Phonological awareness skills of school age children on the autism spectrum: Associations among emergent literacy, cognitive functioning and musical beat perception

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List of Abbreviations

ADI-R	Autism Diagnostic Interview–Revised
ADOS	Autism Diagnostic Observation Schedule
AMMT	Auditory-Motor Mapping Training
APA	American Psychiatric Association
AQ	Autism-Spectrum Quotient
BAT	Beat Alignment Test
CDC	Centers for Disease Control and Prevention
DSM	Diagnostic and Statistical Manual of Mental Disorders
EPF	Enhanced Perceptual Functioning model
Gold-MSI	Goldsmiths Musical Sophistication Index
HiFA	Hits minus False Alarms
IQ	Intellectual Quotient
MBCT	Melodic-Based Communication Therapy
MR	Matrix reasoning
OPERA	Overlaps, Precision, Emotion, Repetition, Attention hypothesis
PA	Phonological awareness
PATH	Precise Auditory Timing Hypothesis
PDD	Pervasive Developmental Disorders
PDD-NOS	Pervasive Developmental Disorder – Not Otherwise Specified
RRB	Restricted Interests/Repetitive Behaviours
SCI	Social Communication and Interactions
SCQ	Social Communication Questionnaire

SRS	Social Responsiveness Scale, 2nd edition
TD	Typical development
TTT	Trigger-Threshold-Target model
VC	Vocabulary
WASI	Wechsler Abbreviated Scale of Intelligence, 2nd Edition
WISC	Wechsler Intelligence Scale for Children, 5th Edition

Abstract

Investigations of the phonological awareness (PA) skills, a significant predictor for reading achievement, of autistic children have focused primarily on the preschool age period and show inconsistent findings, with most studies failing to include children with a wide range of cognitive abilities. This dissertation explores PA skills of school-age autistic children with varying levels of cognitive abilities and autism characteristics; and adopts a strength-based approach, utilizing the strengths and interests of persons on the autism spectrum, such as music, to palliate areas of challenge. This dissertation aims to elucidate the development of PA skills of school age children on the autism spectrum with heterogeneous cognitive profiles and autistic traits through several objectives. The first objective is to review the literature on the efficacy of intervention programs that have aimed to promote emergent literacy skill (i.e., PA and word recognition) development for autistic children (manuscript 1). Findings from manuscript 1 highlight that despite promising results showing gains in emergent literacy skills through computer-based, and non-computer-based intervention modalities, replication studies with larger samples and experimental designs are needed to establish evidence-based practice for teaching emergent literacy skills to autistic children. The second objective is to compare the PA abilities of autistic children to neurotypical children and to explore the relationships among cognitive skills, autism traits and PA abilities (manuscript 2). Findings from manuscript 2 reveal that autistic and neurotypical children show comparable PA abilities and highlight the contribution of non-verbal cognitive abilities to the PA skills of autistic children. The final objective of this dissertation is to explore the relationship between musical beat perception and PA skills of autistic children (manuscript 3). Results from manuscript 3 show that PA and beat perception are positively correlated for autistic children. Taken together, the findings from this dissertation have significant educational implications for

children across the spectrum as they underscore the role of non-verbal cognitive abilities on PA development and hold the potential to inform the implementation of intervention programs targeting early literacy skills. Findings also provide preliminary evidence for beat perception, a strength-based and non-verbal stimulus, as a valuable alternative early literacy screening tool for autistic children who present with a wide range of developmental profiles.

