (Charman et al., 2011; Dawson et al., 2007).

Age is also thought to play a significant interacting role with IQ, which continues to crystalize through typical learning and brain development, with stability increasing into the elementary school ages (Howlin et al., 2014; Schneider et al., 2014). However, different findings have been reported about the mechanisms by which IQ impacts ER over the course of development (Dyck et al., 2006). Among persons on the AS, however, some studies have found IQ to most greatly impact the performance of children (Kuusikko et al., 2009), in others the performance of adolescents (Rump et al., 2009), or adults (Lozier et al., 2014); and yet in others, no differences were found in relation to age among those with higher IQ scores (O'Connor et al., 2005). Given such marked variability in findings, careful consideration of IQ is needed when comparing AS and non-AS groups (Harms et al., 2010).

Researchers who have accounted for verbal cognitive abilities and age have often found comparable performance between persons on the AS and TD persons, in facial ER (Castelli, 2005; Dyck et al., 2006; Ozonoff et al., 1990, Loveland et al. 1997), vocal ER (e.g., Golan et al., 2007) or musical ER (e.g., Heaton et al., 2008, Quintin et al., 2011), whereas group differences have often been found when accounted solely for nonverbal abilities (e.g., Hobson et al., 1986ab). Among children and adults on the AS, Trevisan and Birmingham (2016) found that age, verbal and nonverbal cognitive abilities were all positively associated with performance on ER tasks, with the strongest relationship being associated with VIQ ($r = 0.42$), possibly due to greater variability in this component of IQ. Nevertheless, accounting for cognitive abilities, and in particular verbal cognitive abilities, is not a consistent practice, which can subsequently impact conclusions and conceptualizations– and especially those derived from reviews and meta-analyses–that continue to describe ER differences as inherent to autism, rather than to cognitive variability between groups.

Alexithymia

Another relevant characteristic to consider in research involving persons on the AS and emotion processing is alexithymia. Alexithymia is a multifaceted trait broadly characterized by difficulties with identifying and describing emotions (Nemiah et al., 1976; Sifneos, 1973), as well as externally-oriented styles of thinking (Bagby et al., 1994; Taylor, 2000). Expansions of this conceptualization have grown to also emphasize cognitive versus emotional aspects of alexithymia. Type I alexithymia is described as experiencing a reduced range of emotions ("affective dimension") as well as a reduced ability to verbalize felt emotions ("cognitive dimension"), whereas Type II alexithymia is thought to encompass difficulties solely with the cognitive aspects of emotion processing, though one's experience of emotions may be unaffected (Bermond et al., 1999; Vorst & Bermond, 2001). Higher levels of alexithymia have been associated with differences in basic emotion processing, theory of mind, empathy, and emotion regulation among non-autistic clinical populations (see Luminet & Zamariola, 2018, for a review); as such, given the relevance of these areas to the socioemotional skills of persons on the AS, alexithymia has become an important characteristic to examine regarding emotion processing among persons on the AS.

Alexithymia is estimated to co-occur in 50-65% of persons on the AS (Hill et al., 2004; Kinnaird et al., 2019), compared with prevalence rates around 10% among the general population (Mattila et al., 2006). Adults on the AS also report higher levels of alexithymia symptoms relative to TD adults (Hill et al., 2004), which are positively correlated with levels of autism traits in adults (Lombardo et al., 2007). They also tend to endorse characteristics associated with Type II alexithymia (Berthoz & Hill, 2005; Griffin et al., 2016; Heaton et al., 2012).

The potential impacts of alexithymia on various aspects of emotion processing among persons on the AS have been studied in both behavioural and neuroimaging studies. For example, Bird, Silani, and colleagues measured neural activity of persons on the AS during empathy paradigms (i.e., judging the pleasantness or unpleasantness of emotional images [Silani et al., 2008], and of elicited pain to self and other [Bird et al., 2010]). They found that reduced neural responses observed in the anterior insula during empathy tasks by adults on the AS relative to TD adults "disappeared" when accounting for higher levels of alexithymia across the groups. That is, levels of alexithymia were predictive of neural responses on these tasks, rather than diagnostic group (AS versus TD). Similar results have been found in additional studies of visual attention to faces (Bird et al., 2011), facial emotion recognition (Cook et al., 2013; Ketelaars et al., 2016; Ola & Gullon-Scott, 2020), facial emotion production (Trevisan et al., 2016; Costa et al., 2017) and interoception (the ability to perceive internal bodily states, including physiological arousal; Shah et al., 2016), as higher levels of alexithymia were associated with decreased task performance of participants on the AS. Moreover, initial evidence from vocal (Heaton et al., 2012) and musical (Allen et al., 2013) stimuli have suggested negative associations with alexithymia among persons on the AS.

The Alexithymia Hypothesis. Based on their initial findings, Bird and Cook (2013) proposed the "alexithymia hypothesis" of autism, which postulates that emotion processing difficulties cited among persons on the AS might result from co-occurring alexithymia rather than autism traits. Specifically, they argued that the mixed findings in the emotion processing literature concerning persons on the AS may therefore reflect a lack of accounting for alexithymia among study participants, highlighting the need for systematic measurement and accounting for alexithymia in ER studies.

The alexithymia hypothesis offers an additional lens through which to conceptualize ER differences noted over the decades preceding it. Alexithymia represents a participant characteristic that may differentially impact performance on ER tasks among a subset of persons on the AS who endorse greater alexithymia symptoms compared with persons on the AS with lower levels of alexithymia. However, as with VCA, the specific mechanism by which alexithymia impacts ER is unclear. In a meta-analysis, Trevisan and Birmingham (2016) found that among persons on the AS, alexithymia was moderately negatively correlated with ER, and IQ was moderately positively correlated with ER; however, their relative impacts within individual studies or groups of participants on ER tasks is not yet known. Additionally, as all of the aforementioned studies involved adults on the AS, generalizability of the alexithymia hypothesis is needed for younger populations, who like adults, also appear to endorse higher levels of alexithymia than their TD peers (Griffin et al., 2016). In a comparison of groups of adolescents on the AS with and without alexithymia, Milosavljevic et al. (2016) found that no differences on a facial ER task between the adolescents on the AS with and without alexithymia when IQ and anxiety symptoms were controlled. Whether these findings generalize to children on the AS, especially among those with variable cognitive profiles, is currently unknown.

Experimental Task Stimuli and Task Demands

In addition to the potential impact of participant characteristics on ER skills, including VCA and alexithymia, differences in ER findings between AS and TD groups have also been thought to account for variability in task stimuli, demands, or difficulty (e.g., Harms et al., 2010; Ozonoff et al., 1990). Our understanding of ER development and processing has mainly been framed by discussion of facial and vocal expressions of emotions, yet emerging findings of accurate recognition of music-evoked emotions among persons on the AS, contextualized by extensive research in music cognition, give rise to alternate possibilities and frameworks for re-considering ER abilities broadly. Further, though the influence of task demands can be difficult to evaluate after the fact, methodological considerations around how tasks are designed, and specifically around how participants are asked to provide their responses, can help to facilitate systematic exploration of their impact on ER performance.

Processing of Musical Stimuli

Music represents a powerful stimulus that can convey emotions, regardless of language and culture (Fritz et al., 2009; Juslin & Sloboda, 2013), and one with which we can understand and study ER processing among TD persons and persons on the AS. Musical exposure often occurs early in development in the form of parental infant-directed singing, or in the sing song-style of early infant-directed speech, which can share music-like features including rhythm, repetitiveness, and pitch contouring (Nakata & Trehub, 2004). It is also typically laden with emotion. As with the processing of facial and vocal emotions, infants as young as 9 months of age begin to discriminate between positively and negatively valenced emotions conveyed in music (Flom et al., 2008), reaching adult-like levels around 5-6 years old (Dalla Bella et al., 2001), and approximating adult-like levels of recognition of happy, sad, fear, anger, and other more complex feeling states in music around 11 years old (Cunningham & Sterling, 1988; Heaton et al., 2008; Hunter et al., 2011), using acoustic cues such as mode (e.g., major versus minor keys), pitch (e.g., level, variation) and tempo (i.e., pace) to determine the emotions conveyed by the music, though ER skills may continue to develop and improve throughout adulthood (e.g., Dalla Bella et al., 2001; Gabrielsson & Juslin, 1996; see Stalinski & Schellenberg, 2012, for a review).

Extensive research has also been conducted toward understanding the neural mechanisms of musical processing, including the processing of emotions from music (see Koelsch, 2014 for a review). Specifically, the processing of musical emotions involves a vast network of interconnected cortical and subcortical brain regions, in addition to basic auditory processing, including the midbrain and striatal areas, the amygdala, hippocampus, cingulate cortex, orbitofrontal cortex (Koelsch, 2014; Blood & Zatorre, 2001). Networks that modulate reward-directed behaviours are also activated in response to emotional cues from music (Koelsch et al., 2006; Menon & Levitin, 2005; Salimpoor et al., 2011).

Among persons on the AS, music has been found to often be a domain of interest and strength (Heaton, 2009; Quintin, 2019). Like TD persons, many persons on the AS share an affinity for music, often report having a great interest in and appreciation for listening to music from an early age (Allen et al., 2009; Heaton & Allen, 2009), and demonstrate comparable listening habits and preferences to TD persons (Bhatara et al., 2013). With regard to cognitive processing of music, robust behavioral evidence demonstrates that relative to IQ- or mental age (MA)-matched TD persons, persons on the AS have comparable or enhanced auditory discrimination of pitches, musical tones and melodies (Bonnel et al., 2003, 2010; Chowdhury et al., 2017; Heaton, 2003, 2005; Heaton et al., 2008; Jamey et al., 2019; Jarvinen-Pasley & Heaton, 2007; Jones et al., 2009; Mottron et al., 2000; Stanutz et al., 2014), musical memory (Heaton, 2003; Heaton et al., 1998, 2008; Stanutz et al., 2014), and auditory-motor rhythm synchrony (Tryfon et al., 2017). Music perception abilities among children on the AS have also been positively associated with nonverbal IQ and age, but not level of autism symptoms (Jamey et al., 2019; Quintin et al., 2013), suggesting that persons on the AS may have a propensity toward musical processing regardless of varying socialization patterns or levels of social functioning.

Music as an Alternate Stimulus for Studying ER in Autism

Compelling findings of musical ER skills provide a unique opportunity to consider alternate approaches to understanding emotion processing of persons on the AS more broadly. In the first empirical study to investigate musical ER skills among children on the AS (mean age of groups: 10 years), Heaton et al. (1999) measured discrimination accuracy between short musical compositions conveying happy and sad emotions, and found that children on the AS demonstrated comparable discrimination accuracy with both a verbal cognitive ability (VCA)-matched TD group and a nonverbal cognitive ability (NVCA)-matched TD group. Additional evidence by Heaton et al. (2008) found that children on the AS performed comparably on a musical ER task with TD children, and with children with Down Syndrome, when VCA was taken in to account. In follow up studies, Quintin et al. (2011) and Stephenson et al. (2016) found that children and adolescents on the AS were also as successful as their TD peers at recognizing happy, sad, and scary musical compositions, when VCA was statistically controlled (mean age: 13 years; Quintin et al., 2011) or when the groups were matched on IQ (Stephenson et al., 2016). However, in the latter study, age-related differences in ER accuracy for scary music were observed between the groups as the 8 to 11-year-old children performed better than the 16 to 18-year-old adolescents in the AS groups, but the reverse pattern was observed for TD participants (Stephenson et al., 2016).

Neuroimaging studies also provide initial evidence supporting intact music-evoked ER skills among persons on the AS. Caria et al. (2011) found that adults on the AS without intellectual disability showed activation of several cortical and subcortical structures associated with auditory processing, music processing, ER, and emotional awareness, and reward response, when listening to happy and sad music, and generally comparable neural and behavioural responses to the TD group. Similarly, Gebauer et al. (2014) found overall comparable activation of cortical, subcortical, and reward networks between adults on the AS and IQ-matched TD adults when identifying happy and sad music.

These findings from the musical domain provide emerging evidence for a nuanced understanding of ER abilities of persons on the AS and may be associated with enhanced processing of emotions in music relative to facial and vocal stimuli. Among persons with greater support needs, these findings may ultimately add credence to emerging evidence towards the use of interventions to promote social communication and interaction among children on the AS, through the incorporation of music into speech- and language-focused interventions (e.g., Chenausky et al., 2016; Lanovaz & Sladeczek, 2012; Lanovaz et al., 2011; Lense & Camarata, 2020; Lim, 2010; Lim & Draper, 2011). Further, improvisational music therapy (IMT) has been shown among children on the AS to improve social interaction and communication skills, such as joint attention (Kim et al., 2008; LaGasse, 2014), turn taking and emotional engagement (Kim et al., 2009), and social communication (Sharda et al., 2018), and may even improve facial and vocal ER skills among children and adolescents on the AS with and without alexithymia (Pedregal & Heaton, 2021), when the development of these skills is the target of the intervention (Crawford et al., 2017; LaGasse, 2017).

Investigating the Dimensionality of Emotion: Categorical and Dimensional Response Options

The majority of ER studies with persons on the AS predominantly involve categorical forced-choice emotion labelling paradigms (Harms et al., 2010), for which the participants need to select an emotion label from a discrete set to find a match to a single presented stimulus. However, task performance using verbal labels may be impacted by variability in the participants' verbal cognitive abilities or level of alexithymia. One way to evaluate whether ER performance is impacted by the demands inherent to categorical emotion labelling tasks is to provide an alternate method of responding. In contrast to the notion that emotions are universally understood and categorized by discrete verbal labels, emotions can also be represented through rating the level of particular characteristics conveyed by the emotion, such as by levels of valence (i.e., positive to negative) and arousal (i.e., high to low intensity or energy). Using continuous ratings of dimensions of valence and arousal may capture a broader representation of emotion than is offered by categorical forced-choice methods (Gross & Ballif, 1991).

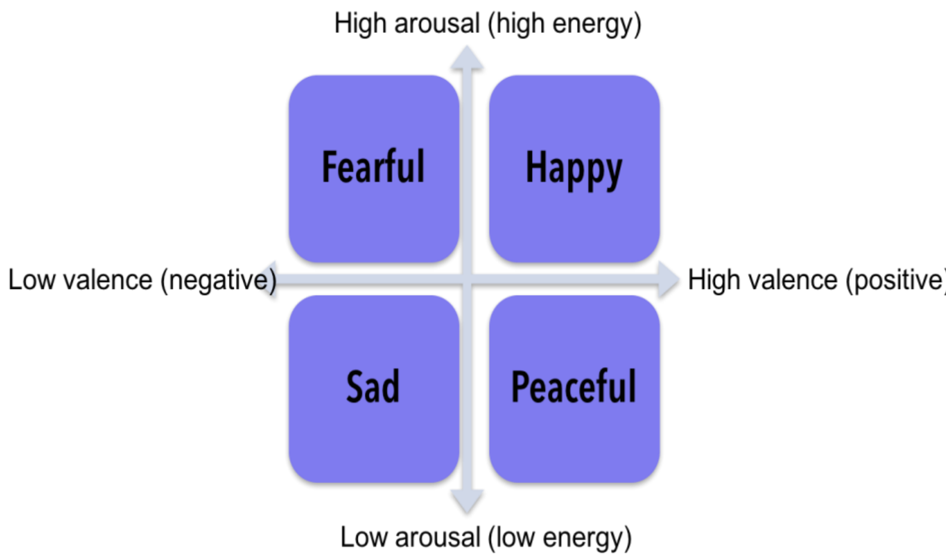
Proponents of the Affect Circumplex Model (ACM; Russell, 1980) posit that emotions or affective states fall on two orthogonal continuums of valence (i.e., 'very positive' to 'very negative') and arousal (i.e., 'high energy' to 'low energy'), derived from two separate neurophysiological systems (see Figure 1 for a simplified version of Russell's [1980] ACM). For example, happiness is considered an affective state resulting from a combination of positive valence and high arousal, whereas fear is thought to result from a combination of negative valence and high arousal (Posner et al., 2005). As such, recognition of emotions is measured using separate Likert scales for valence (e.g., "how positive or negative is the face?") and arousal (e.g., "how energetic or intense is the face?") or by simultaneous measurement using a grid-like depiction, rather than with the use of categorical verbal labels.

In this manner, the use of dimensional models of valence and arousal provides the opportunity to broaden how we ask persons on the AS to recognize components of emotion, by removing constraints associated with categorical verbal emotion labels. In one study, Tseng and colleagues (2014) found similar patterns of responses were displayed between groups of AS and TD children, and AS and TD adults using dimensional ratings to evaluate facial emotions. Yet, a more restricted range of valence and arousal ratings was used by the AS group relative to a mental age-matched TD group, which would otherwise not be evident using a forced-choice emotional label paradigm in which participants are required to select a single correct option.

Ratings of valence and arousal have also commonly been used in musical ER research with non-autistic persons (Gosselin et al., 2005; Vuilleumier & Trost, 2015), and may also be useful for persons on the AS, as they may be more likely to describe their emotional states in terms of descriptors of arousal (e.g., "excitement," "calmness" Allen et al., 2009). For example, Quintin et al. (2011) found that adolescents on the AS did not differ in their ratings of emotional intensity of music (i.e., the arousal dimension of the ACM) compared to TD adolescents after controlling for verbal IQ.

Figure 1

Simplified Affect Circumplex Model



Note. Adapted from "A Circumplex Model of Affect," by J. A. Russell, 1980, Journal of Personality and Social Psychology, 39, 1161-1178 (https://doi.org/10.1037/h0077714). Copyright 1980 by the American Psychological Association.

Finally, considerations around neurophysiological experiences of arousal during emotion processing tasks, and the potential impact of alexithymia, have also been of particular interest among AS researchers, though evidence appears to be mixed. Differences between AS and TD groups on physiological arousal during emotion processing tasks have been found in some studies (Krach et al., 2015; Minio-Paluello et al., 2019; Stephenson et al., 2016), but may "disappear" when alexithymia is considered (e.g., Allen et al., 2013; Gaigg et al., 2018). Additionally, on musical ER tasks using dimensional valence and arousal ratings, differences in patterns of neural activation between AS and TD groups have been found in the left anterior insula, associated with representation of internal bodily states and interoception (Caria et al., 2011; Gebauer et al., 2014), which were hypothesized to potentially be associated with alexithymia among persons on the AS (in line with findings by Bird et al., 2010; Silani et al., 2008 in non-musical ER studies) though this was not explicitly measured.

Alternate Frameworks for Thinking about Autism: Re-Conceptualizing ER through Process-Focused Theories

Consideration of various contributing factors to the mixed ER findings allows for important methodological challenges to be addressed when comparing groups and drawing conclusions about their abilities, in a fair and accurate manner. However, reconsidering our theoretical frameworks and perspectives to include process- and preference-focused approaches, relative to traditional deficit-focused models, can inform how we conceptualize ER skills and task performance, and ultimately help us to re-shape our thinking of heterogeneity and neurodiversity among persons on the AS.

In the 'empathizing-systemizing theory of autism,' for example, Baron-Cohen (2002, 2009) hypothesized that social differences between autistic and non-autistic persons may stem from preferences of autistic persons to seek out tasks or domains that utilize skills in systemizing (i.e., analyzing and predicting the rule-based behaviour of systems) over empathizing (i.e., analyzing and predicting the social behaviour and mental states of people), impacting relative proficiency across these domains. Similarly, Klin et al. (2003) proposed that differences in how persons on the AS interact within naturalistic social situations (embodied social cognition) may be related to the types of stimuli that are most salient or interesting to them (the 'enactive mind' approach; Klin et al., 2003). For example, whereas TD persons may preferentially attend to social stimuli in the environment (e.g., facial expressions), persons on the AS may instead prefer attending to and interacting with other salient aspects of the environment (Klin et al., 2003; Jones & Klin, 2009).

In terms of neurocognitive processing more broadly, proponents of the "weak central coherence" theory (Frith, 1989; Happé 1996; Happé & Frith, 2006) proposed that persons on the AS may exhibit a cognitive bias in which they tend to focus on the details and have, at times but not always, a reduced ability for global processing of the 'big picture,' including in social-emotional situations. In response, the Enhanced Perceptual Functioning (EPF) theory (Mottron & Burack, 2001; Mottron et al., 2006) also provides a framework for considering how such process-focused approaches to interacting with the world may impact the processing of ER specifically. The EPF theory suggests that persons on the AS may have a default or preferential bottom-up approach to processing the perceptual features of a stimulus that favours local, rather than global aspects. In this framework, global processing among persons on the AS is not necessarily impaired (as proposed by the WCC theory; Frith, 1989; Happe, 1996), but may be deprioritized relative to local processing. In comparison, TD persons may favour a top-down, global or holistic processing style, and deprioritize processing at the level of local perceptual cues. As such, differential styles of processing between AS and TD groups may be further reinforced by exposure to and engagement with preferred types of stimuli and experiences. For example, without specific instruction on what aspects of social stimuli to attend to, TD children may spend more time visually attending to the holistic socioemotional content conveyed in faces and voices than do children on the AS (Constantino et al., 2017), whereas children on the AS tend to demonstrate enhanced local processing of non-emotional perceptual features of faces (Hubl et al., 2003; Samson et al., 2012), speech (Järvinen-Pasley et al., 2008) and audio-visual synchronous biological motion (Klin et al., 2009).

As such, process-focused theories thus provide a valuable lens for reconceptualizing the mixed findings in the ER literature, by suggesting that rather than considering certain skills from the perspective of "deficit," persons on the AS, like TD persons, possess and hone processing skills that, through an iterative process of interest, engagement, and learning, become more specialized toward the processing of certain types of stimuli than others. Moreover, the EPF theory allows for consideration of alternate modalities from which relevant information can be processed at multiple levels, such as music. For example, understanding the diversity of ways that emotional information can be processed and how these processing styles interact with other relevant participant characteristics and task demands, ultimately have the potential to impact how such information is tailored and presented.

Rationale, Specific Aims, and Hypotheses

Efforts to understand mechanisms of socialization have often appeared to result in a narrow focus on identifying and remediating challenges (through a deficit- or disability-focused lens); however, considering the individual strengths and preferences of persons on the AS may be essential to providing optimal, inclusive, and tailored supports and services for a wide range of social, communication, and behavioural needs across the lifespan. Increased calls for the societal incorporation of heterogeneity through a lens of neurodiversity apply as much if not more to how research on basic cognitive and behavioural processes are conducted (Baron-Cohen, 2017; Georgiades et al., 2013; Pellicano & den Houting, 2021), including re-considering concepts and approaches that lend themselves well to a shifting perspective, and include the unique processing patterns and preferences of persons on the AS (Burack et al., 2016).

Thus, the goal of the current dissertation is to investigate mechanisms of ER processing among persons on the AS. Specifically, I aimed to comprehensively evaluate the question of the specificity and universality of basic ER differences among persons on the AS relative to TD persons, given mixed findings in the literature, by considering the impact of participant-level characteristics and task-specific factors related to ER, and by utilizing musical stimuli as an alternate, strengths-based approach to studying ER. This question is explored through three overarching study aims, with specific hypotheses outlined below.

The aim of Study 1 was to investigate the impact of specific participant characteristics – verbal cognitive ability and alexithymia – on performance on basic emotion processing tasks by persons on the AS. Whereas verbal IQ or verbal cognitive ability (VCA) has been a characteristic of interest for a long time in emotion processing research, the contributions of alexithymia have only recently begun to be investigated, and moreover, these characteristics have been investigated separately thus far. Thus, the goal of Study 1 was to evaluate the relative contributions of verbal cognitive ability and alexithymia to basic emotion processing task performance among persons on the AS and TD persons. Through a comprehensive systematic literature review, I assessed the empirical literature for basic emotion processing studies that included a measure of both VCA and alexithymia. No formal hypotheses were put forth;

however, special attention was paid to additional participant or study characteristics (e.g., age, sex, type of measurement instruments used, experimental paradigms) that could potentially moderate the relative contributions of these participant factors to task performance.

The aim of Studies 2 and 3 was to evaluate the impact that task stimuli and task demands contribute to the emotion recognition (ER) performance specifically, among children on the AS, while also considering the impact of VCA and alexithymia. Several findings of relative strengths in recognizing music-evoked emotions by children on the AS have been observed, but how their ER skills from music directly compare with their skills from frequently used socially explicit stimuli (faces, voices), and how their skills across these domains compare with TD children, is not yet known. Based on the previous ER literature across stimulus types, in Study 2, I evaluated the hypothesis that children on the AS might demonstrate a relative strength in musical ER compared with TD children, whereas the TD group might display a relative strength in facial and vocal ER compared with children on the AS, while also considering the impact of VCA. I also hypothesized that whereas TD children may not differ in their ER performance among musical, facial, and vocal stimuli, children on the AS may have better ER performance with musical stimuli, relative to facial and vocal stimuli. In an exploratory manner, another focus of Study 2 was to examine the extent to which task demands contribute to potential differences in ER performance relative to TD persons, using response options that included both categorical forced-choice labels and ratings of dimensional valence and arousal. As this aim was exploratory, I did not venture specific hypotheses regarding between or within-group differences from response options used.