Résumé

Les études sur les compétences en matière de conscience phonologique (CP), un facteur prédictif important pour la réussite en lecture, des enfants autistes se sont principalement concentrées sur la période préscolaire et rapportent des résultats contradictoires puisque la plupart des études n'ayant pas inclus des enfants présentant une diversité de capacités cognitives. En outre, il est souhaitable de se diriger vers des études fondées sur les forces, ce qui peut être réalisé en utilisant les forces et les intérêts des personnes autistes, comme la musique, pour pallier leurs difficultés. Ainsi, la présente thèse vise à élucider le développement des aptitudes de CP chez les enfants autistes d'âge scolaire présentant des profils cognitifs et traits d'autisme hétérogènes. Le premier objectif est de recenser la littérature sur l'efficacité des programmes d'intervention visant à promouvoir le développement des compétences émergentes en matière d'alphabétisation (c'est-à-dire la CP et la reconnaissance des mots) chez les enfants autistes (manuscrit 1). Les résultats du manuscrit 1 soulignent que, malgré les résultats prometteurs montrant des gains en matière d'alphabétisation émergente grâce à des intervention sur ordinateur ou non, des études de réplication sont nécessaires pour établir une pratique fondée sur des preuves pour l'enseignement de l'alphabétisation émergente aux enfants autistes. Le deuxième objectif est de comparer les capacités de CP des enfants autistes à celles des enfants neurotypiques et d'explorer la relation entre les compétences cognitives et les traits d'autisme et les capacités de CP (manuscrit 2). Les résultats du manuscrit 2 révèlent que les enfants autistes et neurotypiques montrent des capacités de CP comparables et soulignent la contribution des capacités cognitives non verbales sur la CP des enfants autistes. L'objectif final de cette thèse est d’explorer la relation entre la perception du rythme musical et les capacités de CP d'enfants autistes (manuscrit 3). Les résultats du manuscrit 3 révèlent que la CP et la perception du rythme musical sont positivement corrélés chez les

enfants autistes. Dans l'ensemble, les résultats de cette thèse ont des implications éducatives significatives pour les enfants autistes, car ils soulignent le rôle des capacités cognitives non verbales sur le développement de la CP et ont le potentiel d'informer la mise en œuvre de programmes d'intervention ciblant les compétences d'alphabétisation émergente. Les résultats fournissent également des preuves préliminaires pour la perception du rythme musical, un stimulus non verbal, en tant qu'outil alternatif pour le dépistage précoce de l'alphabétisation pour les enfants autistes qui présentant des profils de développement hétérogènes.

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Contribution to Original Knowledge

This dissertation aimed to advance our knowledge of the development of phonological awareness skills for school age autistic children with heterogeneous cognitive profiles and autism characteristics, from a strength-based perspective. The three manuscripts that constitute the present dissertation prioritized including autistic children with diverse developmental profiles to represent the autistic community to the greatest extent possible. Accordingly, a strength of the current dissertation is the particular emphasis placed on characterizing and validating the autism diagnoses of the children included across manuscript through diverse standardized measures and screening questionnaires and ensuring that heterogeneous cognitive profiles and autistic traits are represented.

Manuscript 1 helped to shed light on the peer-reviewed literature on intervention programs that have aimed to promote specific emergent literacy skills for autistic children and highlighted that this area of research is lacking for autistic children compared to other populations. The limited available research suggests that children on the autism spectrum benefit from interventions aiming to increase their phonological awareness skills. Numerous intervention programs within the review required adaptations to meet the individual support needs of autistic children. As such, Manuscript 1 contributes to the literature through recommending that investigations on the relationship between areas of strength for autistic children and early literacy is warranted to inform interventions programs and to establish evidence-based practice for teaching emergent literacy skills.

Manuscript 2 provided insight into the mechanisms underlying phonological awareness development for autistic children who present with a wide range of support needs, cognitive profiles, autism characteristics and co-occurring conditions. Previous research attempting to elucidate the phonological awareness skills of autistic preschool and school age children report mixed findings (e.g., Westerveld et al., 2020 vs. Dynia et al., 2014) and utilize varying group designs. Findings from Manuscript 2 are a valuable contribution to the school age literature on the phonological awareness skills of autistic children as the study design included group matching across chronological age and verbal and non-verbal/perceptual reasoning cognitive skills. Results clarified the discrepancies among previous studies in the field by showing that the phonological awareness skills of school age autistic children are comparable to non-autistic children and revealed that perceptual reasoning skills play a greater role in early literacy development for autistic children compared to non-autistic children. Together, Manuscripts 1 and 2 contribute to the growing body of research on emergent literacy skills and autism by highlighting the importance of investigating the relationship between areas of strength for autistic children and early literacy, while at the same time, bearing in mind the role of perceptual reasoning skills, perhaps even over verbal skills, for the reading development of autistic children. As such, increased knowledge of the unique cognitive profile of autistic children should lead to adaptation to the curriculum and consideration of the environment goodness-of-fit to meet their learning profiles (Leadbitter et al., 2021).