Finally, the aim of Study 3 was to empirically explore the impact of alexithymia on ER task performance across the multiple stimulus types and response options, through an analysis of a subset of the data from Study 2. Specifically, following my findings in Study 1, the goal of Study 3 was to evaluate the alexithymia hypothesis for ER skills from music, compared with faces and voices, among a subset of the participants on the AS and TD participants from Study 2. This subset of participants was first grouped by level of autism traits and then by level of alexithymia traits, while also considering the impact of VCA. Although the alexithymia hypothesis would suggest that reduced musical ER accuracy would be found by persons with higher levels of alexithymia, given that autism and alexithymia traits are highly correlated, I did not venture specific hypotheses regarding comparisons of groups categorized by levels of autism and alexithymia traits.

Chapter 3: Study 1

This chapter is an exact reproduction of the following article, published in the journal Research in Autism Spectrum Disorders.[2]

Emotion processing and autism spectrum disorder: A review of the relative contributions of alexithymia and verbal IQ

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Citation: Sivathasan, S., Fernandes, T. P., Burack, J. A., & Quintin, E. M. (2020). Emotion processing and autism spectrum disorder: A review of the relative contributions of alexithymia and verbal IQ. *Research in Autism Spectrum Disorders, 77*, 101608. https://doi.org/10.1016/j.rasd.2020.101608

[2]Chapter 3 (Study 1; Sivathasan et al., 2020) was accepted for publication using the phrasing "people with autism spectrum disorder (ASD)" prior to published guidance from Bottema-Beutel et al. (2021) and CASDA (2020), which informed our prioritization of the phrasing "persons on the autism spectrum (AS)." Prior and subsequent chapters in this dissertation prioritize the latter terminology unless otherwise indicated.

Abstract

Background: People with autism spectrum disorder (ASD) have a unique way of navigating the social world around them, including processing emotions. Discrepancies in emotion processing between persons with ASD as compared to typically-developing individuals have been attributed to lower levels of verbal intelligence or the co-occurrence of alexithymia, a personality trait defined as a specific difficulty in identifying and expressing emotions. The purpose of this paper was to systematically review and summarize the literature on alexithymia, while accounting for verbal intelligence, in relation to the emotion processing of people with ASD.

Method: Of the 309 identified empirical papers, 13 were eligible for inclusion in this review. Information was compiled on performance on emotion processing tasks, measures of alexithymia, verbal IQ, and ASD symptom severity, as well as age range, sex, and type of study (e.g., behavioural, neuroimaging).

Results: The majority of studies included adults with average to above average verbal IQ. Overall, the findings from the 13 studies represent preliminary evidence that verbal IQ has a strong influence on performance on behavioural emotion processing tasks, while alexithymia influences physiological and brain responses to emotion tasks.

Conclusions: Both verbal IQ and alexithymia play an important and potentially distinct role in explaining how people with ASD process emotions at a behavioural and physiological level.

Keywords: autism; emotion processing; verbal intelligence; alexithymia

Introduction

A fundamental challenge for people with autism spectrum disorder (ASD) lies in difficulties navigating the social world around them, including processing emotions (Baron-Cohen & Belmonte, 2005). Emotion processing (EP) involves specific skills including identifying, recognizing, and generating basic emotions within oneself and others, and cuts across different levels of affective representation, including broad dimensions of valence and arousal, discrete emotions such as happiness and fear, and experiences such as those of pain. Emotional information is often provided implicitly from cues including facial and vocal expressions, prosody, semantics, and even through music. These lower order EP skills have certain implications for higher order socio-emotional skill development, including underlying the more complex processes of theory of mind, the ability to attribute mental states (e.g., emotions, beliefs, intentions) to oneself and others, empathy, and social cognition more broadly.

Much of the evidence regarding EP among people with ASD is predominately measured using tasks of emotion recognition (ER), and indicates often less accurate recognition of emotions in comparison to typically-developing (TD) people. In two overlapping meta-analyses that included studies from the past 40 years, accuracy on recognition of facial (N = 43; Lozier et al., 2014) and facial, vocal (verbal and non-verbal), and gestural emotional (N = 48; Uljarevic & Hamilton, 2012) expressions was reduced among people with ASD as compared to TD persons. Evidence from a meta-analysis of 13 neuroimaging studies also indicated that people with ASD display idiosyncratic neural processing of facial emotions compared to TD persons (Aoki et al., 2015). However, mixed findings at the individual study level, including some evidence of no group differences (e.g., Castelli, 2005; Ozonoff et al., 1990), have led some researchers (e.g., Bird & Cook, 2013; Ozonoff et al., 1990) to suggest that group differences may be accounted for by variables other than diagnostic group, i.e. other than ASD. Two distinct hypotheses have been offered about the potential source of the individual differences on EP skills within and between participant groups, specifically, verbal intelligence and alexithymia.

Verbal Intelligence

One hypothesis is that the EP difficulties found among people with ASD may be better explained by reduced performance on measures of verbal intelligence (verbal IQ or VIQ; henceforth used interchangeably). Recent prevalence estimates suggest that most children with ASD have an IQ score in the average range (44% above 85 and 25% in the "borderline" range of 70 > IQ < 85), whereas 31% have a comorbid intellectual disability (IQ < 70) (Christensen et al., 2018). Further, nearly 30% of people with ASD display stronger non-verbal than verbal skills (rendering the overall Full Scale IQ [FSIQ] less representative of intellectual potential than IQ subscales for a subset of the ASD population; Charman et al., 2011; Dawson et al., 2007). Given these population-level IQ differences and disparities across domains of functioning between people with ASD and TD people, accounting both for overall IQ and for areas of strengths and weaknesses across areas of functioning is essential for meaningful between-group comparisons (Burack et al., 2002, 2004).

The influence of verbal IQ may be especially relevant in EP research as the experimental tasks typically require that responses involve the use of verbal emotion labels (e.g., "choose which word corresponds with the facial emotion – happy, sad, fear"), abstract verbal reasoning, and verbal responses (e.g., "how does this person feel?"). In a recent meta-analysis, Trevisan and Birmingham (2016) found a significant aggregate correlation of $r = 0.42$ between verbal IQ and emotion recognition accuracy among 12 studies involving processing of emotions from faces. Verbal IQ has also been associated with performance on vocal (e.g., Golan et al., 2007) and musical (e.g., Heaton et al., 2008; Quintin et al., 2011) emotion recognition tasks. However, accounting for IQ, through group matching or as a statistical covariate, has not been adopted as a consistent practice, and a consensus about the specific effect of verbal IQ on EP by people with ASD has yet to be reached.

Alexithymia

Emotion processing difficulties among people with ASD might also be explained by co-occurring alexithymia, a personality trait defined as a specific difficulty in identifying and expressing emotions (Bird & Cook, 2013). Whereas alexithymia affects approximately 10-15% of the general population (Joukamaa et al., 2007; Parker et al., 1989), it is thought to be present in up to 40-65% of people with ASD (Berthoz & Hill, 2005; Silani et al., 2008). Alexithymia was identified as a construct in the early 1970s in the general population, and found to be present in several clinical populations or "disorders of affect regulation" (Sifneos, 1973, 1996; Taylor et al., 1997) including in persons with post-traumatic stress disorder (Frewen et al., 2008), depression and anxiety disorders (Marchesi et al., 2000), schizophrenia (Van't Wout et al., 2007), and eating disorders (Westwood et al., 2017). Further, in the general population, alexithymia has been found in the general population to be associated with EP behaviourally (e.g., facial emotion recognition, Jessimer & Markham, 1997) and neurologically (e.g., anterior cingulate dysfunction; Gündel et al., 2004).

Alexithymia is thought to be a multidimensional variable, comprising of both cognitive and affective aspects. Whereas Type I alexithymia is characterized as a reduced range of emotions experienced (affective dimension) as well as a reduced ability to verbalize felt emotions (cognitive dimension), Type II alexithymia encompasses solely the cognitive difficulty, with the affective dimension thought to be unimpaired (Vorst & Bermond, 2001). Thus, several distinct affective disorders may incorporate different aspects of alexithymia, with ASD thought to be primarily associated with Type II alexithymia (Heaton et al., 2012). Positive associations have been identified between higher traits of alexithymia and difficulty on EP tasks, rather than of diagnostic group (e.g., Allen et al., 2013; Cook et al., 2013).

Objectives

A significant body of work has been focused on the influence of verbal IQ on EP, with the majority of evidence in support of overall positive associations (e.g., Trevisan & Birmingham, 2016). Less work has been focused on alexithymia and EP, with preliminary findings indicating that better emotion processing is related to better ability to verbalize emotional experiences broadly (e.g., Bird & Cook, 2013). However, understanding whether these two processes (VIQ and alexithymia) are distinct, and confer distinct influence on EP, remains to be explored. Given the piecemeal individual study findings suggestive of potential relationships between both verbal IQ and alexithymia on emotion processing among people with ASD, a systematic investigation of the literature including both of these candidate traits is warranted, in an attempt to understand the relative contribution of verbal IQ and alexithymia to EP.

Thus, the goal of this systematic review is to collate and assess the empirical findings concerning the impact of alexithymia and verbal IQ on EP among persons with ASD, given that differences in both alexithymia and verbal IQ may disproportionally affect the emotion processing of this population. Further, as a great deal more research (e.g., that which is included in the aforementioned meta-analyses) has been conducted specifically on the influence of verbal IQ, and in an attempt to make direct comparisons and explore effects of their unique contribution where possible, we purposefully restricted the scope of this investigation to studies in which both measures of verbal IQ and of alexithymia were included. Special attention will be paid to relevant participant or study characteristics (e.g., age, sex, type of measurement instruments used, experimental paradigms) that may impact the study findings, as well as to nuanced findings to appropriate levels of generalization. Such an investigation is relevant toward understanding factors contributing to heterogeneity across the spectrum, as well as to providing potential targets for tailored socio-emotional interventions.

Method

Search Strategy

The methodology used to conduct the current systematic review adheres to established in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PRISMA group, 2009). Studies were identified via a literature search using three electronic databases to allow for coverage across the fields of study of medicine, science, and social science: "Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily 1946 to Present", "PsycINFO 1806 to July Week 4 2019", and "Web of Science." The following keywords were included as search terms, depending on the database used: "alexithymia" AND "autism" OR "autistic" OR "ASD" OR "Asperger" (in order to capture participants diagnosed under previous versions of the DSM). Alexithymia, a relatively newer concept to ASD research, was purposefully chosen as a search term over IQ in order to limit the subsequent manual search to studies that also include IQ, rather than the reverse (as many more studies unrelated to emotion processing involve IQ but not alexithymia). A unique search was conducted in accordance with each database's individual classification system in order to prevent searches that were not overly restrictive. For example, the keyword "autism spectrum disorder" is classified in PsycINFO as a topic under which all relevant articles including that keyword are “tagged” (yielding 40,942 hits), whereas “alexithymia” yielded 4520 hits as a keyword compared to 2791 hits as a topic.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are provided in Table 1. The information that was compiled included performance on emotion processing paradigms designed to objectively measure EP (rather than self-reported EP abilities), measures and scores of alexithymia, IQ, and ASD symptom severity, as well as age, sex, type of study (e.g., behavioural, physiological, neuroimaging), and summary of relevant results with consideration of the contribution of verbal IQ and alexithymia to EP. As the relationships among the main variables of interest (EP, verbal IQ, and alexithymia) have not explicitly been explored in tandem, other participant characteristics (i.e., age, sex) were purposely left unrestricted in order to complete a comprehensive survey of the available literature. Study methodology and results were also reviewed for inclusion and exclusion criteria.

Results

Data Compilation

A comprehensive literature search conducted on July 22, 2019 yielded 417 entries (67 from Ovid MEDLINE(R), 106 from PsycINFO, and 244 from Web of Science), and 309 unique entries after duplicates were removed using a reference citation software (i.e., Mendeley). Sixty-eight entries were retained for full-text review by the first and second author, of which 13 included a measure of verbal skills or verbal IQ, alexithymia, and results of an EP task (Figure 1). These 13 studies were selected independently by the first and second authors as the main focus of this review and of the results presented below. An additional 12 studies including FSIQ (incorporating both verbal and nonverbal components of IQ) were retained for a secondary qualitative analysis comparing findings from the FSIQ studies with those measuring verbal IQ, which were again selected independently by the first and second authors.

The relevant results of the 13 studies are presented in Table 2, in which the variables of interest are further summarized. Although no time restriction was placed on the search, we found that all of the articles that met eligibility criteria were published within the past 10 years. Experimental paradigms varied substantially, and are reviewed in comparison with those with similar characteristics. If the studies included additional tasks other than EP (e.g., theory of mind) only the EP tasks were reviewed and reported.

Participant Characteristics

Participant Groups

Variability was observed in the composition of the participant groups across the studies. Two of the 13 studies included participants who the authors noted as having "high-functioning autism" or Asperger's syndrome, whereas the remaining studies included participants with combinations of diagnoses of ASD, Autistic Disorder, Asperger's syndrome, and pervasive developmental disorder. Abbreviation of the specific term used by each study's authors to describe TD participants was maintained in Table 2 (e.g., control, neurotypical); otherwise, non-ASD groups will henceforth be referred to as the "comparison group." In 9 of the reported 13 studies, people with neurological and/or psychiatric comorbidities were excluded from participation in both groups (n = 5) or the comparison group (n = 4). Only one study (Milosavljevic et al., 2016) included two groups of participants with ASD (with and without alexithymia) and did not exclude those with psychiatric comorbidities (i.e., anxiety and depression).

Sex

Across the studies, the participant groups (both those of persons with ASD and the comparison groups) consisted of mostly males (75% of the group or more, *n* = 8), with only males included in 3 of the studies. Only one study (Schneider et al., 2013) involved a comparison between males and females with ASD and their same-sex TD peers. As the prevalence ratio is of 4:1 males to females diagnosed with ASD (Christensen et al., 2018), these groups would be considered fairly representative of sex distribution at a population level.

Age

Most studies (*n* = 11) were conducted with adult participants, with a mean age spanning 24 to 40 years across groups and studies. Therefore, the results of these studies are largely only generalizable to early and middle adulthood. Only one study included children (mean ages: 9-10 years; Trevisan et al., 2016) and one included adolescents (mean age: 15 years; Milosavljevic et al., 2016).

ASD Symptomatology

In all 13 studies, at least one standardized measure of broad ASD symptomatology was used to confirm the presence of ASD symptoms among the participants in the ASD group, and in most cases, to confirm the absence of symptoms in the comparison groups. Although the participants in all of the ASD groups had formal ASD diagnoses made by qualified health professionals, significant individual variability of scores was reported, including scores below established symptom cut-off scores among the participants in the ASD groups. Scores on the primary measure were reported in eleven studies (see Table 2).

Most of the studies (*n* = 10) involved a version of the Autism-Spectrum Quotient (AQ; Baron Cohen et al., 2001), a quick self-report screener of ASD symptoms or traits. In addition to an adolescent self-report version of the AQ, Trevisan et al. (2016) also included a parent-report version for those participants under 11 years of age. Reported mean scores across studies on the AQ for ASD groups were ≥ 32, which is the cut-off score considered as most useful for research studies. In some cases, the individual participants with ASD had scores on the AQ as low as 18 (self-report) and 9 (adolescent or parent-report), and at least two individual TD participants were reported to have an AQ score ≥ 32 (*n* = 1 adult self-report, Minio-Paluello et al. [2009]; and *n* = 1 adolescent or parent-report; Trevisan et al., [2016]). The pattern of the findings with outliers removed was not reported by Minio-Paluello et al. (2009) and was unchanged in the Trevisan et al. (2016) study. However, score ranges and/or standard deviations with which to evaluate individual scores overall were reported in *n* = 4 and *n* = 8 studies, respectively.

The parent-version of the Social Responsiveness Scale 2nd edition (Constantino & Gruber, 2012), another common diagnostic screener for ASD symptoms, was used in one study (Milosavljevic et al., 2016) to identify two ASD groups with reported score ranges between 21-137, representing a wide range of symptom variability.

Scores on a version of the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2008) for the ASD group were reported in 5 of the studies (Bird et al., 2010; Gaigg et al., 2018; Kliemann et al., 2013; Krach et al., 2015; Schneider et al., 2013). The reported mean Total Scores on the ADOS (ranging from 2-17, *n* = 3, one did not report a range) or Social Domain-specific scores (mean [SD] = 9.5 [4.5], *n* = 1) were above the suggested cut-off scores (Lord et al., 2008) of 7 and 4 for the Total and Social Domains, respectively.

Overall, many of the participants included in the ASD group did not necessarily show significant ASD symptoms via self- or observer-report, and group means remained near established cut-offs, suggesting that the studies generally included people with fewer and/or milder ASD symptoms.

Verbal and Full Scale IQ

The standard scores of the verbal IQ (VIQ) composite from a version of the Wechsler Adult Intelligence Scale (WAIS; Wechsler 1981, 1997, 2008), or its shortened form, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999, 2011) were used in nine of the studies. Scores from a German verbal intelligence test (Wortschatztest; Schmidt, & Metzler, 1992; Mehrfachwahl-Wortschatz-Intelligenztest; Lehrl, 1999) were used in two other studies. On these tests, the IQ scores are normally distributed among the general population (mean = 100, standard deviation [SD] = 15). Among the 11 studies in which VIQ composite scores were used, the mean scores were generally average to above average, ranging from 105-121 across the groups. Individual participants with scores below 85 were included in only two studies; as the scores ranged from 73-138 in Murray et al. (2017) and 61-120 in Milosavljevic et al. (2016). In the remaining two studies (Allen et al., 2013; Trevisan et al., 2016), raw scores on the British Picture Vocabulary Scale (Dunn & Dunn, 2009) and the vocabulary subtest of the WASI VIQ were reported. Regardless of the type of test that was used, explicit matching of groups for VIQ were noted in virtually all of the studies. In the one exception, Milosavljevic et al. (2016) reported a slightly lower VIQ in the group of participants with ASD and alexithymia compared to the group of participants with ASD and without alexithymia group (p = .05).

Full Scale IQ (FSIQ) scores were also reported in seven of the 13 studies, with mean standard scores ranging from 108 to 122. In six of these studies, the groups were also matched on FSIQ. Milosavljevic et al. (2016) were the only authors to include and match groups on lower mean standard FSIQ scores, between 92-95 (and reported individual participant scores between 70-119). Overall, the generalizability of findings from this review are largely restricted to people with average to above average verbal intelligence, and fairly equivalent verbal and non-verbal skills.

Alexithymia

The level or severity of alexithymia symptoms was examined in 10 of 13 studies with a version of the Toronto Alexithymia Scale (TAS; Bagby et al., 1994). The TAS is a self-report measure of agreement with 20 items (measured with a 5-point Likert scale) comprising three factor subscales: Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), and Externally-Oriented Thinking (EOT). The total score (combining all three factors) of the 20-item TAS was used in nine studies, whereas the EOT subscale score of a previous version (TAS-26) was used in the other study. Additionally, a version of the Bermond-Vorst Alexithymia Questionnaire (BVAQ; Vorst & Bermond, 2001) alone or in addition to the TAS was used in four studies. The BVAQ includes 40-items measuring cognitive and affective empathy via five subscales (Emotionalizing, Fantasizing, Identifying, Analyzing, and Verbalizing), self-reported on a 5-point Likert scale. Finally, the Children's Alexithymia Measure (CAM; Way et al., 2010) was used in one study involving children (Trevisan et al., 2016), to obtain parent report of observable symptoms, via 14, 4-point Likert scale items (producing a single factor score between 0-42).

Multiple accepted cut-off scores contributed to the significant variability of quantitative measurement of alexithymia. TAS-20 scores between 52-60 are indicative of mild to intermediate alexithymia, while scores >61 denote high alexithymia (Bagby & Taylor, 1997). By comparison, BVAQ total scores range from 20-100 with suggested cut offs of 43-45 for absence of alexithymia, and 50-53 for presence of alexithymia (Loas et al., 2015). Among the studies in this review, the mean scores on the TAS-20 ranged from 50-63 for the group of persons with ASD and 34-50 for the comparison group. In three of the 4 studies which used the BVAQ (as well as the TAS-20) matched groups on alexithymia and scores were reported. Bird et al. (2010) and Gaigg et al. (2018) reported mean scores ranging between 44 to 54 across groups. Komeda et al.

(2019) reported overall mean BVAQ scores between 85-90, suggestive of the presence of alexithymia symptoms among both the ASD and TD groups; notably, however, standard deviation scores were also relatively high, between 37-45. Among most of the remaining studies (8 out of 9), the groups were not matched on alexithymia, with the ASD groups having higher alexithymia scores than the comparison groups. In one case, Heaton et al. (2012) did not report what appear to be significant group differences (ASD group [*n* = 20]: *M* = 60.7, *SD* = 15.5, versus the comparison group [*n* = 20]: *M* = 36.1, *SD* = 8.9).

Overall, the group means generally fell near established cut offs for alexithymia, with few studies reporting inclusion of participants with very severe levels of self-reported alexithymia. Further, most of the analyses involved total alexithymia scores, and therefore conclusions about cognitive versus affective aspects of alexithymia were not possible.

Emotion Processing Task Results and Influence of Alexithymia and VIQ

Relevant results for each study (including means, standard deviations, and score ranges, when available) are outlined in Table 2, with findings concerning individual differences and EP described in greater detail below. The results are summarized by experimental paradigm type and by methodology (i.e. behavioural versus neurophysiological).

Social Emotion Recognition

“Classic” social (i.e., face, voice, multimodal) emotion recognition (ER) paradigms were used in approximately half of the reviewed studies (*n* = 6) to study the emotion recognition component of EP, as the task was to determine which emotion is being portrayed by a person. Three studies (including two of the aforementioned six) also involved social ER tasks to identify the participants’ self-perceived emotional experiences while observing emotion-eliciting stimuli, described below.

Facial Emotion Recognition. Facial expressions as the modality to study emotion recognition were used in four studies; three studies involved a comparison between a group of people with ASD with a group of people with TD, and one study involved the comparison of two groups of people with ASD (with and without alexithymia). With adult participants, Katsyri et al. (2008) and Murray et al. (2017) found no significant differences on overall performance on facial ER tasks between the ASD groups and age- and VIQ-matched comparison groups, despite higher total alexithymia scores in the ASD groups. Conversely, Kliemann et al. (2013) found reduced ER performance for the ASD group versus the comparison group, when the groups were matched on age, VIQ, and one of the three TAS-26 subscales of alexithymia (Externally-Oriented Thinking). Across these three studies, the participants were all of similar ages and VIQ scores, however, the severity of the two other subscales of the TAS-26 (Difficulty Identifying Feelings, and Difficulty Describing Feelings) in Kliemann et al.'s (2013) study is unknown, despite their greater relevance to facial emotion recognition. Although alexithymia was not specifically examined in these three studies, trends or significant negative correlations between alexithymia and task performance were found in the two studies with additional analyses (Katsyri et al., 2008; Kliemann et al., 2013).

Milosavljevic et al. (2016) compared adolescent age-matched participants with ASD with and without alexithymia. This comparison allowed for the unique "control" of ASD symptoms (matched between groups). After statistically controlling for VIQ (as well as anxiety symptoms), Milosavljevic et al. found no difference between groups on facial ER task performance. Thus overall across the four studies, facial ER accuracy appears to be influenced to some degree by both VIQ and alexithymia, despite variability in task demands (i.e., matching verbal labels to static photos or dynamic videos, looking at the eyes, matching lower and upper halves of faces, and use of filters).

Vocal Emotion Recognition. Heaton et al. (2012) found reduced accuracy for the participants with ASD versus an age-, VIQ- and FSIQ-matched comparison group on a combined verbal and nonverbal vocalizations ER task. ER performance was negatively correlated with alexithymia scores overall, which were nearly two times greater in the ASD group versus the comparison group (though statistical comparison of alexithymia between groups was not reported). In this study, FSIQ was correlated with vocal ER performance in the comparison group but not the ASD group, suggesting differential impact of IQ, and likely alexithymia and ASD symptoms (both higher in the ASD group), on ER performance depending on the sample.

Multimodal Emotion Recognition. Emotion recognition (ER) tasks with multiple social inputs arguably comprise the most ecologically valid representations of emotional expression in daily life. In one study, Schneider et al. (2013, part B in Table 2) measured ER using videos of actors displaying emotional versus neutral facial expressions, prosody, and verbal semantic content (i.e., emotional or neutral sentences). The participants were asked to rate how the actor felt on a visual analog scale of -3 (very negative) to +3 (very positive) and, therefore, did not need to identify the emotion using a verbal label response. Their responses were then analysed as a match or mismatch with the stimuli. Schneider et al. also included groups composed of roughly equal numbers of age- and VIQ-matched males and females with and without ASD (the females with ASD were slightly younger than the females in the comparison group, $p = .05$). No group differences were found in the comparison between males with and without ASD. No differences were found among the female groups when the situation was emotional (with specific emotions or intensity patterns collapsed and analyses presented in aggregate). However, reduced performance accuracy by females with ASD versus comparison females was found for identifying how the actor felt when the situation was neutral (i.e., neutral situations were rated as more emotional).

Music Emotion Recognition

Aside from ER measured in the social modalities, the use of music as a modality to study ER is of interest in the ASD research literature as people with ASD tend to enjoy music and possess musical skills comparable with the general population (e.g., Bhatara et al., 2013; Heaton et al., 2008). In the one study that involved musical emotion recognition, Allen et al. (2013) found no group differences between the ASD group and the age-, VIQ-, and alexithymia-matched comparison group when alexithymia was accounted for, and that lower alexithymia scores were predictive of better task performance, corroborating general findings from social modalities. However, AQ scores were not reported, and therefore ASD symptom severity was not described.

Self-Perception and Production of Emotions

Three studies were focused on how people with ASD perceive or identify their own emotional states in reaction to videos of actors' emotions. These tasks differed from classic ER paradigms in that they depended less on a verbal response (e.g., matching an emotion word or label to a stimulus). Using the same stimuli in their multimodal ER task, Schneider et al. (2013, part A in Table 2) administered a self-perception task on which the participants rated how they felt in response to viewing videos of an actor relaying a neutral or emotional story (i.e., coordinated facial expressions, prosody, and semantic content), on a visual analog scale of -3 (very negative) to +3 (very positive). They found that, as compared to those without ASD, the emotions of age- and VIQ-matched participants with ASD matched less with the actor's emotions. Additionally, their emotions were more intense than the actors' emotions in the neutral condition, but less intense in the emotional condition. However, higher alexithymia scores among the persons with ASD were not accounted for in this analysis. In a similar study, Gaigg et al. (2018) also asked their participants to rate how they felt in terms of valence (positive/negative) and arousal (intensity of their felt emotion), while viewing affective (social and non-social) images. They found no differences on ratings of valence or arousal between the ASD group and the age-, VIQ, and alexithymia-matched comparison group, but found that alexithymia was negatively correlated with arousal ratings.

Among children, Trevisan et al. (2016) measured the experience of participants with and without ASD while viewing videos intended to elicit emotional (positive, negative, and neutral) responses. The amount of facial emotional expression produced by the participants was used as a proxy for appropriate emotional reactivity. Across both groups, they found that alexithymia was negatively correlated with overall frequency of facial expressions produced, as well as with the production of negative facial expressions, and positively correlated with production of neutral facial expressions. No relationship was found with positive facial expressions. ASD symptoms and alexithymia scores were higher in the ASD group versus the comparison group, although Trevisan et al. noted no significant effect of ASD symptoms (measured with the Autism Quotient) on the production of facial emotions after alexithymia was considered. The participants were approximately the same age across the groups (mean age of 10 for the participants with ASD group vs. 9 for the comparison group, $p < .05$) and the groups were matched on a subtest measure of verbal IQ (vocabulary subtest score). Thus, alexithymia seems to have a unique contribution to the production of facial emotions, independent of ASD symptoms and verbal IQ.

Across these three studies, group differences in self-perception or production of emotions tended to disappear when both alexithymia and verbal IQ were considered by Gaigg et al. (2018) and Trevisan et al. (2016), whereas group differences were found in Schneider et al. (2013, part A) when alexithymia was not controlled. As would be expected, alexithymia likely bears a significant impact on identifying or producing one's own emotional response on behavioral tasks, however to tease this effect apart from the influence of verbal IQ, more studies are needed to examine the robustness of this preliminary finding. In summary, 10 studies (i.e., 7 of emotion recognition, and three of self-perception and production), reported in 9 papers, of emotion processing by persons with ASD versus comparison groups were reviewed. In 5 of the 7 ER studies in which verbal IQ was taken into account, no group differences were reported on emotion processing accuracy in the social (Katsyri et al., 2008; Milosavljevic et al., 2016; Murray et al., 2017; Schneider et al., 2013, part B) and musical (Allen et al., 2013) modalities, regardless of either the varying levels of alexithymia symptoms among groups or whether alexithymia was controlled statistically in group comparisons. This suggests that verbal IQ may have a stronger influence than alexithymia on tasks that involve the recognition of basic emotions. However, the findings from three of the 7 ER studies that were specifically focused on the influence of alexithymia symptomatology broadly (Allen et al., 2013; Heaton et al., 2012; Katsyri et al., 2008), and from one that was focused on the externally-oriented thinking subscale of the TAS-26 (Kliemann et al., 2013) included negative associations between alexithymia symptomatology and task performance as higher alexithymia scores were associated with less accurate recognition of emotions. Further, in the studies of emotional self-perception and production, no differences were reported between ASD and comparison groups when verbal IQ was taken into account, although negative associations between alexithymia and task performance were found in two of the three studies (Gaigg et al., 2018; Trevisan et al., 2016). Thus, given the variability in these findings, as well as among task demands themselves, both verbal IQ and alexithymia should be controlled on tasks of basic emotion processing as both may have an influence on performance.

Empathy for Pain

Understanding one's own and others' experience of pain is an important evolutionary preservation function that promotes pro-social behaviour. The experience of pain involves sensory, cognitive, and affective-motivational aspects, which form a complex neural network known as the "pain matrix" (Melzack, 1999), the affective aspect of which recruits the same neural pathways as empathy more broadly (Singer et al., 2009). This review includes four studies with various behavioural empathy-for-pain paradigms, three of which also involved neuro-physiology measures. Bird et al. (2010) used an in vivo small electric shock provided to the participant and a companion (close other), and participants rated their level of unpleasantness to self-pain and other pain. They found that despite no group differences in physiological pain thresholds, the ASD group rated a low pain condition as more unpleasant compared to an age-, VIQ-, and alexithymia-matched comparison group, whereas no effects of the high pain condition or between alexithymia and pain were noted.

Photo or video exposure to physically- and socially-painful experiences were used in two studies to study correlates of empathy. Social pain can be thought of as the vicarious empathic experience of another person's physical or emotional pain (e.g., vicarious experience of another person's embarrassment or rejection). Minio-Paluello et al. (2009) showed participants videos of painful and non-painful actions to a social (hand) and non-social stimulus (tomato) and collected behavioural ratings of arousal and aversion to the videos. Alternatively, Krach et al. (2015) had participants rate the intensity of physical pain observed in photos (compared to neutral photos), as well as level of embarrassment to socially painful/undesirable drawn scenes (compared to a socially neutral scene). Across both of these studies, no differences in behavioural ratings of pain intensity across physical, social, and no pain conditions were found between the groups pf persons with ASD and the VIQ-matched comparison groups despite higher alexithymia scores in the ASD groups.

In another study of empathy for social pain, Komeda et al. (2019) used vignettes to convey social pain and need for help more broadly, featuring ASD or TD protagonists. The participants were asked to rate their level of cognitive empathy toward the protagonist, as well as whether they would be motivated to help. Komeda et al. (2019) found that the participants with

ASD displayed greater cognitive empathy and helping motivation toward ASD protagonists as compared to the VIQ-matched TD participants, when alexithymia and AQ scores were controlled, but no differences were found between the groups in cognitive empathy and motivation toward TD protagonists after these variables were considered. Further, they found that cognitive empathy was associated with the cognitive alexithymia subscale of the BVAQ, which was significantly higher among the participants ASD versus the TD participants (although the overall BVAQ scores were not significantly different between groups). Overall, data from these studies suggest that alexithymia may not have a strong influence on behavioral ratings of physiological or social pain of ASD versus VIQ-matched typically-developing people, perhaps because of a reduced reliance on a need for identifying or expressing emotions (which taps more into alexithymia) as compared to expressing an understanding of one's own and others' pain.

Neurophysiological Correlates of Emotion Processing

In addition to behavioural data, additional, objective measures of EP (neurological or physiological data) by people with ASD in comparison to their TD counterparts were collected in 6 of the 13 studies in this review. Within the context of emotion recognition paradigms, Gaigg et al. (2018) and Allen et al. (2013) found no group differences of physiological arousal (measured via galvanic skin response), and instead found that alexithymia was negatively correlated with physiological arousal across age-, VIQ-, and alexithymia-matched groups. Further, Schneider et al. (2013) found no group differences in EP-related brain activation (using whole brain fMRI analyses), when alexithymia was considered. Instead, significant differences were found between the sexes within the ASD group, with greater activity of bilateral medial frontal gyri (associated with executive functions and decision-making) in the males versus the females. Reduced activity in the periaqueductal gray (associated with pain and threat) extending to the left amygdala (associated with emotion processing) was found in the females with ASD versus the females in the comparison group, but no differences were found among males. However, the interpretation of these differences must be qualified as the females in the ASD group had greater mean AQ scores (41) as compared to the males (34.9), whereas in the comparison group, the males had slightly higher scores (11.9) as compared to the females (7.9).

Some neurophysiological differences were found in empathy-for-pain paradigms. Krach et al. (2015) found reduced pupil dilation to social pain versus neutral stimuli in the ASD group versus the VIQ-matched comparison group, but no significant group effect in pupil dilation comparing physical pain and neutral photos. Minio-Paluello et al. (2009) found that the ASD group had less muscle-specific modulation, as measured by electromyography (EMG) technology, to pain videos as compared to the comparison group, but no group differences in overall corticospinal reactivity. Further, neuroimaging results via fMRI and transmagnetic cranial stimulation (TMS) showed less activation overall in the ASD versus comparison group for the social pain versus neutral contrast, but not for the physical pain versus neutral contrast (in which both groups had bilateral activation of the anterior insula cortex [AIC] and anterior cingulate cortex [ACC], both involved in emotion processing; Krach et al., 2015), and no group differences for corticospinal reactivity (a marker of empathic physiological arousal) measured via TMS (Minio-Paluello et al., 2009). However, in both of these studies, the participants with ASD reported higher levels of alexithymia than the comparison group, which was not taken into account in the analyses. In contrast, when alexithymia was controlled, Bird et al. (2010) did not find any group effect for left AIC activity to other pain, and instead found that a difference in left AIC activity was discernable when comparing the difference between participants with low versus high alexithymia. Thus, given that only one of these studies controlled for alexithymia symptoms, the extent to which group differences in empathy for pain detected at the neural or physiological levels are attributable to symptoms of alexithymia or ASD remains unclear.

In summary, there were no reported differences between groups in physiological responses to emotional stimuli when controlling for alexithymia and VIQ (Allen et al., 2013; Gaigg et al., 2018). Differences in neurological activity also seem to be influenced by level of alexithymia, rather than diagnosis, as group differences in brain activation were no longer present when alexithymia was accounted for (Bird et al., 2010; Schneider et al., 2013). In empathy for pain studies, reduced pupil dilation and brain activation, particularly in the ACC and AIC (Krach et al., 2015), and less muscle-specific modulation (Minio-Paluello et al., 2009) was found in people with ASD compared to a typically-developing (TD) comparison group, however, only differences in VIQ were controlled for, not alexithymia. Thus, researchers should consider whether group differences in neurophysiology would remain after controlling for alexithymia in empathy for pain paradigms as compared to emotion recognition tasks.

In considering behavioural measures of empathy for pain paradigms, no clear pattern of results is evident. People with ASD may show stronger empathic reactions to in vivo pain (small electric shocks) in themselves and a close other (e.g., friend, caregiver) than VIQ- and alexithymia-matched comparison participants (Bird et al., 2010). Conversely, the use of observational methods to elicit empathy (viewing pictures of unknown others in physical or social pain) did not allow for the detection of behavioural differences between ASD and VIQ-matched comparison groups, despite higher levels of alexithymia among the participants with ASD (Krach et al., 2015; Minio-Paluello et al., 2009). Eliciting empathy for TD protagonists via vignettes also did not detect differences between ASD and VIQ-matched groups, even after alexithymia and autism symptomatology were controlled (Komeda et al., 2019).

Considering Full Scale IQ

As few studies in the literature included both measures of alexithymia and VIQ, a cursory look was taken at the behavioural results from 12 additional studies (11 using adult samples, all with average to above-average FSIQ scores) that met the original review criteria but included FSIQ (including both verbal and non-verbal components) instead of VIQ specifically, to determine whether this variable could also be informative. In sum, in 4 of the 5 studies in which an empathy-for-pain paradigm were used, no group differences were found between the ASD and FSIQ-matched comparison group when alexithymia was considered (Fan et al., 2014; Hoffmann et al., 2016; Thaler et al., 2017). Further, when alexithymia was not statistically controlled, it was found to be significantly negatively correlated with task performance (Gu et al., 2015). Conversely, Lassalle et al. (2019) found no differences on performance accuracy on two empathy-for-pain tasks (face and limb) between the ASD and FSIQ-matched comparison groups; although statistically higher mean alexithymia scores were found among the ASD group, the range overlaps (ASD group [n = 16]: M = 53.69, SD = 9.10, range = 35.69 vs. comparison group [n = 14]: M = 44..93, SD = 9.56, range = 23-64).

On social EP paradigms, no differences were found between the groups with a facial EP task specifically measuring: broad ER skills in adolescents (Wieckowski & White, 2017); on tasks involving rating pleasantness or unpleasantness of affective images (Silani et al., 2008); emotion recognition from the eyes (Oakley et al., 2016); ER from faces and voices together (Ketelaars et al., 2016; Mul et al., 2018), ER of anger and disgust (Cook et al., 2013); or ER face-body cue integration for anger and disgust (Brewer et al., 2017), when alexithymia was matched at the group-level (n = 2), statistically considered (n = 4) or even when alexithymia was not controlled for (n = 1).

An overall pattern of results regarding the influence of alexithymia on EP is evident when holding FSIQ constant, at least in the case of average to above average IQ. This may be due to the likelihood of a “flat profile” (i.e., where both verbal and non-verbal skills are strong), but this cannot be ascertained confidently without individual level data. Nevertheless, these findings, in combination with the 12 studies that included VIQ reviewed in this investigation, provide compelling evidence for the need to measure and account for variability in both alexithymia and IQ among people with ASD, in order to make fair and accurate within- and between-group comparisons about EP.

Discussion and Implications

The purpose of the current systematic review was to attempt to identify the relative influence of alexithymia and verbal IQ to emotion processing by people with ASD, in comparison to typically-developing people. While greater levels of alexithymia are correlated with reduced performance across a variety of EP paradigms and across groups, it also tends to be higher in, but not specific to, people with ASD, creating the illusion that alexithymia and ASD are one in the same. Given the variability of alexithymia scores across groups and studies, group-matching or statistically accounting for its influence is necessary to parse out the influence of diagnostic group versus alexithymia on EP.

We considered the relative influence of verbal IQ, as compared to alexithymia, on EP. Across the studies, the findings seem to suggest, albeit tentatively, that verbal IQ may have a greater influence than alexithymia on performance on behavioural EP tasks (i.e., basic emotion recognition, emotional self-perception, and production); however, negative associations were also often found between alexithymia and task performance such that higher reports of alexithymia were associated with reduced accuracy in task performance. On behavioural ratings of empathy for pain tasks, no differences were found using observational methods and vignette ratings for VIQ- and alexithymia-matched groups, but differences were reported when the task involved in vivo electric shocks to the self and a close other, and relied less on a cognitive understanding of empathy. Further, when examining physiological and brain response to EP tasks, group differences disappeared after alexithymia was considered. In cases in which ASD or alexithymia symptoms did not account for group differences, verbal IQ seemed to have an influence on participants' comprehension of task instructions more generally, whereas conversely, alexithymia is considered a trait and was related to emotion-induced physiological responses. That is, as alexithymia may often not be self-reported due its subtleties or the lack of awareness among the individuals whom it affects, it may be more easily detectable with physiological measurements (and indeed, VIQ is also measured by clinicians or researchers, rather than self-reported). A growing body of literature suggests that alexithymia may be linked with atypical or reduced interoception (self-perception of the body's internal physiological state and sensations) in the general population and among persons with ASD (e.g., Murphy et al., 2018; Shah et al., 2016). Alternatively, a lack of group difference on EP tasks could be due to task ceiling effects, resulting in a lack of correlation between scores on alexithymia measures and EP tasks. However, given such variability in task design and demand, both verbal IQ and alexithymia should be controlled to more precisely answer questions related to diagnosis.

These conclusions must be considered with regard to the limitations inherent in the studies that were included in the review. Nearly all of the studies in this review included adults with VIQ scores above 85 as part of their study inclusion criteria, and consequently, conclusions can only be generalized to this subset of the ASD adult population. Thus, conclusions about the influence of alexithymia when verbal IQ is held constant are also limited to those with varying levels of alexithymia and average to above average verbal IQ. To understand the impact of verbal IQ as compared to alexithymia on EP, the reverse analysis of holding alexithymia constant while accounting for variation of verbal IQ needs to be conducted. Furthermore, the relationship between verbal IQ and alexithymia needs to be explicitly explored, as emerging patterns between reduced emotional language processing (e.g., measured via word generation, priming tasks, prosodic cues; see Welding & Samur, 2018 for a review) and higher symptoms of alexithymia have been described. Hobson et al (2019) argue in their “alexithymia-language hypothesis” that the emergence of language processing deficits more generally may lead to alexithymia. Additional research involving these potential relationships among persons with ASD or in other clinical populations in which language may be impacted by congenital (e.g., deafness, learning disabilities) or acquired conditions (e.g., stroke) is needed.

As discussed, the experimental paradigms included in the studies reviewed were highly variable, and the level of task demands within and between studies is difficult to measure, which contributes to the difficulty in teasing apart and summarizing study findings. For example, tasks that are heavily verbal (e.g., tasks that require multi-step verbal responses, use abstract language, include ratings of degree of intensity) may potentially be more taxing for persons with low average VIQ scores than more concrete visual-matching paradigms (e.g. tasks that use emoticons, pictures of faces, single-word labels), or those which include fewer response options. Concordantly, group comparisons involving persons with ASD and other groups are difficult to evaluate across studies due to differences in matching (at the participant-level versus the group-level) and the wide variability in group matching variables (e.g., verbal IQ, nonverbal IQ, full scale IQ). Whichever variable is used to match groups or individual participants may inherently restrict the natural variability of that particular trait (e.g., as this often occurs with inclusion of people with average, versus lower IQ scores). Many of the same considerations are also relevant to the study of alexithymia traits, in regards to matching and involving the use of different cut-off scores on the relevant measures.

The composition of groups with regard to specificity of ASD diagnoses and of potential comorbid psychiatric conditions among the groups of persons with ASD or the comparison groups, was not explicitly explored in the majority of studies included in this review.

Specifically, commonly co-occurring conditions with ASD and/or alexithymia, such as anxiety disorders, were included and investigated in just one study (Milosavljevic et al., 2016), and thus potential influence of these conditions among persons with ASD as well as comparison groups (when it was not excluded) on EP findings is unknown. Further, despite diagnostic labels assigned to the groups of persons with ASD group versus the comparison groups, some participants with ASD endorsed few ASD symptoms, and alexithymia scores were also relatively low overall. Finally, information on socioemotional interventions to which participants with ASD may have been exposed was not provided in the reviewed studies, which can variably influence performance on EP tasks.

Another inherent limitation to this body of research involves the use of self-report questionnaires for measuring alexithymia and autism symptoms. Namely, the accuracy of self-reported descriptions of emotional experiences and social skills challenges is difficult to ascertain as these are areas of difficulty for people with ASD. Caregiver-report can be a useful addition, though this certainly is not always a feasible or relevant option. Clinician-led evaluations remain the gold standard for assessing ASD symptomatology, and features of alexithymia could be evaluated in a similar manner (i.e., via interview with a trained professional). Although tools have been developed to clinically evaluate alexithymia (e.g., the Toronto Structured Interview for Alexithymia [Bagby et al., 2006], Beth Israel Hospital Psychosomatic Questionnaire [BIQ; Sifneos, 1973] and a modified BIQ [Taylor et al., 1997]), they are rarely used–despite recommendations for the use of multi-method assessment (Bagby et al., 2020)–which appears to be due, in large part, to the length of time required to conduct the semi-structured clinical interviews. Further research is also needed to assess the validity and reliability of clinical interviews in relations to self-report alexithymia measures (as has been found to be strong between the gold standard Autism Diagnostic Observation Schedule [ADOS-2, Lord et al., 2012] and the Social Responsiveness Scale [SRS-2; Constantino & Gruber, 2012] for example). Some preliminary evidence suggests good interrater reliability among college participants with average cognitive abilities (see Bagby et al., 2020 for a review), but more is needed for persons functioning at lower IQ levels or those with comorbid developmental conditions. Thus, additional research using clinician, caregiver, and self-report measures in these populations may confer added confidence for better understanding the presentation of alexithymia among people with ASD and/or with lower VIQ scores.

Null results were reported in many of the studies reviewed. Null results do not confirm no differences between groups on the target performance or behaviour, as there can be many reasons for non-significant group differences, including a lack of statistical power. From an analytical perspective, covariation removes extraneous variation statistically, but this cannot be removed from the person's lived experience. Thus, even those studies that provide "clean" findings are limited in their generalizability. Considering other types of analyses, such as path analyses, may provide valuable information regarding the unique and shared variance accounted for by alexithymia and VIQ, providing a more contextual, nuanced understanding of EP in a highly heterogeneous population.

Future Directions: Considering Heterogeneity

As is often described of people with ASD, heterogeneity is the rule, not the exception (Pelphrey et al., 2011). When conducting research on EP among people with ASD, differences in IQ profiles, ASD subtypes, gender presentation of socio-emotional skills, developmental trajectories, for example, must be considered. We need to find ways to measure and include participants with IQ scores below 85 (who make up approximately half of the ASD population). Verbal IQ may offer a unique or greater contribution to EP, relative to other individual differences, among people with ASD who fall in this sub group. For example, our recent findings suggest that adolescents with ASD with VIQ scores above or below 80 recognize emotions in faces and music accurately but emotions are rated as more intense by adolescents with ASD with VIQ scores below 80 compares to those with VIQ scores above 80 (Dahary et al., 2018). In addition, accounting for FSIQ when verbal and nonverbal skills are relatively equivalent and representative of the individual's overall cognitive abilities may be worthwhile, however comparing groups on verbal, non-verbal, and FSIQ when possible may allow for discovery of potential relative influences of each of these aspects to EP.

Emotion processing difficulties appear to be a fundamental challenge of people with ASD; however, these difficulties may not be specific to them. If EP difficulties are inherent to the etiology of ASD, they should be apparent across studies, and paradigms, and not be associated with more than one variable (Ozonoff et al., 1990). Alexithymia and verbal IQ are two relevant candidate variables, and researchers should account for the influence of these variables together. Considering variability along the spectrum based on differences in verbal IQ and alexithymia symptoms is necessary in order to understand whether one or both are independently associated with emotion processing in the service of fair group comparisons in research.