Manuscript 3 is the first study to explore the relationship between beat perception (i.e., a perceptual/non-verbal and strength-based stimulus) and phonological awareness for autistic children, which has been previously explored in neurotypical research (e.g., Anvari et al., 2002; Eccles et al., 2020; Mortiz et al., 2013; Politimou et al., 2019). Findings from Manuscript 3 reveal that beat perception and phonological awareness skills are related for autistic children, suggesting that, as in neurotypical development, they stem from a common auditory mechanism. Conclusions drawn from Manuscript 3 indicate for the potential of an alternative and strength-based approach to traditional verbal tasks, in identifying early literacy skill difficulties among autistic children. Further, Chapter 6 provides an in dept discussion of findings as they relate to the use of music interventions to enhance literacy skills.

In contrast with a large body of research highlighting deficits and impairments for autistic children, the present dissertation is innovative in its focus on exploring the strengths and interests (music) of this population in relation to areas of challenge (e.g., oral language). An in-depth discussion of the contributions of the scoping review and two empirical studies to the field of literacy development of autistic children are presented in Chapter 6.

Contribution of Authors

Chapter 1 was written and edited by Charlotte Rimmer (CR) with feedback from Eve-Marie Quintin (EMQ).

Chapter 2 was written and edited by CR with feedback from EMQ.

Chapter 3 is composed of Manuscript 1, which is an exact replication of the article entitled, *Emergent Literacy Skills and Autism: A Scoping Review of Intervention Programs*, published in the peer-reviewed journal of *Research in Autism Spectrum Disorders* in July 2022. The manuscript was written and edited by CR with feedback from EMQ. The literature search process including screening of titles, abstracts and full texts, completing the ancestral searches, and data extraction were carried out independently by CR and Hadas Dahary (HD). All authors approved the final manuscript.

Chapter 4 is composed of Manuscript 2, which is an exact replication of the article entitled *Phonological awareness skills of school age autistic children and the role of perceptual reasoning skills*, which has been submitted for publication in July 2022. The manuscript was written and edited by CR with feedback from EMQ and Grace Iarocci (GI). CR collected and analyzed the data and drafted the manuscript. Gwenaëlle Philibert-Lignières (GPL) contributed to the data collection and analysis. EMQ provided supervision and critically revised the work. All authors approved the final manuscript.

Chapter 5 is composed of Manuscript 3, which is an exact replication of the article entitled, *Links between musical beat perception and phonological skills for autistic children*, which was submitted for publication in March 2022, and is currently under review. CR and EMQ had the research idea for this article. CR collected and analyzed the data and drafted the manuscript. HD contributed to the creation of the experimental task, as well as to the data collection and analysis.

EMQ provided supervision and critically revised the work. All authors approved the final manuscript.

Chapter 6 was written and edited by CR with feedback from EMQ.

Chapter 7 was written and edited by CR with feedback from EMQ.

Note: Manuscripts contained within this dissertation in Chapters 4 and 5 represent original contributions to the field of autism and emergent literacy research. The present dissertation was supported by the Joseph-Armand Bombardier Canada Graduate Scholarships Program – Doctoral Scholarship awarded to Charlotte Rimmer.