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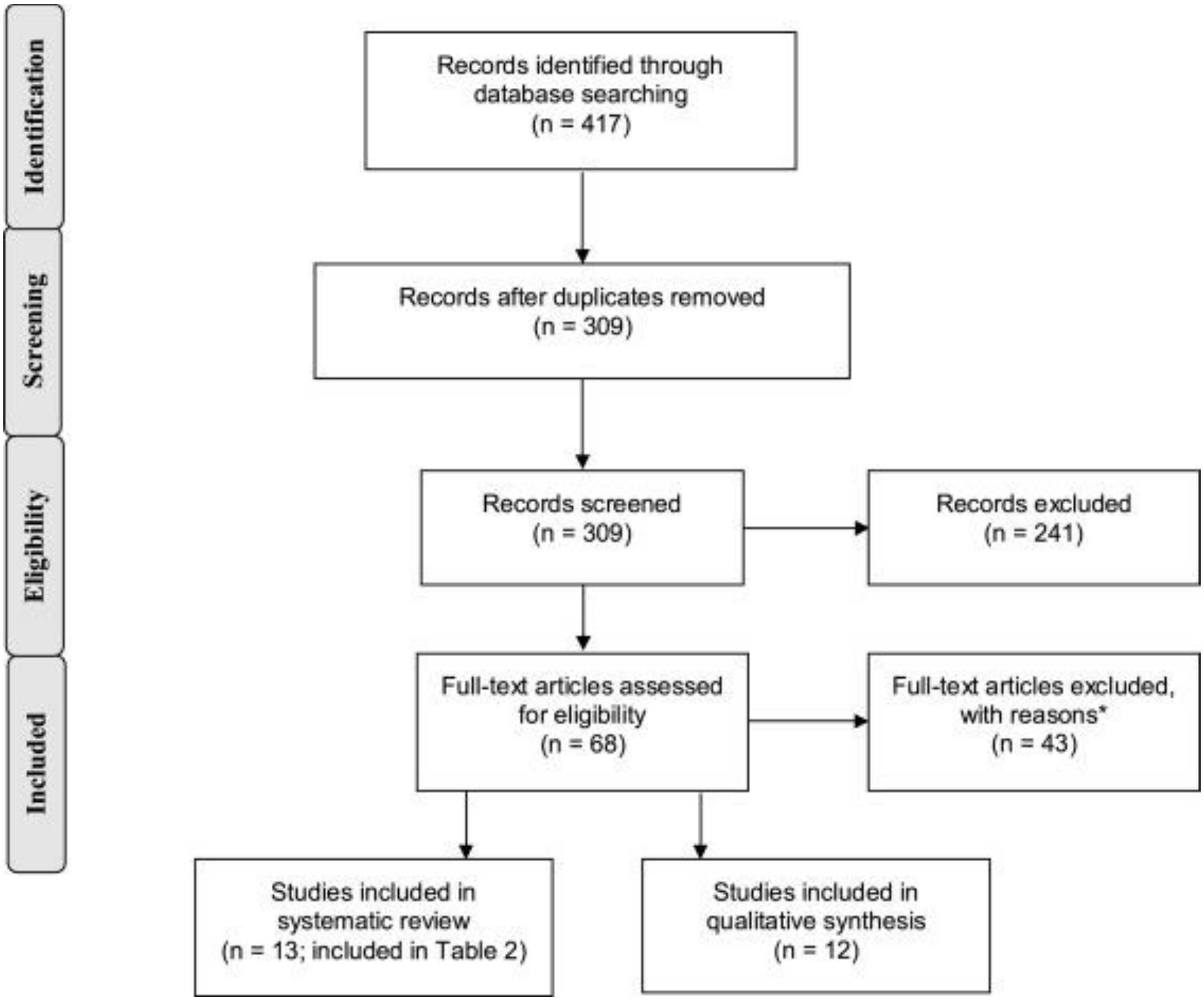
Appendix: Tables and Figures

Figure 1

PRISMA Flow Diagram of Included and Excluded Studies



Note. *Reasons for exclusion: no explicitly described measure of verbal or general or full-scale (i.e., verbal and nonverbal) IQ or scores not reported (n = 15); no measure of alexithymia (n = 11); not an experimental design/task (n = 2); not a basic emotion processing task (i.e., higher order mentalizing (n = 2); moral dilemma (n = 5); empathizing toward someone eating a lemon (n = 1); basic non-emotional interoception or face processing (n = 4); not written in English (n = 1); conference proceeding (n = 1); dissertation (n = 1). From "Emotion processing and autism spectrum disorder: A review of the relative contributions of alexithymia and verbal IQ," by S. Sivathasan, T. P. Fernandes, J. A. Burack, & E. M. Quintin, 2020, Research in Autism Spectrum Disorders, 77, 101608 (https://doi.org/10.1016/j.rasd.2020.101608). Copyright 2020 by Elsevier Ltd.

Table 1

Inclusion/Exclusion Criteria used in Screening Articles

Criteria	Inclusion	Exclusion
Population	"Participants with ASD" must have a characterized diagnosis of an autism spectrum disorder (using DSM-5/ICD-10 criteria or previous) either as reported by gold-standard ASD diagnostic instruments (e.g., ADOS, ADI-R; reported scores not required), or professional clinical judgement (e.g., physician, psychologist). Studies including "participants with autistic traits" eligible for inclusion if autistic traits are measured and reported using a standardized self- or other-report tool (e.g., Autism Quotient). No age/sex restriction.	No description of established method of characterization used for participants with ASD or participants with autistic traits (described in inclusion criteria).
Study Design	Randomized controlled design or quasi-experimental design with a comparison group (no specific inclusion criteria of comparison group necessary).	Non-experimental designs (e.g., case studies, systematic reviews). No comparison group.
Emotion processing paradigm	External/objective measurement of emotion processing abilities using an experimental (behavioural, physiological, or neuroimaging) paradigm. Emotion processing definition used includes tasks measuring basic emotion recognition, empathy for pain, first & second-order theory of mind/perspective-taking/empathizing.	Subjective report of emotion processing abilities. Paradigms that measure higher-order aspects of empathy (e.g., moral dilemmas, complex emotion processing, higher order mentalizing about self/other representations).
Methodological approach	Quantitative design and data analysis	Qualitative design and data analysis
Individual difference measures	Standardized objective measure of general intelligence (i.e., verbal and nonverbal IQ components) or verbal IQ only with aggregate scores reported. Standardized measure of alexithymia (self- or other-report) with aggregate scores reported.	No reported IQ or alexithymia measure administered, or no aggregate scores reported for one or both measures. Reported use of non-verbal IQ measure only.
Publication type/date	Peer-reviewed published scientific journal articles accessible online, published in English. No publication date restriction.	Non-peer reviewed scientific journal articles (e.g., conference proceedings, theses/dissertations). Published journal articles in language other than English.

Note. From "Emotion processing and autism spectrum disorder: A review of the relative contributions of alexithymia and verbal IQ," by S. Sivathasan, T. P. Fernandes, J. A. Burack, & E. M. Quintin, 2020, Research in Autism Spectrum Disorders, 77, 101608 (https://doi.org/10.1016/j.rasd.2020.101608). Copyright 2020 by Elsevier Ltd.

Table 2

Summary of Studies including a Measure of Verbal IQ, Alexithymia, and Effects on Emotion Recognition Task Performance

Author (Year)	Participants	Age	ASD Scores	IQ Scores	ALX Scores	Experimental Paradigm	Task Performance & Relevant Results
Allen et al. (2013)	N=23 ASD (18 male) N=24 TD (18 male)	32.5 years (13.7) 36.9 years (12.3)	AQ: Scores not reported	BPVS: ASD=154.7 TD=150	BVAQ (factors 2 & 4): Scores not reported, but noted as n.s. group diff.	Musical ER task 1)Word-to-music ER association checklist 2)GSR during #1	1)ALX (-) predicted task performance*; N.s. group diff. in word association when ALX accounted for 2) N.s. group diff. in GSR to ER task; Effect of ALX* and musical experience* on GSR
Bird et al. (2010)	N=18 ASD (18 male) N=18 Con (18 male)	34.6 years (13.3), 19-60 35.0 years (12.8), 22-63	ADOS Total: ASD=13/18 > cut off of 7, 2-17	WAIS-III VIQ: ASD=117.3 (13.4) Con=118.9 (7.9) WAIS-III FSIQ: ASD=115.8 (14.6) Con=118.8 (11.7)	TAS-20: ASD=57.2 (11.8), 37-80; Con=50.3 (14.5), 27-72 BVAQ: ASD=54.2 (8.4); Con=51.4 (9.7)	Empathy for pain task (small electric shock) 1)Likert rating of level of unpleasantness to self (“self-pain”) and close other (“other pain”) 2)fMRI (a. whole brain and b. ROI) during #1	1)ASD group rated low pain more unpleasant vs.TD group*; N.s. group diff. for high pain; Rel’n between ALX & pain n.s. 2)a. Left AIC activity in low ALX & low vs. high ALX diff.*; N.s. effect of ADOS scores on brain activity or ALX b.TAS-20 (-) corr. with left AIC activity to other pain*; N.s. group effect of left AIC to other pain after accounting for ALX
Gaigg et al. (2018)	N=13 ASD (13 male) N=13 TD (12 male)	38.8 years (11.9), 25-61 40.8 years (10.9), 19-57	AQ: ASD=37.1 (6.4), 26-45 TD=16.9 (6), 4-23 ADOS Total : ASD=9.6 (3.6), 5-17	WAIS-III VIQ: ASD=108.5 (11.3) TD=110.3 (15.5) WAIS-III FSIQ: ASD=108.5 (14.2) TD=108 (14.6)	BVAQ: ASD=47.8 (9.1), 36-64 TD=44.6 (7.9), 34-61	Affective image ER task 1)Likert rating of how image made them feel (+/-valence) and intensity of their emotion (arousal) 2)GSR during #1	1)N.s. group diff. for valence or arousal ratings 2)N.s. group diff. for GSR; GSR (+) correlated with arousal ratings across groups*; ALX (-) correlated with GSR* and arousal ratings*, n.s. group diff
Heaton et al. (2012)	N=20 ASD (15 male) N=20 Con (15 male)	33.7 years (12.8) 33.6 years (12.1)	AQ: ASD=34.7* (5.9), 26-47 Con=10.2* (4.6), 4-18	WASI VIQ: ASD=106.4 (17.5) Con=109 (12.8) WASI FSIQ: ASD=109.1 (18.4) Con=109.5 (15.1)	TAS-20: ASD=60.7 (15.5) Con=36.1 (8.9)	Verbal and nonverbal vocalization ER task 1)Select corresponding emotion label	1)↑ ER accuracy overall for TD vs. ASD group*, and for nonverbal vs. verbal voices*; ER (+) correlated with FSIQ for TD* but not ASD group; ER (-) correlated with ALX across groups*
Katsyri et al. (2008)	N=20 AS (13 male) N=20 Con (13 male)	32 years (10) 31 years (8)	ADOS: scores not reported	WAIS-R VIQ: AS=110 (11) Con=116 (8) WAIS-R FSIQ: AS=112† (13) Con=116† (11)	TAS-20 AS=55* (12) Con=36* (6) (7/20 ASD >60 cut off, 0/20 for Con)	Facial ER task (static & dynamic) with “strong” “slight” and “no” filters Likert rating of certainty for how well each of 6 emotions matched each stimulus	1)N.s. group diff. for overall ER, nor for static vs. dynamic stimuli; N.s. group effect for slight and no filter; ↑ ER for strong filter in Con vs. AS group; Strong – no filter diff (+) correlated with ALX in Con* but not AS group

Table 2 *(Continued)*

Author (Year)	Participants	Age	ASD Scores	IQ Scores	ALX Scores	Experimental Paradigm	Task Performance & Relevant Results
Kliemann et al. (2013)	N=24 ASD (15 male) N=24 NT (15 male)	30.4 years (8.52) 30.3 years (8.37)	AQ: ASD=37.4* NT=14.4* ADOS=10.7 (3.5), 7-15 (n=21 ASD)	MWT VIQ: ASD=108 NT=106	TAS-26, EOT subscale: ASD=15.4 (4.4), 8-24 NT=13.6 (3.2), 8-19	Facial ER task (dynamic emotional videos) Match emotion label to whole face (Explicit); Match lower to upper half of face (Implicit)	↑ ER for NT vs. ASD group*; ↑ ER for explicit vs. implicit tasks for NT* but not ASD; N.s. group effect for valence strength or error patterns; AQ (-) corr. with overall ER*; (-) trend between ALX & implicit† not explicit
Komeda et al. (2019)	N=22 ASD (15 male) N=20 TD (12 male)	26.8 years (7.3) 24.0 years (4.2)	AQ: ASD=32.8* (6.4) TD=17.8* (7.3)	WAIS-III VIQ : ASD=111.1 (14.3) TD=115.7 (9.5) WAIS-III FSIQ : ASD=108.0 (12.4) TD=114.4 (8.8)	TAS-20: ASD=50.5 (23.1) TD=39.3 (12.3) BVAQ: ASD=90.6 (45.9) TD=85.6 (37.1)	Cognitive empathy (CP) + helping motivation (HM) vignettes Likert rating-CP and HM for TD vs. ASD protagonist	↑ CP & HM to ASD protagonist by ASD vs. TD group* when IQ, ALX, & then AQ controlled (via stepwise HLM) & CP corr. With cog. ALX subscale of BVAQ; ↑ CP & HM to TD protagonist by TD vs. ASD group* when IQ controlled but n.s. after ALX & AQ
Krach et al. (2015)	N=16 ASD (16 male) N=16 HC (16 male)	21.5 years* (2.9) 24.3 years* (2.3)	AQ: ASD=30.1* (8.8); HC=11.9* (5.7) ADOS-Social Affect Score=9.5 (4.5)	WAIS VIQ: ASD=117.5 (14.4) HC=113.3 (10.7)	TAS-20: ASD=55.5* (14.3) HC=44.9* (10)	Empathy for pain task 1)Likert rating-pain intensity to photos physical pain (PP) or neutral (PN) conditions 2)Likert-rating embarrassment to socially undesirable (SP) or neutral (SN) drawn scenes 3)Pupillometry during #1-2 (n =11) 4)fMRI (a. whole brain & b. ROI) during #1-2	1)N.s. group effect for PP & PN 2)N.s. group effect for SP & SN 3)N.s. group effect of dilation to PP vs. PN conditions; ↑ Dilation to SP vs. SN for HC* but not ASD group; Dilation (+) corr. with brain activation* 4)a. ACC, AIC, thalamus, cerebellum, IFG & temporal gyrus activity to SP vs. SN in HC*; b. activity in left AIC & ACC* (+) corr. with SP vs. SN in HC but not ASD; SP (+) corr. with hippocampus for ASD*; Bilateral AIC & ACC activity to PP vs. PN* in both groups, n.s. diff
Milosavljevic et al. (2016)	N= 31 ASD+ALX (30 male) N= 25 ASD-ALX (24 male)	15.5 years (.5) 15.4 years (.5)	SRS parent report: ASD+ALX =84.6 (26.3), 32-131 ASD-ALX =85.2 (29.6), 21-137	WASI VIQ: ASD+ALX=86.8† (13.5), 61-120 ASD-ALX=93.6† (11.6), 77-112 WASI FSIQ: ASD+ALX=92.8 (12.5), 70-119 ASD-ALX=95.5 (10.6), 77-113	TAS-20: ASD+ALX =61.42* (7.2), 52-78 ASD-ALX =42.8* (6.7), 28-51	Facial ER task (match corresponding emotion label to facial expressions)	N.s. group diff. between ASD+ALX vs. ASD-ALX on facial ER task after accounting for VIQ and anxiety; ALX (-) correlated with VIQ†

Table 2 *(Continued)*

Author (Year)	Participants	Age	ASD Scores	IQ Scores	ALX Scores	Experimental Paradigm	Task Performance & Relevant Results
Minio-Paluello et al. (2009)	N= 17 AS (17 male) N=20 NT (20 male)	28 years (7.2) 25.3 years (6.7)	AQ: AS=37* (5), n=14; NT=18* (6), n=14; (14/16 AS with score > cut off of 32, and 1/16 NT)	WASI VIQ: AS=118.7 (9.7) NT=121.3 (8.3) WASI FSIQ: AS=118.9 (15.6) NT=122.9 (6.9)	TAS-20: AS=63* (10), n=14 NT=41* (8), n=14	Empathy for pain task 1)Visual analog scale rating of arousal & aversion to videos of painful & non-painful actions to hand & tomato 2)TMS of left PMC & EMG of hand during video	1)N.s. group effect for subjective ratings in #1 and #2 (post-TMS) for arousal, aversion, pain intensity, unpleasantness to painful and non-pain videos, except ↑ arousal to 1 static* (non-pain) hand video in NT vs. ASD 2)N.s. group diff for overall corticospinal reactivity; ↑ muscle-specific modulation to pain videos in NT vs AS group*
Murray et al. (2017)	N= 20 ASD (20 male) N= 20 Con (19 male)	30.6 years (6.5) 30.7 years (6.3)	AQ: ASD=34.2* (7.4), 18-48; Con=15.6* (7.2), 5-30	WASI/WAIS-III/IV VIQ: ASD=105.1 (17), 73-134 Con=111.3 (11.5), 81-138	TAS-20: ASD=61.6* (10.1) Con=46.6* (11.1) (52.6% ASD >60 cut off, 20% of Con)	ER task (match emotion label to photos of eyes [RMET] and videos of faces [TASIT-P1])	1)Trend ↑ RMET† ER for Con vs. ASD group; n.s. group diff for TASIT-P1
Schneider et al. (2013)	N= 28 ASD (15 male), 9 inpatient N= 28 Con (15 male)	32.7 years (10), male 29.9 years† (9), female 34.3 years (9.7), male 27.9 years† (7), female	AQ: ASD male =34.9* (9.2), ASD female =41 (4.2)* Con male =11.9* (7.1), Con female =7.9 (3.3)* ADOS Total: ASD=14/28 > cut off of 7	WST VIQ: ASD male =109.9 (7.9), ASD female =108.1 (10.8) Con male =115.1 (11.4), Con female = 112.9 (7.2)	TAS-20: ASD male =60.6* (11.6), ASD female =59.1* (12) Con male =41.5* (10.8), Con female =37* (8.6)	ER task (videos of neutral [N] & emotional [E] faces, prosody & semantic content) 1)Rate how intensely a. they felt (Self) and b. how the actor felt (Other) via visual analog scale 2)fMRI during #1 (whole brain analyses)	1)a.↑ Self intensity ratings to N*, ↓ to E* by ASD vs Con; 1)b.↓ Other intensity ratings for N by ASD vs. Con females*, n.s. diff for female E, male E or N;↓ Other intensity for N*, trend for E† by ASD vs. Con females, n.s. diff for males; N.s. sex effect for Con 2)↑ bilateral mFG activity by ASD males vs. ASD females*, ↓ activity in left amygdala*, ↑ PAG activity* in ASD females vs. Con females; n.s. diff for males; n.s. effect of ALX in sex-specific comparisons
Trevisan et al. (2016)	N= 17 ASD (13 male) N= 17 NT (13 male)	10.2 years* (1.8), 7-13 9 years* (1.3), 7-11	AQ parent- (7-11) or self-report (12-13): ASD=32.9* (8.9), 9-45 NT=17.4* (9.6), 4-32	WASI vocab subtest: ASD=27.8 (10.7), 3.48 NT=26.3 (7), 15.39	CAM parent report: ASD=17.3* (8.6) NT=8.4* (8.9)	Facial expression production task (FACET) analysis of positive (Pos), negative (Neg), & neutral (Neut) facial expressions produced while watching emotional videos	ALX (-) associated with overall facial expression*; ALX (-) correlated with production of neg* expressions and (+) correlated with neut*, n.s. rel'n with pos expressions; N.s. effect of AQ scores on facial expressions after ALX accounted for

Note. Age, ASD Symptoms, IQ Scores, and Alexithymia Scores columns indicate mean (standard deviation), and range, if available
Abbreviations: ACC=anterior cingulate cortex; ADOS=Autism Diagnostic Observation Schedule; AIC=anterior insula cortex; ALX=alexithymia; AQ=Autism-Spectrum Quotient AS=Asperger syndrome; ASD=autism spectrum disorder; BPVS=British Picture Vocabulary Scale;

BVAQ=Bermond Vorst Alexithymia Questionnaire; CAM=Children's Alexithymia Measure; Con=Control group; Corr=correlated; Diff=difference; EMG=electromyography; ER=emotion recognition; FACET=facial recognition software; fMRI=functional magnetic resonance imaging; FSIQ=full scale intelligence quotient; GSR=galvanic skin response; HC=healthy control; HLM=hierarchical linear modelling; mFG=medial frontal gyrus; MWT=Mehrfachwahl-Wortschatz-Intelligenztest; N.s.=not significant; NT=neurotypical; PAG=periaqueductal gray; PMC=primary motor cortex; Rel'n=relationship; RMET=Reading the Mind in the Eyes Test; ROI=region of interest; SRS=Social Responsiveness Scale; TAS=Toronto Alexithymia Scale (20- and 26-item versions); TASIT-P1=Awareness of Social Inference Test-Emotion Recognition subsection; TD=typically-developing; TMS=transmagnetic cranial stimulation; VIQ=verbal intelligence quotient; WASI=Wechsler Abbreviated Scale of Intelligence; WAIS=Wechsler Adult Intelligence Scale (Revised [R] and 3rd [III] editions); WST=Wortschatztest;
Symbols: (+)=positive; (-)=negative; ↑=greater/increased; ↓=less/reduced. *Statistically significant group differences reported at $p < .05$, †trending significance, $p = .05$. From "Emotion processing and autism spectrum disorder: A review of the relative contributions of alexithymia and verbal IQ," by S. Sivathasan, T. P. Fernandes, J. A. Burack, & E. M. Quintin, 2020, Research in Autism Spectrum Disorders, 77, 101608 (https://doi.org/10.1016/j.rasd.2020.101608). Copyright 2020 by Elsevier Ltd.

Bridge Between Study 1 and 2

In Chapter 3, Study 1 (Sivathasan et al., 2020), I assessed the relative impact of verbal cognitive ability (VCA) and alexithymia on emotion processing among persons on the AS. Through a systematic review of the literature that included both of these participant characteristics, in relation to performance on an emotion processing task (N = 13), our findings suggested that VCA (referred to in Study 1 as "verbal intelligence" or verbal "IQ" scores) and alexithymia both play an important and distinct role in influencing the ways emotions are processed, above and beyond autism. That is, persons on the AS and TD persons generally performed comparably on emotion processing tasks when VCA and alexithymia were taken into account. However, VCA may have a greater impact on behavioural responses associated with emotion processing, whereas the impact of alexithymia may be more readily observable when considering neurophysiological correlates of emotion processing. Findings from Study 1 also revealed that the studies reviewed primarily included adult participants on the AS and TD adults with mean VCA scores in the average to above average ranges, and generally low mean scores on measures of autism traits in the AS groups. Moreover, half of the available studies assessed behavioural performance on tasks of basic emotion recognition (ER) using conventional facial and vocal stimuli, and only one eligible study included basic ER from music.

Thus, to better understand the specificity and universality of basic ER differences among persons on the AS while incorporating strengths-based approaches, the goal of Study 2 in Chapter 4 was to extend the findings of Study 1 to consider behavioural performance on basic ER tasks through a direct comparison of musical versus socially-explicit facial and vocal stimuli, among children on the AS (n = 25) and TD children (n = 23) aged 6-13 years, with a broad range of VCA scores and autism traits. Finally, to consider whether available response options also contributed to potential ER differences between AS and TD groups, both categorical emotion labels and dimensional ratings of valence and arousal were offered as response options. Direct between and within group comparisons of performance by stimulus type and by emotion (happy, sad, fear) were achieved by designing a novel behavioural ER paradigm for Study 2, using E-Prime software to display short presentations of musical, facial, and vocal emotions in randomized block order. Differences in performance using categorical responses and dimensional valence and arousal ratings (counterbalanced in presentation order among the participants) were also compared between the AS and TD groups. Based on the findings from Study 1 highlighting the influence of VCA on behavioural tasks, VCA (calculated and described in Study 2 as "verbal mental age") was considered as a covariate in the analyses for Study 2. Alexithymia was subsequently considered along with VCA among a subset of Study 2 participants in a follow up study (Study 3) presented in Chapter 5.

The manuscript for Study 2 in this chapter, entitled "Basic emotion recognition of children on the autism spectrum is enhanced in music and typical for faces and voices" is in its final form to submit for publication, with tables and figures displayed in an appendix at the end of the manuscript.

Chapter 4: Study 2

Basic emotion recognition of children on the autism spectrum is enhanced in music and typical for faces and voices

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Keywords: emotion recognition, autism, music, face, voice

Abstract

In contrast with findings of reduced facial and vocal emotional recognition (ER) accuracy, children on the autism spectrum (AS) demonstrate comparable ER skills to those of typically-developing (TD) children using music. To understand the specificity of purported ER differences, the goal of this study was to examine ER among children on the AS and TD children from music compared with faces and voices. Twenty-five children on the AS and 23 TD children (6-13 years) completed an ER task, using categorical (happy, sad, fear) and dimensional (valence, arousal) ratings, of emotions presented via music, faces, or voices. Compared to the TD group, the AS group showed a relative ER strength from music, and comparable performance from faces and voices. Although both groups demonstrated greater vocal ER accuracy, the AS group performed equally well with music and faces, whereas the TD group performed better with faces than music. Both groups performed comparably with dimensional ratings, except for greater variability by the AS group in valence ratings for happy emotions. These findings highlight a need to re-examine ER of children on the AS, to consider how facilitating strengths-based approaches can re-shape our thinking about and support for autistic persons.

Introduction

Differing patterns of emotion recognition (ER) have long been cited as significant components of the socialization profile that is characteristic of persons on the autism spectrum as compared to non-autistic or “typically-developing” (TD) persons (Baron-Cohen, 1988, 2002; Baron-Cohen et al., 1999; Hobson, 1986a; Hobson, 1986b; Lozier et al., 2014; Uljarevic & Hamilton, 2012). However, virtually all of the evidence of relative ER challenges or “deficits” has been based on findings with paradigms in which the presentation of emotions occurs in the context of socially explicit facial and vocal stimuli. This evidence of reduced ER accuracy diverges from that of comparable abilities between persons on the autism spectrum and TD persons to recognize emotions when the tasks are presented in the context of music (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016), a domain in which autistic persons have been found to display a variety of unique abilities (e.g., Heaton, 2008; Mottron et al., 2013; Quintin, 2019). To better understand the nature of these disparate findings, we investigated ER skills with musical, as compared to facial and vocal, stimuli using both categorical and dimensional response options in order both to provide a nuanced understanding of ER processing across various types of stimuli and to consider the ways that strength-based approaches can re-shape our thinking about persons on the autism spectrum.

Music is a stimulus with which persons on the autism spectrum regularly and readily engage in their day-to-day lives, and with which they have demonstrated a variety of skills and strengths (Quintin et al., 2019 for a review). Autistic persons have shown enhanced pitch discrimination of musical tones and melodies (Bonnel et al., 2003, 2010; Heaton, 2003, 2005; Mottron et al., 2000) and musical memory (Heaton et al., 1998, 2008; Stanutz et al., 2014) as compared to mental age (MA)-matched TD or non-autistic persons. Among children on the autism spectrum, verbal production may be enhanced through the incorporation of music into speech- and language-focused interventions, particularly for children who have greater language and learning needs (e.g., Chenausky et al., 2016; Lense & Camarata, 2020; Lim, 2010; Lim & Draper, 2011). Further, music therapy has been shown to improve social interaction and communication skills, such as joint attention (Kim et al., 2008; LaGasse, 2017), turn taking (Kim et al., 2008), and social communication (Sharda et al., 2018) when the development of these skills is the target of the intervention.

The study of ER skills of persons on the autism spectrum involves a similar strengths-based approach via the inclusion of musical stimuli. For example, Heaton et al. (1999) found that children on the autism spectrum show comparable abilities to MA-matched TD children in distinguishing music conveying happy (typically in a major musical scale) and sad (in a minor scale) emotions. Concordantly, comparable ER ratings of happy, sad, and fearful musical excerpts between children and adolescents on the autism spectrum and their TD peers have been found when differences in verbal IQ were controlled (Quintin et al., 2011; Stephenson et al., 2015). Similar performance on behavioral ER tasks as well as on those involving the activation of emotion processing and reward neurocircuitry when listening to happy and sad music have been shown between autistic and non-autistic adults (Caria et al., 2011; Molnar-Szakacs & Heaton, 2012). The evidence from these musical ER studies suggests that autistic persons appear to be able to recognize basic emotions conveyed by music comparably to their TD peers of a similar developmental level. In contrast, the findings from meta-analyses of behavioral ER studies indicate medium to large overall effect sizes across studies indicating lower accuracy levels on recognition tasks of basic emotions among autistic adults and children as compared to non-autistic participants when socially explicit stimuli (e.g., faces, voices) were used (Lozier et al., 2014; Uljarevic & Hamilton, 2012; Velikonja et al., 2019). This suggests a discrepancy between findings based on socially explicit stimuli versus less socially explicit stimuli that can also convey emotions (i.e., music).

Attempts to reconcile such discrepancies need to address how music differs in its conveyance of emotion as compared to explicitly social facial and vocal stimuli. Emotions are most commonly presented in an interpersonal or self-reflective context, such as through social observation and interaction or through an internal emotional experience. This use of socially explicit facial and vocal stimuli in ER studies with persons with autism may contribute to the finding of reduced ER accuracy on behavioral tasks. For example, differences in facial ER accuracy relative to non-autistic persons could be related to early developmental differences in reduced attention to eyes and faces (Jones et al., 2008) or to the reduced value and salience of social versus non-social stimuli that begins in childhood (Klin et al., 2003; Pelphrey et al., 2002). In contrast, music can elicit an affective reaction in the listener without requiring a need to understand or empathize with the composer's mental states or emotional intentions (Griffin et al., 2016; Heaton, et al., 1999). Emotions are conveyed in music through variations in structural auditory aspects such as tempo, timbre, pitch, and mode, and thereby afford a unique yet common and familiar vehicle for emotional experience (Swaminathan & Schellenberg, 2015). Accordingly, the primary goal of the current study is to reconcile reported differences in ER among children on the autism spectrum, specifically to determine whether music affords autistic children a relative ER strength in comparison with explicitly social (i.e., facial and vocal) stimuli and whether such a pattern of strengths and challenges is observed among their TD peers. If children on the autism spectrum demonstrate relative ER strengths using less socially explicit stimuli and TD children demonstrate relative ER strengths using more socially explicit stimuli, we could speculate that differing routes for understanding and teaching ER skills are available to children with diverse strengths and needs.

The disparities in findings across studies may also be due to the differences in the measurement techniques that are used in experimental designs and methodologies in ER research (e.g., Harms et al., 2010, Jones et al., 2010; Nuske et al., 2013; Ozonoff et al., 1990; Uljarevic and Hamilton, 2012). Based on the theory of basic emotions being universally expressed and recognized (Ekman et al., 1972; Ekman, 1992), ER abilities are frequently measured with behavioral paradigms with these discrete categorical representations (e.g., happy, sad, fear) through a forced-choice response format with verbal labels. However, emotional expressions can also be considered a product of dimensional attributes, particularly valence (positive to negative) and arousal (high to low energy) (Russell, 1980), and therefore can be measured using continuous ratings (Posner et al., 2008; Russell, 1980; Swaminathan & Schellenberg, 2015, for a review). While some of the earliest experimental studies of ER among autistic persons have involved a categorical approach (e.g., Hobson, 1986a; 1986b), the use of dimensional methods has become more common (e.g., Caria et al., 2011; Tseng et al., 2014). Accordingly, in order to capture dynamic aspects of emotions across each domain along a continuum of valence and arousal ratings, our second goal was to provide a direct comparison of musical, facial, and vocal ER among children with and without autism with dimensional ratings versus traditional categorical response options.

Objectives and Hypotheses

The main objective of this study was to compare the processing of basic emotions using musical, facial, and vocal stimuli among children on the autism spectrum (AS) and TD children. In comparing the groups, we hypothesized that the AS group would demonstrate a relative strength in musical ER compared to the TD group, whereas the TD group might display a strength in ER with socially explicit stimuli (faces, voices) relative to the AS group. We also hypothesized that there would be discrepancies in ER with a relative weakness in facial and vocal ER as compared to musical ER within the AS group, whereas we did not expect any significant difference in performance among musical, facial, and vocal ER within the TD group.

We also explored the use of dimensional ratings of valence and arousal across the musical, facial, and vocal stimulus types. As this aim was exploratory, we did not venture specific hypotheses regarding between or within group differences. To allow for a direct comparison of ER across the three domains, we developed an integrated experimental task displaying the musical, facial, and vocal stimuli, with categorical and dimensional response options presented for each item presented. We focused on comparisons from the three basic emotions of happy, sad, and fear that can be reliably conveyed by music (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016).

Method

Participants

The initial group of participants included 29 children on the autism spectrum (AS) recruited from special education schools or classrooms and 24 TD children recruited from schools or the general community in Quebec, Canada. The data from five participants (4 AS and 1 TD) were excluded from the analyses because one participant with autism did not complete the verbal comprehension portion of the cognitive test and the scores on the experimental task of the other four participants were multivariate outliers. Accordingly, the final group of participants (*N* = 48) included 25 children on the autism spectrum (19 males) aged 9-13 years (*M* = 11 years) and 23 TD children (11 males) aged 6-12 years (*M* = 9.7 years).

All of the AS participants had an educational code of autism spectrum disorder derived from expert diagnoses from pediatricians, child psychiatrists, or psychologists (for a discussion of the educational code system in Quebec, see Fombonne et al. 2006; Lazoff et al., 2010). The Parent and Teacher versions of the Social Responsiveness Scale, 2nd edition (SRS-2; Constantino & Gruber, 2012) were also used to ascertain the presence or absence of autistic traits among the AS group and TD group, respectively. The average SRS Total T-Score was greater than the clinical cut-off of 60 for the AS group and below 60 for the TD group. Four AS participants had T-Scores slightly below (between 54-59) the cutoff and three TD participants had scores at or above (60-62). As a similar pattern of results were found when the analyses were run with and without these seven participants with the categorical response option, the full dataset was used in the reported analyses.

The verbal scales of the Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V; Wechsler, 2014) in English or French, or the Wechsler Abbreviated Intelligence Scale, Second Edition (WASI-II; Wechsler, 2011) in English (no French version available) were used to estimate cognitive skills, and scores obtained were derived from the Verbal Comprehension Index (VCI) and Full-Scale IQ. Verbal mental age (VMA) was calculated using the VCI and chronological age, and used as our measure of verbal cognitive ability in order to account for variability in VCI and age ranges between the groups (AS group VMA: $M = 8.48$ [5-11 years]; TD group VMA: $M = 10.03$ [5-15 years]) consistent with recommendations to match groups and/or consider the effects of verbal mental age on ER task performance (Russo et al., 2021; Sivathasan et al., 2020; Trevisan et al., 2016).

The AS and TD groups differed significantly in terms of SRS-2 Total Scores, chronological age, IQ, and VMA (Table 1). Thus, VMA was considered as a covariate in our analyses of the group comparisons. Maternal educational attainment levels and annual income reported by 75% of participants' caregivers did not differ significantly between groups (see Supplementary Info Table 1). Specific demographic data on race & ethnicity were not systematically collected during this study and were therefore not available.

[INSERT TABLE 1 HERE]

Experimental Task

Musical, Facial, and Vocal Stimuli

The ER task included 72 different musical, facial and vocal stimuli depicting emotions of happy, sad, or fear. The task was divided into 3 blocks (one per stimulus type: music, faces, voices), with each block containing 24 items (8 happy, 8 sad, and 8 fear). Each item within a block was presented briefly on the computer screen for 1.5-2 seconds. The order of the three stimulus types (music, faces, voices) was counterbalanced across the participants and the order of the items within each stimulus block was randomized.

Faces. The participants viewed 24 photos of closed-mouth faces (happy, sad, or fear) selected from the NimStim Set of Facial Expressions (Tottenham et al., 2009), a well-validated set of photos of facial expressions conveying basic emotions. Four ethnicities (i.e., African-American, Asian, Caucasian, Hispanic) provided an ethnically diverse sample. In total, 8 unique adult actors (n = 4 females) represented 3 emotions (3 emotions x 2 sexes x 4 ethnicities = 24 faces). Each selected facial expression had a reliability coefficient of .78 or greater, based on validation with TD adults (Tottenham et al., 2009).

Voices. The participants listened to 24 selected vocal sounds from the Montreal Affective Voices battery (MAV; Belin et al., 2008), a validated set of nonverbal emotional vocalizations (e.g., laugh = happy, cry = sad, scream = fear) produced by 10 actors (*n* = 5 female). Each actor's vocalization was validated by TD adults, producing a reliability coefficient of ≥ .67.

Music. The participants listened to 24 short instrumental melodies or succession of chords played on a violin, from the Musical Emotional Bursts battery (MEB; Paquette et al., 2013), a validated set of musical clips designed as a musical counterpart to the MAV stimuli. Each selected clip conveying happiness, sadness, or fear, had a reliability coefficient of .70 or greater validated with TD adults.

Categorical and Dimensional Response Conditions

A three-tiered response system (a categorical condition and a two-part dimensional condition) was provided following the presentation of each stimulus item within the three blocks. The order of response conditions was counterbalanced across the participants, with half of the participants (*n* = 24) responding with the categorical condition first and the other half with the dimensional condition first.

Categorical Condition. In the categorical response condition, each item was presented and then followed by the on-screen instruction, "Which emotion?" with three verbal labels of happy, sad, and fear (the word scared was used when depicting emotions evoked through faces and voices, and scary for emotions evoked through music; see Figure 1). The participants selected their response by clicking on one of the three options using a mouse. Emotion recognition performance accuracy was determined by the percentage of correct responses per emotion separately, and also per stimulus type.

Dimensional Condition. In the dimensional response condition, the presentation of each item was followed by the on-screen instruction, "How positive or negative is the face (or voice or music)?" The participants provided a valence rating on a 5-point Likert scale (from very negative to very positive). They were also asked "How energetic is the face (or voice or music)?" to which they provided an arousal rating on a 5-point Likert scale (from very low energy to very high energy). Dimensional Likert scale anchors were paired with cartoon icons. In order to minimize the verbal demand of the task and to make the task more child-friendly, addition and subtraction symbols were used for the valence scale and batteries with varying levels of energy for the arousal scale, (see Figure 1).

Procedure

All of the procedures for this study were approved by McGill University's Research Ethics Board (#101-0716). As Quebec is a bilingual (English and French) province, all of the materials and procedures were available or translated into both languages, and administered in the participant's dominant language by bilingual clinically-trained research staff. The participants were tested in a research lab at the university or in the child's school or home. Written informed consent was obtained from the parents and written or verbal assent was provided by each participant prior to the beginning of the study.

All of the participants successfully completed a basic hearing test at www.legroupeforget.com. The hearing test and experimental task were administered on a PC laptop with over-ear headphones. The experimental task was completed in the E-prime (version 3.0) environment using a laptop and mouse. In order to ensure the comprehension of both response conditions, a practice session was administered first. All of the instructions were available on the screen in the participants' dominant language and were read to them during the practice session. A more extensive explanation of the Likert scales was provided during the practice session if needed. The experimental task took approximately 20 minutes to complete.

Analysis Plan

Separate three-way mixed analyses of covariance (ANCOVAs) were run for each of the categorical, dimensional valence, and dimensional arousal response options, to understand the effects of group (AS, TD), stimulus type (music, face, voice), and emotion (happy, sad, fear), while controlling for VMA of all the participants. Significant effects were further examined in two ways: 1) between-group comparisons, using two-way ANCOVAs to examine group differences in task performance for each stimulus type and/or emotion, controlling for VMA of all the participants; and 2) within-group comparisons, using repeated measures ANCOVAs to examine differences in task performance across stimulus types and/or emotions within each group, controlling for VMA for each group. Bonferroni corrections for multiple comparisons was applied when appropriate. Task performance means and means adjusted for VMA are presented in Tables 2 and 3.

Results

Categorical Response Condition

The three-way interaction among group, stimulus type, and emotion on categorical ER accuracy ratings was not statistically significant, F(2.98, 134.22) = 2.15, p = .098, η_p^2 = .045. A main effect of stimulus, F(1.61, 72.24) = 7.48, p = .002, η_p^2 = .14, and a two-way interaction between group and stimulus, F(1.61, 72.24) = 6.58, p = .004, η_p^2 = .13, were found when controlling for VMA (see Table 2 and Figure 2). Follow up analyses revealed a significant between-group difference in ER accuracy within the musical stimuli, F(1,45) = 5.40, p = .025, η_p^2 = .11, as the AS group had higher mean accuracy than, or outperformed, the TD group when recognizing emotions presented in music. In contrast, no differences were found between the AS and TD groups on ER accuracy within the vocal stimuli, $F(1, 45) = .22$, $p = .64$, $\eta_p^2 = .005$, and facial stimuli, $F(1, 45) = .94$, $p = .34$, $\eta_p^2 = .02$, suggesting that the AS and TD groups performed equally well in terms of ER accuracy from voices and faces.

The two-way interaction between group and stimulus type was also explored by comparing ER accuracy ratings across the three stimulus types (music, face, voice) within each group. The main effect of stimulus type was significant within the TD group, $F(1.31, 27.43) = 6.98$, $p = .009$, $\eta_p^2 = .25$, but not within the AS group, $F(2, 46) = 1.09$, $p = .34$, $\eta_p^2 = .045$. Nevertheless, given our a priori hypothesis, we compared responses across stimulus types within both groups. In both groups, ER accuracy was highest for emotions from voices (AS group: $M = .92$, TD group: $M = .91$), $ps \leq .001$. Children in the TD group recognized emotions more accurately from faces compared to music, $p < .001$, whereas no significant difference was found between ER accuracy from faces and music for the AS group, $p = .36$.

Neither the main effects of group and emotion nor the interaction effects of emotion by stimulus type and emotion by group were significant (all p values > .05), suggesting that happy, sad, and fear emotions were equally well identified within and between the AS and TD groups, and across the stimulus types. VMA was not a significant covariate in the model, and neither the interaction effects of VMA by emotion nor of VMA by stimulus type were significant (all p values > .05).

These results support our hypothesis that children on the autism spectrum show a strength in identifying emotions within the musical stimuli compared to TD children. However, contrary to another hypothesis, the TD children did not demonstrate a strength in ER from facial and vocal stimuli as compared to children on the autism spectrum. Our within group hypotheses were also not supported. Specifically, the children on the autism spectrum did not demonstrate a relative weakness in facial or vocal ER as compared to musical ER. Both groups had better ER accuracy from voices, and the children on the autism spectrum performed comparably between faces and music, whereas the TD children performed better with faces than music. Overall, the autistic children showed a strength in recognizing emotions in music in comparison to the TD children, but not in comparison to their ability to recognize emotions in faces and voices.

[INSERT TABLE 2 HERE]

Dimensional Response Condition

Valence Ratings

A three-way interaction among group, stimulus type, and emotion on valence ratings was not statistically significant, $F(4, 180) = .86$, $p = .49$, $\eta_p^2 = .02$. Neither a significant main effect of emotion nor a significant two-way interaction between group and emotion, $F(1.52, 68.35) = 4.30$, $p = .026$, $\eta_p^2 = .09$, were found while controlling for VMA. Follow up analyses revealed a significant group difference in valence ratings for happy emotions, $F(1, 45) = 11.77$, $p = .001$, $\eta_p^2 = .21$, such that the AS group rated happy emotions as significantly more positive as compared to the TD group. In contrast, no differences were found between the AS and TD groups on mean valence ratings of sad, $F(1, 45) = .57$, $p = .46$, $\eta_p^2 = .01$, or fear emotions, $F(1, 45) = .66$, $p = .42$, $\eta_p^2 = .01$, suggesting that the AS and TD groups rated emotional valence for these two negative emotions similarly (see Table 3 and Figure 3).

The main effects of group and stimulus type, and the interaction effects of stimulus type by group and stimulus type by emotion were not significant (all p values > .05), suggesting that the valence of emotions for both groups was equally well identified regardless of the stimuli in which they were presented. VMA was not a significant covariate in the model, and the interaction effects between VMA and emotion and stimulus type were not significant (all *p* values > .05).

These results suggested that both the groups rate the valence of emotions similarly (i.e., happy emotions as more positive than sad and fear), regardless of the stimuli in which they were presented, although the children with AS rated happy emotions as more positive than did the TD children.

[INSERT TABLE 3 HERE]

Arousal Ratings

A three-way interaction among group, stimulus type, and emotion on arousal ratings was not statistically significant, F(4, 180) = 1.01, $p = .40$, $\eta_p^2 = .022$. Further, the two-way interactions between group and stimulus type, F(2, 90) = 2.47, $p = .09$, $\eta_p^2 = .052$, and group and emotion, F(2, 90) = 1.87, $p = .17$, $\eta_p^2 = .04$, were not significant. These results suggest that the AS and TD groups showed comparable patterns of arousal ratings across emotions and stimulus types (see Table 2 and Figure 4).

A main effect of emotion on arousal ratings was found overall, F(1.65, 74.22) = 13.97, $p < .001$, $\eta_p^2 = .24$, and within each group separately (AS group: F(2, 46) = 7.71, $p = .001$, $\eta_p^2 = .25$; TD group: F(1.58, 33.26) = 6.63, $p = .006$, $\eta_p^2 = .24$). Both of the groups rated happy emotions (AS: *M* = 4.12; TD: *M* = 3.84) as more arousing than fear (AS: *M* = 2.97; TD: *M* = 2.94), and fear as more arousing than sad (AS: *M* = 2.65; TD: *M* = 2.62), all *p* values ≤ .005, after controlling for VMA. Neither the main effects of group and stimulus type, nor the interaction effect of stimulus type by emotion were significant (*p* values > .05), suggesting that the arousal ratings of emotions for both groups were equally well identified regardless of the stimulus type in which they were presented.

Although VMA was not a significant covariate in the overall model ($p = .14$), interactions were found between VMA and emotion, $F(1.65, 74.22) = 4.96$, $p = .014$, $\eta_p^2 = .099$ and between VMA and stimulus type, $F(2, 90) = 3.33$, $p = .04$, $\eta_p^2 = .069$. One-tailed Pearson correlations revealed that VMA was positively correlated with arousal ratings of fear ($r = .37$, $p = .005$), such that children with higher VMA rated fearful emotions as more arousing than those with lower VMA (Bonferroni corrected $p = .0167$ to account for multiple comparisons). No other correlations with emotion or stimulus type reached significance. These results suggested that VMA may have contributed to patterns of arousal ratings for particular emotions (i.e., fear).

Discussion

Our primary objective in this study was to reconcile contrasting findings in the literature on emotion recognition (ER) among persons on the autism spectrum that include challenges or “deficits” in basic ER with socially explicit stimuli (primarily faces and voices) and relative strengths in ER with musical stimuli. We aimed to determine whether relative musical ER strengths among children on the autism spectrum were specific to music, or whether assumptions of difficulty associated with facial and vocal ER needed re-examination methodologically, via a direct group comparison of performance on a traditional categorical behavioral ER task involving musical, facial, and vocal stimuli. Music afforded a unique opportunity to compare ER skills from music to conventional ER paradigms, as musical stimuli can convey emotions without reliance on the usual interpersonal social context. Additionally, we attempted to enhance our understanding of the abilities and styles of emotion processing among children on the autism spectrum by also applying a nontraditional dimensional approach to our multi-stimulus investigation of ER. As such, our secondary objective was to take an exploratory look at patterns of performance between and within the groups using continuous ratings of valence and arousal among music, faces, and voices.

Based on the literature related to our first objective, we offered data-driven hypotheses that children on the autism spectrum as compared to TD children would demonstrate better accuracy with musical ER, and reduced accuracy with facial and vocal ER. We also hypothesized that within the groups, the children on the autism spectrum would demonstrate a strength with musical ER as compared to facial and vocal ER, whereas we expected that the TD children would perform equally well regardless of stimulus type. Given the exploratory nature of our secondary objective, we did not offer specific hypotheses about patterns of responding using dimensional valence and arousal ratings between the groups. To test our hypotheses, we developed an integrated paradigm to examine ER skills with musical, facial, and vocal stimuli conveying happy, sad, and fear emotions, using both a categorical and dimensional response options concurrently.

Patterns of Basic ER among Children on the Autism Spectrum and TD Children

Within the categorical paradigm, we found that the children on the autism spectrum demonstrated greater accuracy in musical ER compared to the TD children, when controlling for VMA, thereby supporting findings of strengths in musical ER among children on the autism spectrum (Heaton et al., 1999; Jarvinen et al., 2016; Quintin et al., 2011; Stephenson et al., 2016). However, in contrast with prior meta-analytic findings (Lozier et al., 2014; Uljarevic & Hamilton, 2012; Velikonja et al., 2019), the children on the autism spectrum and the TD children identified emotions equally well when using the facial and the vocal stimuli. Further, patterns of within-group performance revealed that whereas children in both groups demonstrated the greatest ER accuracy with vocal stimuli, the children on the autism spectrum demonstrated comparable ER accuracy between faces and music but the TD children showed reduced ER accuracy with music as compared to with faces. Within the dimensional paradigm, the groups also performed comparably, with one exception. In terms of valence ratings, the children on the autism spectrum rated happy emotions as more positive than the TD children, but otherwise the groups rated the valence of emotions similarly across the three stimulus types. Further, both groups displayed similar patterns of arousal ratings for the three emotions and across the three stimulus types. Verbal MA did not appear to add any further influence to our findings except for being positively correlated with arousal ratings of fear.

Considering possible explanations for our pattern of findings that stand in contrast with much of the previous ER literature necessitates a relevant discussion of methodological issues, especially as null results were found. Although we found clear discrepancies between the groups on the musical ER task, in which the AS group outperformed the TD group, our tasks may not have been sensitive enough to detect meaningful differences between the groups, thus resulting in comparable ER accuracy patterns for faces and voices. Specifically with regard to our vocal ER task, we used the most basic measure of vocal ER involving short, non-verbal vocalizations (i.e., cries, screams, and laughs) rather than verbal vocalizations which require processing of linguistic aspects of semantic content (e.g., "I am afraid") or prosody of speech (e.g., "That's a big shark!" said in a fearful tone), in order to understand the emotion being conveyed. Although minimizing the verbal component of the task provided confidence that ER from voices was not disproportionately reliant on participants' verbal skills, it may have contributed to high performance accuracy overall. Nonetheless, our findings of comparable performance for ER in faces and voices are consistent with studies of socially explicit ER that also account for VMA or IQ (e.g., Braverman et al., 1989; Buitelaar et al., 1999; Castelli, 2005; Ozonoff, 1990).

The number and type of emotion choices provided also contributes to task difficulty. Our study included three basic emotions that can easily be conveyed in music, as well as in faces and voices (and thus offered a 33% chance of randomly guessing the correct answer), with a single positive emotion and two negative emotions. Group differences may be more readily apparent when measuring complex or higher order emotion processing (e.g., Golan et al., 2007, 2008). Further, the evidence from studies with more complex emotions and more options (and therefore decreased accuracy attributable to chance) indicate that TD groups also perform less accurately than with basic emotion and fewer choices (Elfenbein & Ambady, 2002; Tracy et al., 2010).