Chapter 1: Introduction

To gain a greater understanding of the diversity and complexity of learning profiles across the autism spectrum, the field of autism research has increasingly moved towards exploring the strengths in addition to the challenges experienced by autistic[1] children. The interest in the academic achievement of children on the autism spectrum has been growing over the last decade (Keen et al., 2016), in part due to the rise in prevalence rates[2] of children diagnosed with autism spectrum disorder, a neurodevelopmental condition characterized by impairments in social communication and repetitive patterns of behaviours (American Psychiatric Association (APA), 2013), and due to the push for inclusion and integration of autistic youth within the school system (Williams et al., 2005; Woodman et al., 2016).

Reading is a crucial academic skill to acquire as it leads to enhanced future learning opportunities, academic achievement, adaptive skills, social skills, and occupational attainment (Nally et al., 2018; Westerveld et al., 2018). Investigations into the reading profiles of autistic children have revealed considerable diversity in reading profiles. A number of children on the autism spectrum experience challenges in reading comprehension (Davidson & Ellis Weismer, 2014; Henderson et al., 2014; Nation et al., 2006), decoding (Nation et al., 2006), and word reading abilities (Westerveld et al., 2018). Meanwhile, between 6-20% of autistic children present with hyperlexia (Ostrolenk et al., 2017), a strength in word decoding and recognition alongside difficulties with reading comprehension skills and verbal abilities (Silberberg &

[1] Although no definite consensus has been established in terms of language practices in autism research, this dissertation uses identity-first language ("autistic", "on the autism spectrum") to reflect a common preference among the autism community (Bottema-Beutel et al., 2021; Bury et al., 2020; CASDA, 2020).
[2] The Centre for Disease Control and Prevention (2018) states that the prevalence rate of children diagnosed with autism spectrum disorder has risen from one in 68 (2010-2012) to one in 44 (2018).

Silberberg, 1967). In essence, a review of the literature suggests a heterogeneous reading profile among children on the autism spectrum ranging from difficulties to enhanced skills.

Research highlights a link between children's oral language skills and future reading abilities (Catts, 1999; Roth et al., 2002) and shows that challenges with oral language skills may place children at an increased risk for reading difficulties (Nation & Norbury, 2005; Norbury & Nation, 2011), which is important given that children on the autism spectrum tend to have difficulties in oral language compared to non-autistic peers (Dynia et al., 2014; Smith Gabig, 2010). Specifically, challenges in receptive and expressive oral language skills for autistic children expand across linguistic domains (i.e., semantics, morphology, syntax) and seem to be particularly impaired in pragmatics (understanding of how context contributes to meaning) given the social impairments associated with autism (Eigsti et al., 2011; Westerveld et al., 2016). For instance, language difficulties of children on the autism spectrum are compounded by challenges in social interactions/communication. Specifically, evidence shows that autistic children demonstrate deficits in orienting to speech sounds (Lepistö et al., 2005), which hinders language acquisition and decreases the opportunity for language learning experiences (Vaiouli & Andreou, 2018). In general, language development is a significant difficulty experienced by some children on the autism spectrum, as it is estimated that approximately 30%-50% of autistic children do not have functional verbal speech (CDC, 2014; National Autism Association, 2014; Sandiford et al., 2013). Language difficulties, specifically a lack of functional and spontaneous speech by age 6, are a significant predictor for the social and adaptive prognosis of autistic children (Szatmari et al., 2003; Venter et al., 1992). Further, research investigating the characteristics of first-degree relatives of individuals on the autism spectrum, namely the broader autism phenotype (BAP) studies, show less complex speech in first-degree relatives of autistic individuals (Landa et al.,

1991) and a higher rate of language delays in younger siblings of autistic children (Gamliel et al., 2009). These findings highlight the importance of considering language impairments associated with the condition (Eigsti et al., 2011).

Given that reading is a language-based skill (Roth et al., 2002) and that children on the autism spectrum show difficulties in oral language, it is important for research to examine significant precursor skills to reading achievement, including phonological awareness, which is the ability to intentionally manipulate and analyse sound structures of spoken language (Hudson et al., 2017; Scarborough & Brady, 2002; Schuele & Boudreau, 2008). Phonological awareness skills may be particularly important to investigate as they are a significant predictor for reading achievement of children on the autism spectrum (Dynia et al., 2017).