Furthermore, by design, the dimensional condition does not lend itself to constrained and categorical performance metrics, but rather allows for examination of general patterns of response using 5-point Likert scales to measure continuous components of valence and arousal. Of the 12 comparisons across two dimensions, three emotions, and three stimulus types, the only difference was found in the perception of valence for happy emotions. The patterns of continuous valence and arousal ratings across all other emotions and stimulus types were virtually indistinguishable.

A Case for Equifinality: Enhanced Perceptual Functioning in ER

Rather than demonstrating a singular mechanism and pattern of processing by which both groups achieve comparable task performance, our findings may instead highlight unique styles of processing for each group that lead to similar outcomes. Cicchetti and Rogosch (1996) argued that the principles of multifinality and equifinality allow us to better understand possible mechanisms for observable outcomes among different populations. Whereas multifinality infers that similar developmental circumstances may lead to a heterogeneity of outcomes, equifinality suggests that various circumstances or abilities may lead to similar outcomes. The lens of equifinality specifically has been readily applied to conceptualize the heterogeneity of both genetic and behavioral characteristics of autistic persons (i.e., multiple factors may predispose an individual to have autism). For example, Burack et al. (2016) and others have argued that persons on the autism spectrum may engage in different styles of cognitive processing than TD persons, and thus call for greater exploration of the various ways autistic persons engage with stimuli, rather than viewing cognitive or task performance as "deficient" or atypical compared to a reference standard.

The usefulness of applying a lens of equifinality to understand differing mechanisms of cognitive processing and ER among autistic and non-autistic persons is evidenced in the contributions of the Enhanced Perceptual Functioning (EPF) model (Mottron & Burack, 2001; Mottron et al., 2006). According to the EPF model, autistic persons may have a default or preferential bottom-up approach to processing the perceptual features of a stimulus that favors local, rather than global aspects. In this framework, global processing among persons on the autism spectrum is not necessarily impaired, but may be deprioritized relative to local processing. In comparison, TD persons may favor a top-down, global or holistic processing style, and deprioritize processing at the level of local perceptual cues. Differential styles of processing between groups may be contributed to or further reinforced by continued exposure and engagement with salient and motivating cues. For example, TD children spend more time looking at socially explicit stimuli (e.g., caregiver interactions, videos of social scenes) than do children on the autism spectrum (Constantino et al., 2017) and therefore gain greater experience with emotional content conveyed in faces and voices. By comparison, children on the autism spectrum tend to demonstrate enhanced local processing of non-emotional perceptual features of socially explicit faces (Hubl et al., 2003; Samson et al., 2012), speech (Järvinen-Pasley et al., 2008) and audio-visual synchronous biological motion (Klin et al., 2009), in addition to their enhanced perceptual processing of less explicitly social stimuli, such as music.

Across all three stimulus types, basic emotions can be decoded using both top down and bottom up approaches, and thus both groups of children in our study were successful at decoding emotions using their preferential styles of processing in order to categorize emotions similarly on our task. Bottom-up processing of music may confer an additional advantage to children on the autism spectrum, who show strengths in decoding perceptual musical cues (i.e., pitch, tone, energy) (e.g., Heaton, 2008; Mottron et al., 2013). Thus, compared to TD children, music may readily invoke the enhanced perceptual processing styles of children on the autism spectrum and be a privileged means for conveying emotions for them.

Implications

For a characteristic or challenge to be considered a core "deficit" primary to any particular group, it should be specific and universal to that group, and should be one of the most persistent or impairing features (Ozonoff et al., 1990; Zelazo et al., 1996). Overall, our findings are inconsistent with the notion that children on the autism spectrum demonstrate a core "deficit" in basic ER, and we attempt to delineate this through our findings in several ways. In terms of specificity, using a child-friendly, multi-response paradigm designed to minimize reliance on verbal cues, we found typical ER performance across the facial and vocal accuracy tasks, and comparable ratings of emotional valence and arousal, demonstrate indisputable basic ER capabilities of children on the autism spectrum. The notion of the universality of ER differences was also not borne out, given our study's findings of relative strength of children on the autism spectrum in musical ER, and ultimately underscores that discussions of ER broadly need not be restricted to the traditional facial or vocally expressed emotions.

The musical ER strengths highlighted in our study support the growing evidence of the benefits of music therapy for children on the autism spectrum (LaGasse, 2017). Our findings contribute to the notion that musical strengths, including typical or enhanced processing of music-evoked emotions, may be a key component of the success of music programs and therapies that target social communication and interaction skills (Kim et al., 2008; LaGasse, 2017; Lense & Camarata, 2020; Sharda et al., 2018) and speech and language interventions that incorporate music (Chenausky et al., 2016; Lim, 2010; Lim & Draper, 2011). Music therapy, education, and interventions may be successful because they leverage emotional and cognitive strengths (Quintin et al., 2019) and are motivating and accessible to children on the autism spectrum because they readily engage with and enjoy music (Allen et al., 2009; Bhatara et al., 2013).

Conclusion

The findings from this study of ER across multiple basic emotions, stimulus types, and response options, help to dispel notions of deficits of the ability to explicitly recognize and label basic emotions of autistic children relative to non-autistic TD children. Instead, findings of comparable ER accuracy (in faces and voices) or relative strengths (in musical ER) depending on the stimulus type provides support for the use of music therapy, education, and interventions. Ultimately, our findings contribute to efforts to provide a nuanced understanding of the ways in which we can re-shape our thinking about autistic persons by engaging their preferences and strengths.

Acknowledgements: Support for this research was provided by the Social Sciences and Humanities Research Council of Canada, Fonds de Recherche du Québec - Santé, and the Organization for Autism Research. Funders was not involved in the conceptualization, analysis, or manuscript preparation or submission of this study. We are thankful to the graduate students and research assistants in the Behaviour, Autism and NeuroDevelopment (BAND) Research Group who assisted with data collection, and to the children and families who participated in our study.

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Appendix: Tables and Figures

Table 1

Participant Characteristics of the AS and TD Groups

	AS Group (*n* = 25)			TD Group (*n* = 23)			*p*
	M	SD	Range	M	SD	Range	
Chronological Age	11.02	1.12	9-13	9.70	1.63	6-12	.003
Verbal Mental Age	8.48	1.62	5-11	10.03	2.56	5-15	.018
VCI	77	14	51-104	102	14	73-128	<.0001
FSIQ[a]	79	14	54-109	104	13	78-124	<.0001
SRS-2	71	9	54-88	49	8	40-62	<.0001

Note. Mean (M), standard deviation (SD), ranges, and p values of an independent sample t-test between the AS group and the TD group. Chronological age (CA), and Verbal Mental Age (VMA) are displayed in years. Verbal Comprehension Index (VCI) and Full-Scale IQ (FSIQ) = standard score. Social Responsiveness Scale-2 (SRS-2) Total Score = T-Score.
[a]AS group n = 24, TD group n = 22.

Table 2

Means, Adjusted Means, Standard Deviations and Standard Errors for Categorical ER Accuracy Ratings

	AS Group		TD Group		F	η_p^2
	Mean (SD)	Adjusted Mean (SE)	Mean (SD)	Adjusted Mean (SE)		
Stimulus Type					6.58*	.13
Music	.78 (.14)	.80 (.03)	.70 (.18)	.69 (.03)	5.40*	.11
Face	.80 (.14)	.81 (.01)	.85 (.09)	.84 (.01)	.94	.02
Voice	.92 (.07)	.92 (.03)	.91 (.06)	.91 (.03)	.22	.005
Emotion					3.05	.06
Happy	.89 (.13)	.90 (.02)	.87 (.09)	.85 (.02)		
Sad	.81 (.14)	.82 (.03)	.87 (.11)	.86 (.03)		
Fear	.80 (.14)	.81 (.03)	.74 (.18)	.73 (.03)		

Note. Means adjusted for VMA of the overall sample = 9.22 years. Statistics for individual emotions are not reported because the emotion by group interaction effect was not significant.
*$p < .05$

Table 3

Means, Adjusted Means, Standard Deviations and Standard Errors for Dimensional Ratings of Valence and Arousal

	AS Group		TD Group		F	η_p^2
	Mean (SD)	Adjusted Mean (SE)	Mean (SD)	Adjusted Mean (SE)		
Valence Ratings						
Stimulus Type					1.55	.03
Music	3.00 (.57)	2.97 (.10)	2.80 (.37)	2.83 (.10)		
Face	2.88 (.35)	2.87 (.07)	2.93 (.31)	2.94 (.07)		
Voice	2.93 (.46)	2.93 (.09)	2.84 (.37)	2.85 (.09)		
Emotion					4.30*	.09
Happy	4.32 (.34)	4.33 (.09)	3.91 (.47)	3.90 (.09)	11.77*	.21
Sad	2.12 (.60)	2.09 (.11)	2.19 (.50)	2.22 (.12)	.57	.01
Fear	2.37 (.75)	2.34 (.14)	2.47 (.54)	2.50 (.14)	.66	.01
Arousal Ratings						
Stimulus Type					2.47	.05
Music	3.20 (.46)	3.26 (.10)	3.15 (.59)	3.08 (.11)		
Face	3.03 (.35)	3.04 (.08)	3.15 (.42)	3.14 (.09)		
Voice	3.20 (.60)	3.23 (.12)	3.22 (.53)	3.18 (.12)		
Emotion					1.87	.04
Happy	4.15 (.48)	4.12 (.10)	3.81(.50)	3.84 (.11)		
Sad	2.41 (.59)	2.44 (.12)	2.65 (.56)	2.62 (.13)		
Fear	2.87 (.86)	2.97 (.16)	3.04 (.77)	2.94 (.17)		

Note. Means adjusted for VMA of the overall sample = 9.22 years. Statistics for individual emotions and stimulus types are not reported when corresponding group by stimulus type or group by emotion interactions are not significant.

$^*p < .05$

Figure 1

Example Categorical and Dimensional Response Options

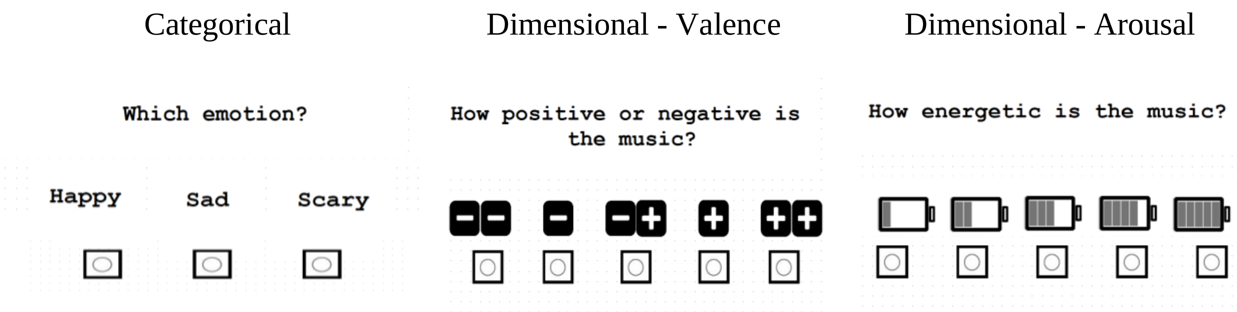
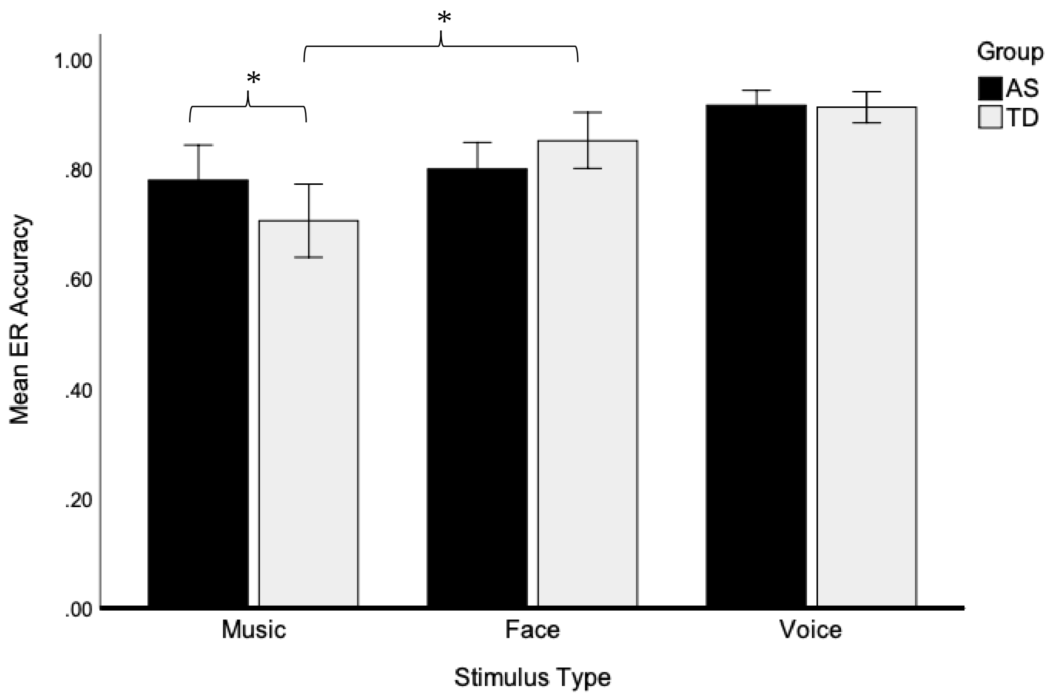


Figure 2

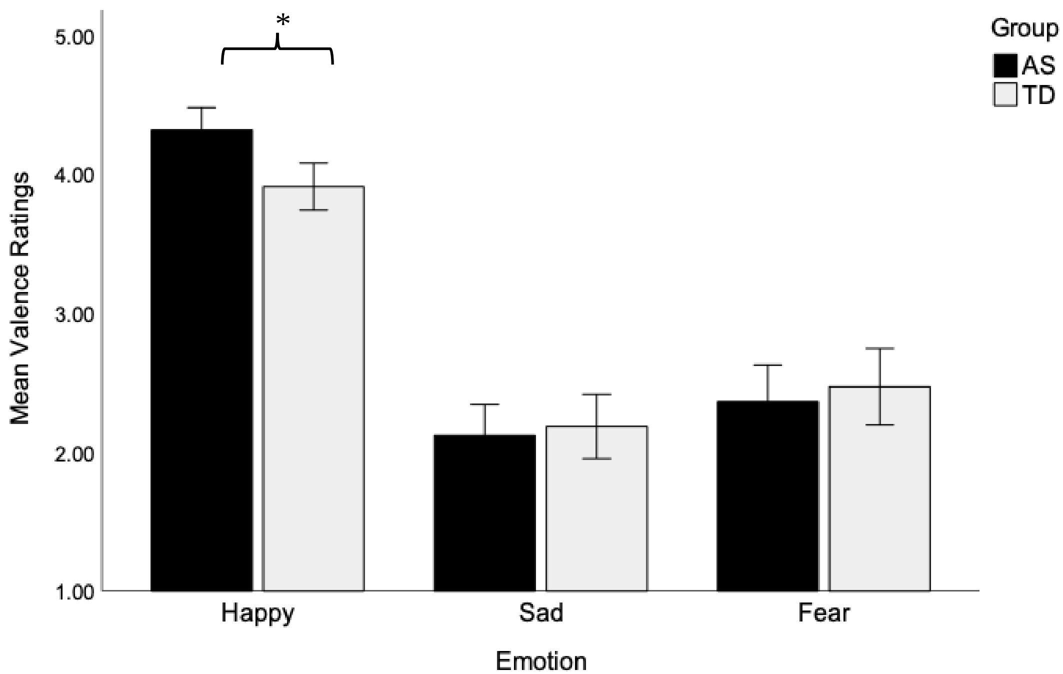
Between- and Within-Group Differences across Stimulus Types in the Categorical Condition



Note. Musical Emotion Recognition (ER) accuracy was significantly higher in the AS group compared to the TD group, whereas the groups did not differ in ER from voices or faces. Whereas both groups had higher ER accuracy from voices, the TD group had significantly lower ER accuracy from music than faces, whereas no differences emerged between music and faces for the AS group. Means and standard error bars are shown.
*p < .05.

Figure 3

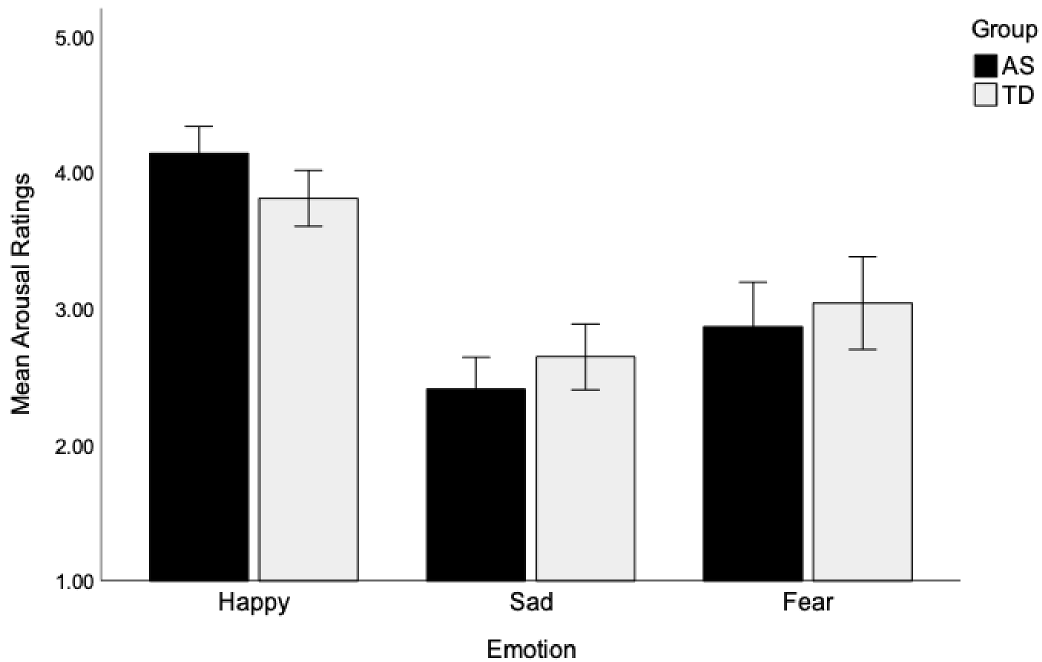
Between-Group Difference in Valence Ratings for Happy Emotions



Note. The AS group rated happy stimuli as more positive than did the TD group, whereas the groups did not differ in valence ratings of sad and fear emotions. Means and standard error bars are shown.
*p = .001.

Figure 4

No Group Differences in Arousal Ratings for Emotions



Note. Both groups rated happy emotions as more arousing than fear, and fear more arousing than sad. Means and standard error bars are shown.

Supplementary Information

Table 1

Family Demographics for the AS and TD Groups

	Total Sample (*N* = 36)	AS Group (*n* = 15)	TD Group (*n* = 23)	*p*
Maternal Education, n (%)				
High School	5 (13.9%)	4 (26.7%)	1(4.8%)	
College	7 (19.4%)	5 (33.3%)	2 (9.5%)	.07*
Undergraduate	10 (27.8%)	3 (20%)	7 (33.5%)	
Post-Graduate	12 (33.3%)	3 (20%)	9 (42.9%)	
Other	2 (5.5%)	0 (0%)	2 (9.5%)	
Annual Income, n (%)				
<$40,000	2 (5.5%)	2 (13.3%)	0 (0%)	.013*
$40,000-$60,000	5 (13.9%)	4 (26.7%)	1 (4.8%)	
$60,000-$80,000	5 (13.9%)	0 (0%)	5 (23.8%)	
$80,000-$100,000	4 (11.1%)	3 (20%)	1 (4.8%)	
$100,000-$125,000	6 (16.7%)	3 (20%)	3 (14.3%)	
>$125,000	5 (13.9%)	2 (13.3%)	3 (14.3%)	
Prefer not to say	9 (25%)	1 (6.7%)	8 (38%)	

Note. Family demographics data were available for 36 of 48 participants.
*p values of Fisher's exact tests between the AS and TD groups were not significant following Bonferroni corrections for multiple comparisons.

Bridge between Study 2 and 3

In Chapter 4, Study 2 aimed to evaluate the impact of task stimuli (music, faces, voices) and task demands (categorical and dimensional response options) on the recognition of basic emotions among children on the AS relative to TD children (ages 6-13 years), while also considering the impact of VCA. Findings from Study 2 suggested that compared to the TD group, the AS group showed a relative strength recognizing emotions from music, and comparable performance from faces and voices, while controlling for VCA (calculated and described as "verbal mental age”). Within group comparisons revealed that the AS and TD groups both performed better using vocal stimuli, though children on the AS performed equally well using musical and facial stimuli, whereas TD children performed better using facial than musical stimuli. Except for greater variability by the AS group in valence ratings for happy emotions, both groups also performed comparably using dimensional ratings of valence and arousal.

Thus, the goal of Study 3 was to expand on findings from Study 2 to evaluate the alexithymia hypothesis from music, compared with faces and voices, and from both categorical and dimensional response options. Secondary analyses were conducted using a subset of the data from Study 2, from 15 children on the AS and 17 TD children (aged 6-12 years) whose caregiver completed a parent-report measure of alexithymia. Study 3 was uniquely able to empirically explore the impact of alexithymia on ER task performance, across the multiple stimulus types and response options, in two ways. Participants in Study 3 were first compared by diagnostic group (AS versus TD) and then by level of alexithymia traits (low ALX versus high ALX), while also considering the impact of verbal mental age as a covariate. Associations between alexithymia, autism traits, and ER task performance were also evaluated.

The manuscript for Study 3 in this chapter, entitled "Brief Report: Examining the impact of alexithymia and autism traits on emotion recognition skills among children on the autism spectrum and typically-developing children" is in its final form to submit for publication, with tables and figures displayed in an appendix at the end of the manuscript.

Chapter 5: Study 3

Brief Report: Examining the impact of alexithymia and autism traits on emotion recognition skills among children on the autism spectrum and typically-developing children

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Keywords: emotion recognition, autism, alexithymia, music

Abstract

Alexithymia, a trait characterized by difficulty describing emotions, is thought to contribute to reduced accuracy on facial and vocal emotion recognition (ER) tasks among persons on the autism spectrum (AS) (the “alexithymia hypothesis”; Bird & Cook, 2013). However, we recently found that children on the AS may demonstrate enhanced skills compared to typically-developing (TD) children in recognizing music-evoked emotions (Chapter 4: Study 2), though the impact of alexithymia on musical ER skills has yet to be elucidated. Thus, the current study aimed to examine the relative influence of alexithymia and autism traits on ER from music, as compared with ER from faces and voices. Fifteen AS and 17 TD children (6-12 years) completed an ER task using categorical (emotion labels) and dimensional (valence, arousal) ratings for happy, sad, and fear emotions. Performance was compared between the groups categorized on the basis of autism traits (AS and TD) and then on the basis of level of alexithymia (low ALX and high ALX), while controlling for verbal cognitive ability. Findings revealed that neither autism nor alexithymia traits were associated with facial and vocal ER accuracy, but that higher levels of alexithymia and autism traits were associated with increased recognition of emotions from music. Further, dimensional emotional valence and arousal ratings were not impacted by variability in alexithymia traits. Overall, these findings were inconsistent with the alexithymia hypothesis; rather, they suggest that the enhanced recognition of musical ER among persons on the AS may also extend to those with co-occurring alexithymia. We thus suggest that the use of music as a strengths-based approach to emotion research and therapies may be similarly accessible and preferable to explore among persons with alexithymia as they are among persons on the AS.

Introduction

Despite the notion that differences in basic emotion recognition (ER) contribute to the unique patterns of social communication and interaction among persons on the autism spectrum* (AS), meta-analytic findings of reduced accuracy on ER tasks by persons on the AS relative to their typically-developing (TD) peers (Lozier et al., 2014; Uljarevic & Hamilton, 2012; Velikonja et al., 2019) are punctuated by findings from a number of individual studies citing comparable ER skills between groups (e.g., Harms et al., 2010, Jones et al., 2010; Nuske et al., 2013; Ozonoff et al., 1990; Quintin et al., 2011). Such disparity in findings may be related to variability in individual traits thought to impact ER performance, if they are not accounted for. For example, consistent with evidence that level of verbal cognitive ability contributes significantly to ER task performance (e.g., Trevisan et al., 2016) and how task responses are captured (Harms et al., 2010), comparable ER accuracy has been found between AS and TD groups when differences in verbal cognitive ability are accounted for statistically or through group matching procedures (e.g., Golan et al., 2007; Heaton et al., 2008; for discussion of considerations in group matching, see Russo et al., 2021). Differences in ER have also predominantly been found using socially explicit stimuli (e.g., faces, voices); however, comparable or even superior performance in recognizing music-evoked emotions has been found among persons on the AS (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016), who have been found to display a variety of unique musical abilities and strengths (Heaton, 2008; see Quintin, 2019, for a review).

More recently, alexithymia, a trait characterized by difficulty identifying and describing emotions (Sifneos, 1973), has also become a variable of interest in understanding potential ER differences among persons on the AS (Bird & Cook, 2013; Trevisan & Birmingham, 2016).

Whereas alexithymia is thought to be prevalent in approximately 10-18% of the general population (Joukamaa et al., 2007), it is estimated to co-occur in up to 65% of persons on the AS (Kinnaird et al., 2019) and is positively correlated with levels of autism traits in adults (Lombardo et al., 2007) and in children (Griffin et al., 2016). Specifically, autism is thought to be associated with Type II alexithymia (Hill et al., 2004), characterized by differences in the cognitive appraisal of emotional experiences and internal states (i.e., experiencing emotions typically but having difficulty verbally identifying, recognizing or describing them), rather than Type I alexithymia, characterized by differences in the affective experience of emotion in addition to its cognitive appraisal (Vorst & Bermond, 2001).

In their "alexithymia hypothesis," Bird and Cook (2013) posited that difficulties with ER might result from co-occurring alexithymia rather than autism symptoms and suggested that the mixed findings among persons on the AS may be a consequence of the lack of consideration of alexithymia. The majority of the evidence for reduced ER accuracy among persons on the AS with greater levels of alexithymia has been found using socially explicit faces and voices among older adolescents (Milosavljevic et al., 2016) and adults (Cook et al., 2013; Heaton et al., 2012; Ola & Gullon-Scott, 2020; see Sivathasan et al., 2020, for a review). In exploring alexithymia and music, Allen et al. (2013) found that autistic adults who report greater Type II alexithymia selected fewer verbal labels to describe their own emotional experience while listening to musical excerpts than did TD adults (Allen et al., 2013); however, they did not explore relationships between alexithymia and recognition of emotions from music specifically. Thus, it is unclear whether the alexithymia hypothesis would apply to musical ER among persons on the AS, given their strengths in the musical domain (Quintin, 2019).

In a study aimed at addressing many of the above-mentioned concerns by directly comparing ER performance from musical, facial, and vocal stimuli among children on the AS and TD children (ages 6-13 years), using both categorical and dimensional response options (Chapter 4: Study 2), we found that the children on the AS (n = 25) displayed similar performance to the TD children (n = 23) when recognizing happy, sad, and fear emotions from faces and voices, but significantly outperformed the TD children when recognizing emotions from music. Additionally, groups did not differ in their performance when asked to provide dimensional ratings of emotional valence and arousal, with the exception of higher valence ratings by the AS group, specifically for happy emotions. These findings were observed while verbal mental age (VMA) was controlled as a covariate; however, as alexithymia measures were not available for all of the participants, we were unable to statistically evaluate the contribution of alexithymia to ER.

Thus, the primary goal of the current investigation was to test the alexithymia hypothesis for ER skills from music, compared with faces and voices, among a subset of the AS and TD participants (N = 32) from our larger study (N = 48; Chapter 4: Study 2) for whom alexithymia data were available. Although findings of reduced musical ER accuracy by persons with higher levels of alexithymia would support the alexithymia hypothesis, given the demonstrated strengths of persons on the AS with musical ER, and that autism traits and alexithymia are correlated but distinct characteristics (Cuve et al., 2021), we did not venture specific hypotheses regarding comparisons of groups categorized by levels of autism and alexithymia traits.

To explore the relative influence of autism and alexithymia on ER individually, we re-examined our ER task data, first with diagnostic category (AS vs. TD) as our between-subjects grouping variable, and then with alexithymia (Low ALX vs. High ALX) as our grouping variable. This analytical approach allowed us to observe the strength of potential associations between patterns of ER performance with each of autism traits and alexithymia traits within the same set of participants, while also controlling for variability in VMA of the group as a whole. Additionally, we examined the impact of autism traits and alexithymia on both categorical and dimensional ER response options from our existing ER task data.

Method

Participants

The participants included 32 children, 15 children with an autism spectrum disorder (ASD) diagnosis (*n* = 11 males) and 17 TD children (*n* = 8 males), representing a subset of data from a larger ER study (N = 48) for whom the Children's Alexithymia Measure-Parent-Report (CAM-PR; Way et al., 2010) and the Social Responsiveness Scale, Second Edition (SRS-2; Constantino & Gruber, 2012) were completed.

The participants' characteristics are summarized in Table 1, displayed first by diagnostic group membership (AS vs. TD) and then by level of alexithymia traits (Low vs. High ALX). As there is no established CAM-PR cutoff score, Low vs. High ALX groups were derived via a median split, such that the participants in the Low ALX group had CAM-PR scores between 0-5 and the High ALX group had scores between 6-29. As expected, most but not all of the participants in the High ALX group had an ASD diagnosis (81%), compared to 13% in the Low ALX group. However, despite similar mean SRS-2 Total scores between the AS and High ALX groups and the TD and Low ALX groups, all of the participants in the AS group had SRS-2 scores above the clinical cutoff (≥60), and all TD children had scores below the cutoff, except for one TD participant with a total score of 61 (who was retained in the reported analyses as the pattern of results excluding this participant remained the same). In both sets of comparisons, the groups were matched on verbal mental age (*ps* ≥ .05).

Procedure

The experimental task design, procedure, and results of the larger study are summarized here and described in full elsewhere (Chapter 4: Study 2). All of the procedures for this study were approved by McGill University's Research Ethics Board, and all of the materials and procedures were administered in the participant's dominant language (English or French). Informed consent was obtained from the parents and assent was provided by each participant prior to the beginning of the study.

The experimental task was completed in the E-prime (version 3.0) environment on a PC laptop using a mouse and over-ear headphones. The ER task included 72 different musical, facial and vocal stimuli depicting happy, sad, or fear emotions, as these are emotions that can be conveyed in all three types of stimuli. Stimuli were obtained from the NimStim Set of Facial Expressions (Tottenham et al., 2009), Montreal Affective Voices battery (MAV; Belin et al., 2008), and the Musical Emotional Bursts battery (MEB; Paquette et al., 2013) validated stimulus sets. A three-tiered response system, involving a categorical condition and a two-part dimensional condition, was provided following the presentation of each stimulus item. In the categorical response condition, each item was presented briefly on a computer screen for 1.5-2 seconds, and then followed by the on-screen instruction, "Which emotion?" with three verbal labels of happy, sad, and fear. In the dimensional response condition, the presentation of each item was followed by the on-screen instructions, "How positive or negative is the face (or voice or music)?" (valence) and, "How energetic is the face (or voice or music)?" (arousal). The participants provided valence and arousal ratings on 5-point Likert scales from very negative to very positive, and from very low energy to very high energy, respectively (see Figure 1 of Chapter 4: Study 2).

The participants' verbal cognitive skills and verbal mental age (VMA) were estimated using the Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V; Wechsler, 2014) or the Wechsler Abbreviated Intelligence Scale, Second Edition (WASI-II; Wechsler, 2011). A parent and/or teacher completed the CAM-PR and SRS-2 for all of the participants.

Results

Mixed analyses of covariance (ANCOVAs) were run for each of the categorical, dimensional valence, and dimensional arousal response options, to explore the interaction effects of group (AS, TD), by stimulus type (music, face, voice), and by emotion (happy, sad, fear), while controlling for VMA. To confirm the reliability of previously observed between-group findings, the results from this set of participants ($N = 34$) are discussed in relation to the larger group from which they were derived (N = 48). Then, the mixed ANCOVAs were re-run with Low and High ALX groups, and the patterns of findings and the magnitude of between-group effects were compared. Results are presented in Table 2.

Group Comparisons for the Categorical Condition

When comparing groups based on diagnostic category (AS vs. TD), a significant interaction was found between stimulus type and group, while controlling for VMA, $F(1.6, 46.37) = 8.93$, $p = .001$, $\eta_p^2 = .24$. Like in the larger sample (Chapter 4: Study 2), simple main effect analyses revealed that the AS and TD groups performed equally well on ER accuracy from faces ($p = .26$) and voices ($p = .54$), but the AS group had significantly higher accuracy scores than did the TD group on musical ER, $p = .027$ (Figure 1). There was no significant emotion (happy, sad, fear) by diagnostic group interaction, $F(2, 58) = 2.83$, $p = .067$, $\eta_p^2 = .089$.

When comparing groups based on level of alexithymia (low vs. high ALX), a significant interaction was also found between stimulus type and group, while controlling for VMA, F(1.6, 45) = 5.34, p = .013, η_p^2 = .16. The Low and High ALX groups performed equally well on ER accuracy from faces (p = .50) and voices (p = .84); however, the significant difference observed between diagnostic groups on ER accuracy from music dropped to a trend level when the groups were categorized by alexithymia (p = .051) (Figure 1). There was a significant emotion by alexithymia group interaction, F(2, 58) = 3.93, p = .025, η_p^2 = .12, but post-hoc analyses failed to reveal any significant between-group differences, *ps* > .05.

Partial correlations controlling for VMA revealed that alexithymia (i.e., CAM-PR total scores) and autism traits (i.e., SRS-2-Total Scores) were not correlated with ER from faces or voices, ps >.05; however, they were both moderately positively correlated with ER from music, indicating that higher levels of alexithymia and autism traits (i.e., lower CAM-PR and SRS-2 total scores) were associated with higher ER accuracy from music. A slightly larger correlation was observed with autism traits (r = .374, p = .019) than with alexithymia (r = .365, p = .022), though a comparison of correlation coefficients was not significant (z = .04, p = .48).

Overall, findings using categorical responses suggest that group differences in musical ER were attributable to diagnostic group (i.e., children on the AS demonstrated higher ER accuracy from music than did the TD group), and to a lesser extent to the level of alexithymia. However, strengths in ER performance from music were associated with higher, rather than lower, levels of alexithymia (and autism traits), when controlling for VMA across the participants. By comparison, groups did not differ in ER accuracy on facial and vocal tasks on the basis of diagnosis or level of alexithymia; and levels of autism or alexithymia traits of the participants were not associated with ER performance from faces and voices.

[INSERT TABLE 1 HERE]

[INSERT FIGURE 1 HERE]

Group Comparisons for the Dimensional Condition

Valence Ratings

Although a diagnostic group (AS vs. TD) by emotion interaction for valence ratings (that was observed in Chapter 4: Study 2) did not reach significance in this subgroup, $F(1.40, 40.67) = 1.76$, $p = .19$, $\eta_p^2 = .024$, a simple main effect of valence ratings for happy emotions was found, indicating that the AS group rated happy emotions more positively than the TD group, $p = .02$, while controlling for VMA. When comparing groups based on level of alexithymia (low vs. high ALX), an emotion by group interaction for valence ratings was not significant, $F(2, 58) = 1.82$, $p = .17$, $\eta_p^2 = .06$, while controlling for VMA. Further, partial correlations between valence ratings for each emotion with CAM-PR and SRS-2 Total scores were not significant, *ps* > .05.

Arousal Ratings

Findings from this subset of the participants remained consistent with the larger study, as no differences emerged in emotional arousal ratings between diagnostic (AS vs. TD) groups when controlling for VMA. Similarly, no differences were found when the groups were defined by level of alexithymia. Partial correlations between arousal ratings for each emotion with CAM-PR and SRS-2 Total Scores were also not significant (*ps* > .05). These findings suggest that patterns of rating emotional arousal were not related to the level of autism or alexithymia traits of the participants in this study, and that both sets of groups rated emotional arousal comparably.

Overall, findings using the dimensional response options suggest that group differences in valence ratings for happy emotions were attributable to diagnostic group (i.e., higher valence ratings by the AS versus TD group), and not to groups categorized on the basis of alexithymia (i.e., participants with low and high ALX rated the valence of emotions comparably). The correlation between SRS-2 scores and valence ratings for happy emotions failed to reach significance ($r = .25$, $p = .08$), which suggests that the AS group perceived happy emotions as more positive, regardless of the participants' level of autism traits. Patterns of valence ratings for sad and fear emotions, or of emotional arousal of the stimuli, were comparable regardless of differences in autism or alexithymia traits.

[INSERT TABLE 2 HERE]

Discussion

The goal of the current study was to explore the impact of alexithymia and autism traits on emotion recognition (ER) using musical stimuli, as compared with frequently-used facial and vocal stimuli. We examined ER performance for happy, sad, and fear emotions in a subset of the participants from our previous study (Chapter 4: Study 2), categorized first by diagnostic group (AS and TD) and then by level of alexithymia traits (low and high ALX), and controlling for verbal mental age (VMA). Our findings revealed similar patterns of ER accuracy across emotions for facial and vocal stimuli between children on the AS and TD children, and between children with low and high ALX; neither level of autism nor alexithymia traits were associated with ER accuracy from faces or voices. By comparison, both autism and alexithymia traits were positively associated with ER accuracy from music, indicating that higher autism and alexithymia traits were associated with increased ER accuracy from music. The strengths in musical ER demonstrated by the children on the AS were also found, to a slightly lesser extent, among children in the high ALX, rather than in the low ALX group. Finally, dimensional responses using emotional valence and arousal ratings were not impacted by alexithymia or autism traits, except for higher valence ratings for happy emotions by AS versus TD children.

As such, our findings were inconsistent with the alexithymia hypothesis (Bird & Cook, 2013). In our study, higher levels of alexithymia were not associated with reduced facial and vocal ER accuracy using categorical emotion labels, nor did alexithymia influence patterns of responses using dimensional valence and arousal ratings. These ER findings may have diverged from the patterns that would be expected by the alexithymia hypothesis, possibly as a result of our attempts to carefully consider the impact of verbal cognitive ability in ER, through statistical and group matching procedures. Specifically, considering verbal mental age allowed us to account for differences in verbal IQ and age between groups. Additionally, the ER task was designed to rely minimally on verbal ability, which also allowed us to observe patterns of ER performance among children with a wide range of cognitive skills. Thus, it is possible that ER difficulties associated with alexithymia may not be as evident after accounting for the impact of verbal cognitive skills to ER. This would be consistent with our conclusions in a recent systematic review (Sivathasan et al., 2020), that verbal skills may have a greater influence on behavioural performance on ER tasks and associated task demands (e.g., identifying conveyed emotions from task stimuli), whereas the influence of alexithymia may be more prominent during ER tasks that require the ability to appraise or connect one's own internal emotional reactions (e.g., physiological responses) with external behavioural responses.

Furthermore, our finding that alexithymia and autism traits were positively associated with musical ER accuracy suggests that higher levels of alexithymia may not negatively impact the skills or processing style that may be unique to the processing of musical emotions. Given that children on the AS tended to also have higher alexithymia scores, it is likely that the unique and enhanced processing of musical emotions demonstrated by children on the AS is less impacted by challenges with appraising one's own or others' emotions than their processing of facial and vocal ER. That is, challenges associated with alexithymia may not be extended to the identification of emotions from less socially explicit stimuli such as music.

Our findings thus extend the evidence of relative ER strengths found from music among persons on the AS (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016) to include those with co-occurring alexithymia. Taken together with our findings, this growing line of research shows that music affords a unique opportunity to study ER of persons on the AS. Our findings also provide support for the utility and accessibility of music therapy and education and for incorporating music in speech therapies as strengths-based approaches not only among persons on the AS (e.g., Chenausky et al., 2016; LaGasse, 2017; Lense & Camarata, 2020; Sharda et al., 2018), but also among persons with alexithymia. Specifically, our results suggest that music can be particularly relevant to support socioemotional learning. Indeed, in a recent pilot study of a brief music-based intervention designed to enhance emotional awareness among adolescents on the AS, Pedregal and Heaton (2021) found preliminary evidence for post-intervention increases in ER accuracy from voices (and to a lesser extent, from faces), as well as improvements in aspects of alexithymia associated with emotional bodily awareness. Music-based interventions thus seem to hold great promise for persons on the AS.

Summary and Future Directions

In sum, we found that the enhanced skills that the children on the AS displayed on a musical ER task were also associated with higher levels of alexithymia. Children on the AS showed comparable performance with the TD children on facial and vocal ER tasks, which was not associated with levels of alexithymia, while considering verbal mental age. These findings are inconsistent with the alexithymia hypothesis and instead offer a window into considering how music can be utilized to possibly enhance non-musical ER skills among persons on the AS or TD persons with higher levels of alexithymia traits. Future directions for this research should consider assessing developmental trajectories of alexithymia among persons on the AS, challenges with which may differ as a function of age and verbal cognitive ability. Ultimately, further exploration of these relationships as associated with categorical and dimensional aspects of ER from music is needed in order to facilitate our understanding of the heterogeneity of characteristics among persons on the AS. Our findings provide further support for the use of strengths-based music programs and interventions to enhance the processing and use of emotional information of children on the AS.

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Appendix: Tables and Figures

Table 1

Participant Characteristics of the AS vs. TD and Low vs. High Alexithymia (ALX) groups

	AS (*N* = 15)	TD (*N* = 17)		High ALX (*N* = 16)	Low ALX (*N* = 16)	
	M (SD); range	M (SD); range	p	M (SD); range	M (SD); range	*p*
Sex	11 males	8 males		11 males	8 males	
Age	10.95 (1.11); 9-12	9.33 (1.61); 6-12	.003	10.57 (1.24); 8-12	9.61 (1.81); 6-12	.09
VMA	8.07 (1.43); 5-10	9.44 (2.25); 5-13	.051	8.21 (1.51); 5-10	9.47 (2.32); 5-13	.13
VCI	74 (15); 51-102	101 (14); 73-128	<.0001	79 (15); 51-102	98 (19); 62-128	.003
FSIQ	75 (13); 54-98	104 (12); 84-124	<.0001	80 (15); 54-107	100 (18); 59-124	.003
SRS-2	75 (7); 65-88	47 (7); 40-61	<.0001	72 (11); 46-88	49 (10); 40-71	<.0001
CAM-PR	15 (8); 3-29	2 (3); 0-9	<.0001	15 (8); 7-29	2 (2); 0-5	<.0001

Note. Mean (M), standard deviation (SD), ranges, and p values of independent sample t-tests between the AS vs. TD groups and Low vs. High Alexithymia (ALX) groups. Chronological age (years), Verbal Mental Age (VMA; years), Verbal Comprehension Index (VCI) standard score, Full Scale IQ (FSIQ) standard score, Social Responsiveness Scale-2 (SRS-2) Total Score, Children's Alexithymia Measure-Parent Report (CAM-PR) Total Score. For FSIQ: AS group n = 14, TD group n = 16.

Table 2

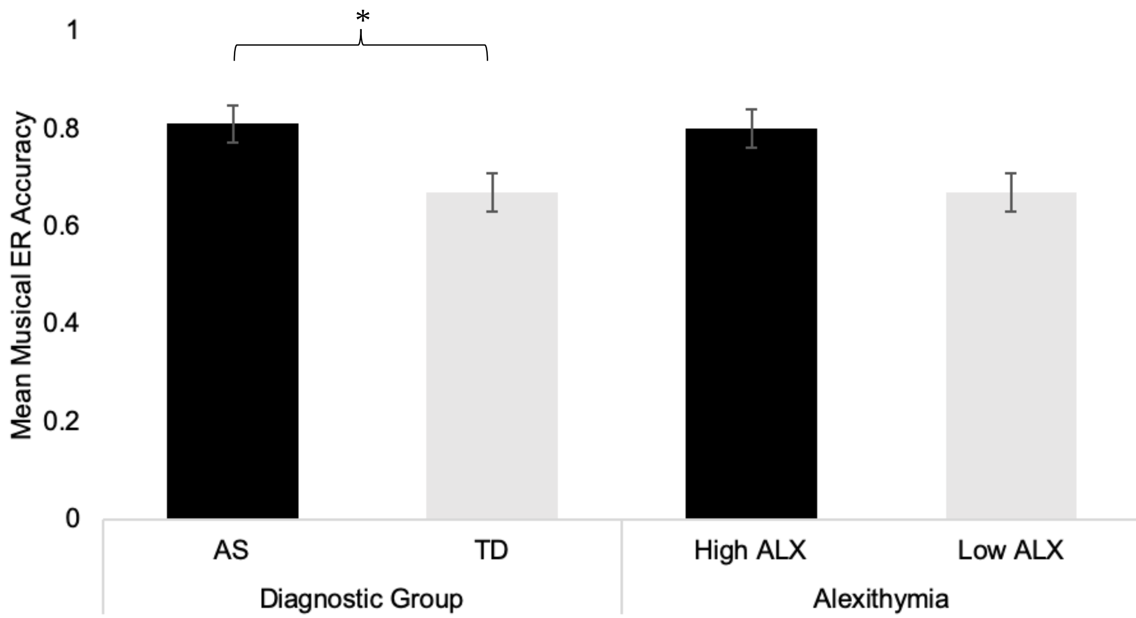
Adjusted Means and Standard Errors for Categorical & Dimensional Condition Ratings

	AS (*N* = 15)	TD (*N* = 17)	F	η_p^2	High ALX (*N* = 16)	Low ALX (*N* = 16)	F	η_p^2
	Adjusted Mean (SE)	Adjusted Mean (SE)			Adjusted Mean (SE)	Adjusted Mean (SE)		
Categorical								
Stimulus Type			8.93*	.24			5.34*	.16
Music	.81 (.04)	.67 (.04)	5.44*	.16	.80 (.04)	.67 (.04)	4.14	.13
Face	.78 (.04)	.84 (.03)	1.33	.04	.79 (.04)	.83 (.04)	.47	.02
Voice	.90 (.02)	.91 (.02)	.40	.01	.90 (.02)	.91 (.02)	.04	.001
Emotion			2.83	.09			3.93	.12
Dimensional-Valence								
Stimulus Type			2.75	.09			1.82	.06
Emotion			1.76	.06			.59	.02
Happy	4.31 (.13)	3.86 (.12)	5.98*	.17	4.17 (.13)	3.96 (.13)	1.18	.040
Sad	2.18 (.16)	2.26 (.15)	.13	.004	2.18 (.16)	2.26 (.16)	.12	.004
Fear	2.50 (.18)	2.53 (.17)	.01	.000	2.48 (.17)	2.56 (.17)	.12	.004
Dimensional-Arousal								
Stimulus Type			2.04	.07			1.89	.06
Emotion			1.63	.05			.88	.03

Note. Means adjusted for VMA of the overall sample = 8.80 years; means for individual stimulus type or emotion comparisons are not reported when the overall interaction effects and simple main effects are not significant. *p < .05.

Figure 1

Between-Group Differences for Musical ER Accuracy by Group Comparison in the Categorical Condition



Note. Musical Emotion Recognition (ER) accuracy was significantly higher in the AS group than in the TD group. No significant differences were found when the groups were organized by High vs. Low alexithymia. The means and standard error bars are shown. *$p < .05$.

Chapter 6: Discussion

Objectives & Rationale

The goal of the current dissertation was to investigate mechanisms of emotion processing among persons on the autism spectrum (AS), specifically with consideration towards evaluating the extent to which basic emotion recognition (ER) differences between persons on the AS and typically developing (TD) persons are ubiquitous among persons on the AS. Early research and conceptualizations of ER were often been framed using "deficit-based" approaches, which tended to be focused on identifying and understanding ER differences as a basis for understanding socialization differences observed between AS and TD persons. As such, many of the published findings over the past 40 years have converged to highlight reduced performance accuracy on ER tasks by persons on the AS (e.g., Lozier et al., 2012; Uljarevic & Hamilton, 2014; Velikonja et al., 2019; Yeung, 2021). However, comparable performance between AS and TD groups has also been reported (e.g., Castelli, 2005; Jones et al., 2010; Ozonoff et al., 1990), particularly in the domain of musical ER (e.g., Gebauer et al., 2014; Heaton et al., 2008; Quintin et al., 2011), and with these findings, an emphasis on the need for careful consideration of relevant participant characteristics and task-specific factors that may differentially impact ER skill development and task performance of persons on the AS relative to TD persons (Harms et al., 2010; Nuske et al., 2012; Ozonoff et al., 1990). These contributing factors, as well as strengths-based approaches to ER, were examined in three studies included in this dissertation.