At first glance, the literature reports mixed findings on the development of phonological awareness skills of autistic children with some studies reporting phonological awareness as an area of challenge (Dynia et al., 2019; Westerveld et al., 2016), while others suggest that it is comparable to that of neurotypical peers and is a relative strength within the profile of children on the autism spectrum (Macdonald et al., 2020; Westerveld et al., 2020). However, a closer look at the research reveals that there are few if any differences between groups matched for verbal and non-verbal cognitive skills; preschool children on the autism spectrum show comparable phonological awareness skills to non-autistic children when verbal skills (Dynia et al., 2014; Westerveld et al., 2020) and non-verbal skills (Westerveld et al., 2020) are accounted for. As such, factors such as autism characteristics, language skills, and cognitive ability may play an important role in phonological awareness development and so may autism characteristics (e.g., Dynia et al., 2014; Fleury & Lease, 2018; Nally et al., 2018; Smith Gabig, 2010; Westerveld et al., 2020). Thus, a comprehensive literature review is presented in Chapter 2 in order to establish the background concepts of interests of this dissertation. Moreover, literacy instruction for children on the autism spectrum has been largely overlooked in educational research (Kamps et al., 2016). The efficacy of intervention programs aimed at promoting phonological awareness has been well established for children with typical development (National Early Literacy Panel (NELP), 2008) but remains to be elucidated for children on the autism spectrum. The relationship between emergent literacy skills and later reading success highlights the importance of targeting the development of these skills for children on the autism spectrum (Dynia et al., 2014). As such, Chapter 3 of this dissertation presents a review of emergent literacy skills (including phonological awareness) training programs for autistic children, and Chapter 4 presents an empirical study that extends prior research on the phonological awareness skills of preschool children to school age children on the autism spectrum with a wide range of cognitive skills, autism characteristics, and co-occurring conditions.

Furthermore, aiming to inform instruction and intervention practices, it is valuable to acknowledge the heterogeneity across the spectrum by considering areas of strengths within developmental profiles. A shift towards strength-based studies is desirable and can be achieved by utilizing the strengths and interests of persons on the autism spectrum to palliate areas of challenge (e.g., Mottron et al., 2009; Remington & Fairnie, 2017). Thus, given the high co-occurrence of language difficulties of children on the autism spectrum it is pertinent to consider the potential of non-verbal stimuli to aid with identifying areas of challenge. The literature on identifying non-linguistic predictors of literacy is growing and suggests that musical predictors, such as rhythm perception and production, is an important ability for literacy acquisition (e.g., Eccles et al., 2020; Moritz et al., 2013; Politimou et al., 2019). Rhythm is defined as the division of time through distinct order and patterns of events (Hardy & LaGasse, 2013) and is one of the most essential organizational elements of music (Thaut et al., 1999). Rhythm plays a central role in learning and development, as the timing of movement is important in several motor and cognitive functions (Thaut et al., 1999). Additionally, rhythm provides linguistic information in music and speech (Bhatara et al., 2011). Rhythmic structure is comprised of many elements, of which musical beat is a fundamental aspect and is defined as an ongoing pulse that occurs at regular intervals in a musical piece (Nave-Blodgett et al., 2021; Toiviainen et al., 2020).