Study 1 was designed to assess, through a systematic review of the literature, the relative impact of two relevant participant characteristics to emotion processing among persons on the AS – verbal cognitive ability (VCA) and alexithymia. Although VCA is thought to be positively associated with ER abilities among TD persons (Lawrence et al., 2015) and persons on the AS (e.g., Ozonoff et al., 1990; Trevisan & Birmingham, 2016), its mechanisms of impact on ER development and ER task performance remains unclear (Harms et al., 2010). Consideration of the impact of alexithymia–a difficulty with identifying and describing emotions–on ER performance is relatively new to autism research, with growing interest in the "alexithymia hypothesis" (Bird & Cook, 2013) that observations of reduced ER accuracy by AS relative to TD groups might be better explained by characteristics associated with co-occurring alexithymia, rather than autism per se. Despite the notion that both VCA and alexithymia are present with greater variability among persons on the AS as compared to TD persons (Christensen et al., 2018; Kinnaird et al., 2019), accounting for these characteristics in group comparisons remains an inconsistent practice. Moreover, VCA and alexithymia have often been considered separately in relation to studying ER performance among persons on the AS (Trevisan & Birmingham, 2016), although they may share a similar inverse relationship as is found among non-autistic persons (i.e., higher VCA scores being associated with lower alexithymia levels; Montebarocci et al., 2010).

Studies 2 and 3 were designed to evaluate the impact of task stimuli (music, faces, voices) and task demands (categorical and dimensional response options) on the recognition of basic emotions among children on the AS relative to TD children, while also considering the impact of VCA (Study 2 and 3) and alexithymia (Study 3). Deficit-focused approaches have tended to be associated with performance on tasks with socially explicit facial and vocal stimuli, and categorical or forced-choice verbal label responses. Thus, in Studies 2 and 3, alternative approaches were used to investigate ER, specifically involving tasks with musical, facial, and vocal stimuli as well as using dimensional ratings of emotional valence and arousal (Russell, 1980), while also considering the impact VCA scores and alexithymia traits on ER.

Research Questions and Hypotheses

For Study 1, I aimed to assess the relative contributions of VCA and alexithymia to emotion processing task performance among persons on the AS through a review of published empirical studies that included measures of both participant characteristics. Given the exploratory nature of this investigation, no formal hypotheses were posited.

For Study 2, given the prior ER research primarily using socially explicit stimuli, as well as evidence from the musical domain, I hypothesized that children on the AS may display a relative strength in ER accuracy on a music-based task relative to TD children, and relative to their performance from facial and vocal stimuli. Conversely, TD children may display a relative strength in facial and vocal ER compared to children on the AS, but may not demonstrate within-group differences in performance among the three stimuli types (music, face, voice). Based on the findings from Study 1 on the contributions of VCA to behavioural task performance, Study 2 hypotheses were offered while considering the impact of VCA. I also explored the use of dimensional ratings of valence and arousal on ER task performance, but did not venture specific hypotheses regarding between or within group differences.

In Study 3, I considered the alexithymia hypothesis for ER skills from music compared with faces and voices among AS and TD groups, while controlling for VCA. The alexithymia hypothesis would suggest that ER task performance broadly would be negatively associated with alexithymia, and therefore that comparable ER performance would be observed between AS and TD groups when controlling for alexithymia. However, given conflicting prior literature considering the role of VCA, correlations between alexithymia and autism traits, and the strengths of children on the AS in the musical domain, the aims of Study 3 were considered exploratory and therefore specific hypotheses about directional associations were not offered.

Discussion of the Findings from Study 1

From an initial search of all empirical studies that referenced autism and alexithymia published through July 2019 (N = 309), only 13 studies of emotion processing task performance among AS and TD groups that also included measures of alexithymia and VCA were identified. In nearly all of the studies, VCA was used as a group-matching variable in comparisons between AS and TD participants. In three of the studies (Bird et al., 2010; Gaigg et al., 2018; Komeda et al., 2019), the AS and TD groups were matched on levels of alexithymia traits, and in one study (Milosavljevic et al., 2016) VCA was statistically controlled in comparisons between AS participants with and without alexithymia. This methodological approach thus allowed for any group differences to be attributed to diagnostic group (i.e., AS or TD) and/or to levels of alexithymia when explicitly evaluated.

Behavioural Emotion Processing Paradigms

Emotion Recognition Tasks. Basic ER tasks were used in seven of the 13 studies, with six involving facial and/or vocal (socially explicit) stimuli and the other involving musical stimuli. A summary of findings from the ER studies revealed that when VCA was considered, no group differences emerged for behavioural task performance from the musical ER study (Allen et al., 2013) or from four of the socially explicit ER studies (Katsyri et al., 2008; Milosavljevic et al., 2016; Murray et al., 2017; Schneider et al., 2013, part B), regardless of whether group differences in alexithymia were controlled. Thus, these findings suggest that behavioural ER task performance may be potentially more significantly impacted by VCA than alexithymia (or diagnostic group), or that controlling for alexithymia does not necessarily impact behavioural task performance beyond the effect of VCA. However, negative correlations between ER task performance and levels of alexithymia traits were observed in the two ER studies in which reduced performance by AS versus VCA-matched TD groups was found (Kliemann et al., 2013; Heaton et al., 2012), as well as in some, (Katsyri et al., 2008, Allen et al., 2013) but not all (Milosavljevic et al., 2016), of the studies that considered alexithymia, suggesting that alexithymia may also contribute less than VCA to behavioural ER performance.

Emotion Processing, VCA, and FSIQ. The same patterns of results found using ER tasks were found in the other 6 studies of measured emotion processing using basic emotional self-perception and production tasks, and among three of four empathy for pain paradigms, providing additional support for the robust influence of VCA to behavioural performance on ER and emotion processing more broadly. A cursory look beyond VCA at Full Scale IQ (FSIQ) in 12 additional behavioural emotion processing studies highlighted that among the majority of studies, no group differences were observed between FSIQ-matched groups of AS and TD adults, regardless of whether alexithymia was considered. However, the mean contributions of verbal versus nonverbal cognitive abilities to FSIQ scores could not be ascertained, and thus these findings together with prior evidence of the specific impact of VCA to emotion processing on its own, provides a rationale for specifically accounting for variability in VCA in group comparisons through group-matching or statistical procedures.

Neurophysiological Correlates of Emotion Processing

Available neurophysiological data from six of the studies in Study 1 highlighted areas in which the impact of alexithymia was more readily observed than on behavioural tasks. The findings revealed that physiological arousal or empathy-related brain activation during emotion processing tasks differed between VCA-matched AS and TD groups when alexithymia was not considered (Krach et al., 2015; Minio-Paluello et al., 2009), but “disappeared” when alexithymia was taken into account (Allen et al., 2013; Bird et al., 2010; Gaigg et al., 2018; Schneider et al., 2013). These findings demonstrate the impact of alexithymia on neurophysiological responses associated with emotion processing, regardless of diagnostic group and beyond the impact of VCA.

Contributions of Study 1

Overall, Study 1 contributed to the field as the first systematic review (Sivathasan et al., 2020) to assess the relative and differential impacts of VCA and alexithymia to behavioural and neurophysiological correlates of emotion processing of persons with AS relative to TD persons. Aggregate findings across 13 studies demonstrated that VCA may have a greater relative impact than alexithymia on behavioural performance on emotion processing tasks, whereas support for the alexithymia hypothesis was more readily observable among underlying neurophysiological correlates of emotion processing. These findings contribute to the evidence in support of combining calls to consider VCA (e.g., Harms et al., 2010; Ozonoff et al., 1990) and alexithymia (Bird & Cook, 2013) when studying emotion processing among persons on the AS, to emphasize the importance of accounting for both of these participant factors in studies involving persons on the AS.

Study 1 also contributed to the field by identifying consistent and broad gaps in the literature on emotion processing and autism, shedding light on important areas for future research. The majority of studies (10 of 13) that included alexithymia and VCA in group comparisons of emotion processing included adult participants (mean age between 24-40 years) with VCA scores in the average to above average ranges, highlighting the dearth of emotion processing research among children on the AS that accounts for alexithymia and VCA in group comparisons. Additionally, most of the participants on the AS included in Study 1 had lower self-reported levels of AS and alexithymia traits. With the exception of one study (Milosavljevic et al., 2016), the alexithymia hypothesis was not explicitly tested at the behavioural level in many of the studies, making it harder to precisely parse out variability associated with autism versus alexithymia traits from any given individual. Finally, VCA and alexithymia appeared to impact performance among various types of behavioural and neuroimaging task stimuli (e.g., basic ER, empathy for pain tasks) and response options (i.e., categorical verbal labels versus dimensional ratings of valence and arousal) tested separately. However, comparisons of performance between various task stimuli and across task demands, and how they interact with participant characteristics, were not directly assessed within any of the included studies.

Discussion of the Findings from Studies 2 and 3

The findings from Studies 2 and 3 expanded on the findings highlighted in Study 1 in several ways. Study 2 included child participants (25 children on the AS and 23 TD children) from specialized schools that served children with various developmental needs and from within the general community. The children's ages ranged between 6-13 years with a wide range of VCA scores (standard scores ranging from 54-124; verbal mental ages ranging from 5-15 years). I focused on this age range as an important developmental stage during which ER skills for various emotions begin to mature (Hunter et al., 2011) and cognitive abilities begin to stabilize (Howlin et al., 2014). As such, potential differences in ER or VCA between AS and TD groups may be more stable than earlier in development, and less influenced by years of learning and experience processing emotions as compared to adulthood. Additionally, I experimentally assessed ER by designing a new behavioural paradigm to directly compare potential strengths-based (musical ER) with conventional approaches (socially-explicit facial and vocal ER), both within and between AS and TD groups. Specifically, the novel ER task in Studies 2 and 3 involved three blocks of 24 musical, 24 facial, and 24 vocal stimuli. The task also offered counterbalanced response options to assess whether potential group differences may be attributed to either the use of categorical verbal labels (happy, sad, fear) or alternate dimensional scales for rating emotional valence and arousal.

In Study 3, I tested the alexithymia hypothesis among the subset of the participants on the AS (n = 15) and TD (n = 17) from Study 2 whose caregivers completed the Children's Alexithymia Measure – Parent Report (CAM-PR; Way et al., 2010). Using similar methodology as Milosavljevic et al. (2016), I compared ER performance between the AS and TD groups, and then between low and high alexithymia groups, while controlling for VCA.

The findings from Studies 2 and 3 revealed that, when controlling for the influence of VMA (Study 2 and 3) and alexithymia (Study 3), no differences were found between the AS and TD groups on facial and vocal ER accuracy. Rather, the children on the AS were better able than the TD children recognizing emotions from music, while controlling for VMA. Within group comparisons revealed that the AS and TD groups both performed better using vocal stimuli, although children on the AS performed equally well using musical and facial stimuli whereas TD children performed better using facial than musical stimuli. When the groups in Study 3 were also compared on their level of alexithymia symptoms (low ALX vs. high ALX), the difference in musical ER accuracy "dropped" to a trend level, though alexithymia and autism traits were found to be positively correlated with musical ER. Overall, these findings suggest that ER accuracy differences were more likely to be attributed to autism rather than alexithymia.

Contributions of Studies 2 and 3

Findings of comparable performance between children on the AS and TD children on the facial and vocal ER tasks when considering VCA (Study 2 and 3) and alexithymia (Study 3) contribute to the field by extending the findings from Study 1 to allow for greater generalizability to child participants with heterogeneity in cognitive ability and autism traits, and provide support for disputing the notion of ER "deficits." Findings from Studies 2 and 3 also contribute to the literature by demonstrating the utility of a newly-developed multi-stimulus ER paradigm to easily and effectively compare skills across multiple stimulus types and response options, in a strengths-based, child-friendly manner. Study 3 also adds to the evidence that the CAM-PR offers a reliable observer-reported measure of alexithymia traits among children on the AS (Griffin et al., 2016; Trevisan et al., 2016), and provides an alternative tool to self-report measures which may be more challenging to use with children with a variety of abilities (Bagby et al., 2020).

In terms of response options, Studies 2 and 3 contributed findings that demonstrated that aside from slightly higher valence ratings for happy emotions by the AS group, overall children on the AS performed similarly to TD children using dimensional ratings of valence and arousal, across stimulus types and emotions. While these findings are in contrast with those by Tseng et al. (2014) of more restricted or less intense ratings using a combined valence and arousal rating method, our findings of comparable performance on two separate 5-point Likert scales offers an alternate method for measuring valence and arousal ratings with children (see Chapter 4, Figure 2, for a visual reproduction of both of the response options).

Contrary to previous findings highlighting negative associations between alexithymia traits and behavioural ER accuracy from music in AS (Allen et al., 2013) and non-AS (Taruffi et al., 2017) groups, the findings from Study 3 indicated that alexithymia, in addition to autism traits, was positively correlated with ER accuracy from music. Therefore, the findings from Study 3 contribute novel evidence to the field that musical ER strengths displayed by children on the AS–in addition to typical performance on facial and vocal ER tasks–appeared to not be negatively impacted by co-occurring levels of alexithymia. While the findings from Study 3 are not in line with the alexithymia hypothesis, they support the overall findings from Study 1 and 2 that VCA may play a greater role than alexithymia in impacting behavioural ER performance. Additionally, as levels of alexithymia traits are found to increase with age among TD persons (Mattila et al., 2006), it may also be the case that the impact of alexithymia traits on ER among persons on the AS may increase with age, thus highlighting the need to consider variability in levels of alexithymia traits among persons on the AS in relation to ER skills, over the course of development, and particularly in relation to outcomes of intervention.

Summary of Contributions of Studies 1, 2 and 3

The notion that ER "deficits" are a core characteristic among persons on the AS, underlying differences in patterns of socialization, has pervaded conceptualizations of persons on the AS in research and practice over the past 40 years (e.g., Hobson, 1986; Baron-Cohen et al., 2005; Yeung, 2021). Yet, calls to challenge this notion have also been persistent (Harms et al., 2010, Nuske et al., 2012), from the consideration of theories that emphasize the processing styles of persons on the AS (e.g., Burack et al., 2016), to the use of alternate, strengths-based methods to study ER via music (e.g., Heaton et al., 1999; Quintin et al., 2011). Against the notion of a core ER "deficit", Ozonoff et al. (1990) argued that for a characteristic to be considered a core feature of autism, it must be specific and universal to all persons on the AS. In line with Ozonoff et al. (1990), Study 2 shows that children on the AS can recognize emotions in faces and voices as well as TD children; and that they even outperform the TD group when recognizing emotions in music. As such, the findings of this dissertation provide support for the notion that ER deficits are not specific to nor universal among persons on the AS. Study 1 also showed an absence of group difference between adults on the AS or with TD when participant characteristics (VCA, alexithymia) are accounted for, thus showing the impact of these participant characteristics on the alleged "ER deficit", as opposed to a deficit being specific to an autism diagnosis per se (Bird & Cook, 2013; Harms et al., 2010; Sivathasan et al., 2020). Further, I examined whether observed differences in the literature might also possibly be attributed to the types and complexity of frequently used socially-explicit stimuli or verbally loaded categorical task demands. However, across the three studies in this dissertation, I found that the adults and children on the AS tended to perform as well or better than the TD comparison groups on ER tasks using musical or socially-explicit facial and vocal stimuli, and that the use of dimensional valence and arousal ratings did not appear to significantly impact performance.

Findings from the three studies provide a renewed context for assessing ER in research involving persons on the AS, in which accounting for heterogeneity in participant characteristics is critical to making accurate conclusions about their abilities. Despite commonality in the presence of core characteristics and patterns of socialization, considering wide-ranging variability in VCA and alexithymia traits among persons on the AS necessitates great care in tailoring approaches to levels of support needed among individuals or subgroups, as would similarly be the case when considering tailoring approaches to variability in skills among diverse groups of TD persons. Specifically, findings of Studies 2 and 3 suggest that educational, therapeutic, and research approaches involving music may be readily utilized to understand and promote socioemotional learning, particularly among persons on the AS with greater support needs.

Limitations and Future Directions

Additional Participant Characteristics for Consideration

Although we chose to focus on evaluating VCA and alexithymia as frequently cited and relevant participant characteristics, evaluation of additional characteristics including age, sex, gender, personality, and mental health are warranted. Studies 2 and 3 attempted to address limitations highlighted in Study 1 regarding the dearth of alexithymia research including children on the AS; however, this research would benefit from a longitudinal approach in order to assess developmental trajectories of ER among persons on the AS over time.

Sex and gender diversity were not examined as variable of interests within the current dissertation, although females are thought to demonstrate better skills in emotion processing and socialization more broadly (Lawrence et al., 2015; Romer et al., 2011). Limited research on female participants on the AS suggests that they may exhibit better ER skills than males (Baron-Cohen, 2009). These findings may be impacted by generally lower levels of alexithymia among females (Ola & Gullon-Scott, 2020), however our findings in Study 2 of comparable and enhanced ER performance among children on the AS held despite a higher proportion of girls to boys in the TD (52% female) versus the AS (25% female) groups.

Future directions may also include examining variability of individual differences within AS groups by considering individual differences in personality and predisposition toward mental health challenges. As a great deal of research among TD persons suggests that personality traits also impact musical preferences (Rentfrow & Gosling, 2003), and may even impact emotional responsiveness to music and levels of autism traits among TD persons (Sivathasan et al., 2021), personality traits should be considered in thinking about musical ER development among persons on the AS.

Co-occurring anxiety and depressive symptoms, which occur at higher rates among persons on the AS than among non-autistic persons (Kim et al., 2000), have also been associated with reduced ER accuracy and social skills (White et al., 2018), and therefore a greater emphasis on accounting for these differences is necessary for making fair and accurate comparisons between AS and TD groups.

Additional Task Stimuli and Demands for Consideration

Emotion recognition was evaluated across only three emotions. The focus of this dissertation was not on ER from individual emotions, per se. Happy, sad, and fear were evaluated as those which are most readily conveyed in music, as well as faces and voices. The choice to use fewer emotions was evaluated with regard to task difficulty. Although the inclusion of only three emotions, as well as only one positive emotion, may contribute to limitations to overall task difficulty, the task was purposefully designed to be accessible to participants with lower than average VCA. Yet, as ceiling effects were not found, the task does not seem to have been overly simplistic. Moreover, comparable performance was also found using two separate dimensional valence and arousal ratings that allowed for more graded (5 point) responses. Nevertheless, in building on this research, future paradigms should include a greater expanse of basic and more complex emotions, and be designed to directly assess between and within-group comparisons using both categorical and dimensional ratings of emotions.

Strengths-Based Clinical and Educational Applications

Shifting perspectives that consider the preferences and unique styles of processing (Burack et al., 2016), have contributed to calls to intentionally study and incorporate heterogeneity and neurodiversity in research among persons on the AS (Baron-Cohen, 2017; Georgiades et al., 2013; Pellicano & den Houting, 2021). Within this framework, adopting a strength-based perspective is crucial for creating optimal, inclusive, and tailored evidence-based supports and services for a wide range of socioemotional needs across the lifespan.

The studies in the current dissertation highlighted a number of relative strengths, particularly in the recognition of basic emotions involving music. The findings of musical ER strengths among children on the AS with a wide range of verbal cognitive abilities, and with increased levels of alexithymia, add to the growing literature citing relative strengths of persons on the AS in the musical domain broadly (see Quintin, 2019, for a review), including in auditory discrimination of musical pitches, tones, and melodies Bonnel et al., 2003, 2010; Chowdhury et al., 2017; Heaton, 2005; Heaton et al., 2008; Jamey et al., 2019; Jarvinen-Pasley & Heaton, 2007; Jones et al., 2009; Mottron et al., 2000; Stanutz et al., 2014), musical memory (Heaton, 2003; Heaton et al., 1998, 2008; Stanutz et al., 2014), and musical emotion processing (Heaton et al., 1999, 2008; Quintin et al., 2011; Stephenson et al., 2016). These strengths are complemented by evident interests in musical activities and music listening (e.g., Allen et al., 2009; Bhatara et al., 2013; Heaton & Allen, 2009).

Ultimately, skill acquisition may be more easily promoted when preferred styles of processing can be readily evoked with particular types of stimuli, as in the case among persons on the AS who may have an enhanced bottom-up approach to decoding emotions in music (e.g., Heaton et al., 2008; Mottron et al., 2013). Thus, tailored interventions that build on and transfer of skills from one domain of strength such as music, to another domain, such as facial ER or regulating internal feeling states, may greatly improve generalizability of these skills for those persons on the AS (Allen & Heaton, 2010; Heaton et al., 2008; Molnar-Szakacs & Heaton, 2012; Pedregal & Heaton, 2021). For example, Pedregal and Heaton (2021) designed a brief five-session group music intervention to teach ER skills to children and adolescents on the AS by incorporating active participation and consensus-building around recognizing emotions conveyed first in short (45-77 second) musical excerpts, and then in considering how people might look, sound, and think when experiencing the emotion, and lastly in describing a personal or familial example of the emotion. Pilot findings demonstrated that adolescents on the AS showed improvements post-intervention on ER tasks identifying emotions in vocal utterances, and to a lesser extent in faces, as well as reductions in alexithymia symptoms. Even over a short duration, such rich multimodal educational techniques show great potential to support persons on the AS with greater alexithymia traits to broaden the context of their emotional awareness and ability to describe emotions in music, others, and the self. Strengths-based approaches to ER using music thus seem particularly promising in order to promote transfer and generalization of skills into the socially explicit emotions, even more so when interventions are implemented in a group setting encouraging social engagement.

Findings from this dissertation also support the growing evidence for the utility of music programs, therapy and education or the inclusion of music in therapeutic interventions in promoting increasing socioemotional and emotional communication skill building among persons on the AS, particularly among those with greater challenges in these areas (e.g., Kim et al., 2008, 2009; LaGasse, 2014; Lense & Camarata, 2020; Lim, 2010; Lim & Draper, 2011; Sharda et al., 2018; see LaGasse, 2017; Quintin, 2019, for reviews). For instance, music therapy improves communication skills (Sharda et al., 2018), emotional synchrony (Kim et al., 2009), joint attention and eye contact with a peer or therapist (Kim et al., 2008; LaGasse, 2014) of children on the AS. Alexithymia, language abilities, and emotion processing, which are all associated (Hobson et al., 2020), may similarly be ameliorated through music-based language interventions, given shared mechanisms of musical and vocal emotion processing (Allgood & Heaton, 2015; Juslin & Laukka, 2003). In fact, minimally verbal children on the AS make greater gains in vocabulary when song is incorporated to traditional speech therapy (Chenausky et al., 2016). Finally, group-based music education programs have the potential to promote inclusion of neurodiverse participants and combat social exclusion and negative attitudes towards children on the AS (Cook et al., 2018), while providing a shared experience that offers the ability for children to utilize their strengths (Draper, 2021). Ultimately, findings from this dissertation provide a framework within which to consider the utility of music in emotion processing research broadly, as well as to re-conceptualize the intersecting impact of personal characteristics, in order to support the strengths, needs, preferences, and styles of processing of persons on the AS.

Chapter 7: Final Conclusion and Summary

The objectives of the current dissertation were to investigate mechanisms of emotion processing among persons on the AS. Specifically, given the mixed findings in the literature, a primary goal was to evaluate the specificity and universality of purported basic ER differences among persons on the AS relative to TD persons by considering the impact of participant characteristics (VCA and alexithymia) and task-specific factors related to ER, utilizing musical stimuli as an alternate, strengths-based approach to studying ER, relative to frequently used socially-explicit facial and vocal stimuli.

These objectives were met via the three studies. In Study 1, I evaluated, through a systematic review of the literature, the relative contributions of VCA and alexithymia to emotion processing task performance broadly among persons on the AS and TD persons, which had previously been studied separately from one another. In Studies 2 and 3, I evaluated the impact that ER task stimuli (musical versus facial and vocal ER) and task demands associated with types of response options (categorical verbal labels and dimensional ratings of valence and arousal) contributed to ER performance among children on the AS, while also considering the impact of VCA and alexithymia. Utilizing a newly-developed ER paradigm, these studies provided the first direct and simultaneous ER comparisons between the groups, stimulus types, and response options.

Across all three of the studies, the participants on the AS generally performed comparably to TD participants across a variety of ages and cognitive abilities, and across a variety of behavioural facial and vocal ER task stimuli and response options, when VCA was considered, thus questioning the specificity of basic emotion recognition differences attributed to persons on the AS as compared with TD persons. Study 1 showed a relationship between VCA and behavioural ER, while alexithymia was associated with neural correlates of ER. When VCA (Studies 2 and 3) and alexithymia (Study 3) were considered, children on the AS outperformed TD children on ER tasks using musical stimuli, an area in which they often demonstrate preferences and strengths. Overall, the findings from the studies in this dissertation highlighted the importance of considering relevant participant characteristics and task-specific factors in ER comparisons between AS and TD groups, and in particular, highlighted the utility of strengths-based approaches involving musical ER. As detailed in the Discussion (Chapter 6), clinical and educational implications of this work include promoting the use of musical stimuli in socioemotional research, education, and intervention programs as alternate preference- and process-focused approaches to ER skill development. Overall, this dissertation encourages our ability to expand beyond deficit-focused approaches to reconsider our perspectives toward and support of persons on the AS.

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