Important overlaps are found between music, language, and early literacy abilities such that all three domains rely on processing structured sound sequences (Patel, 2003; Patel & Iversen, 2007). Specifically, auditory processing mechanisms necessary for musical perception and phonological awareness are related, which provides supporting evidence for the connection between early literacy and musical skills (Anvari et al., 2002). For instance, beat and rhythm perception and production are related to phonological awareness skill in 3- and 4-year-old (Politimou et al., 2019), 5-year-old (Anvari et al., 2002), and 6- to 8- years old children with typical development (David et al., 2007; Eccles et al., 2020; Holliman et al., 2010; Kertesz & Honbolygo, 2021), as well as in 8 to 13 year old children with dyslexia (Huss et al., 2011). In summary, research on the association between musical rhythm and phonological awareness has mostly included children with typical development and specific learning disorders and shows that rhythm perception and production are important predictors of phonological awareness skills within these populations (Anvari et al., 2002; Eccles et al., 2020; Politimou et al., 2019).

Yet, it may be particularly relevant to examine music perception, and specifically, beat and rhythm perception of autistic children as, similar to typically developing youth, youth on the autism spectrum share an affinity for music (Bhatara et al., 2013) and relative strengths in musical abilities (Heaton, 2009). For example, individuals on the autism spectrum show average or above-average musical production and auditory processing abilities (Bhatara et al., 2013; Heaton, 2003) such as enhanced musical memory and melodic perception (Heaton, 2003; Stanutz et al., 2014), distinguishing between pitch frequencies (Bonnel et al., 2010), producing and replicating coherent musical melodies (Quintin et al., 2013), recognizing music-evoked emotions (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016), and showing intact rhythm perception abilities (Jamey et al., 2019). Thus, Chapter 5 of this dissertation consists of an empirical study that investigates the potential for a non-verbal stimulus (musical beat) as a phonological awareness screening tool by investigating the relationship between phonological awareness and beat perception of autistic children.

Finally, evidence from many studies emphasize the value of using music with people on the autism spectrum leading to improvements in social, cognitive, behavioural, and emotional domains (Molnar-Szakacs et al., 2009; Simpson & Keen, 2011). Results from a pilot music program for autistic adolescents encompassing group music making and creation (i.e., creating a short film accompanied with a musical piece) revealed that post music program, adolescents self-reported a significant increase in self-esteem, reductions in anxiety symptoms, and more positive attitudes towards peers (Hillier et al., 2012). Further, reported benefits of using music with people on the autism spectrum include increased appropriate social behaviours (Simpson & Keen, 2011), improved attention to tasks (De Vrines et al., 2015), and positive outcomes in language gains, including increases in gestural and verbal skills (Lim & Draper, 2011; Warren et al., 2010) and speech repetition ability (Chenausky et al., 2016). Future directions for research and approaches to strength-based music programs and interventions for autistic children will be discussed in Chapter 6.

Chapter 2: Literature Review

Autism

Autism spectrum disorder (hereinafter referred to as "autism") is a neurodevelopmental condition of childhood onset characterized by a persistent impairment in reciprocal social communication and social interactions, and the presence of restricted, repetitive patterns of behaviours, interests, or activities (American Psychiatric Association, APA, 2013). The prevalence rate of autism has increased from approximately one in 68 (2010-2012) to one in 54 (2016) over the past decade (Centers for Disease Control, CDC, 2018).

The autism diagnostic criteria in the most current *Diagnostic and Statistical Manual of Mental Disorders – fifth edition* (DSM-5; APA, 2013) has regrouped previously known conditions including Pervasive Developmental Disorders (PDDs), Asperger's Disorder, and Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS). Core diagnostic features fall into classifications that are reliably measured (Lord et al., 2000) and have remained relatively stable since the first conceptualization of the condition in 1943 (Kanner, 1943). The current DSM-5 outlines the diagnostic criterion for deficits in social communication and interaction as the following: deficits in social-emotional reciprocity, in non-verbal communicative behaviours used for social interaction, and in developing, maintaining, and understanding relationships (APA, 2013). The diagnostic criterion for restricted, repetitive patterns of behaviours and interests or activities (RRB) is divided into four subcategories: stereotyped/repetitive motor movements or speech, insistence on sameness/adherence to routines/ritualized pattern of verbal and non-verbal behaviour, highly restricted or fixated interests, and hyper- or hyporeactivity to sensory input or unusual sensory interests (APA, 2013). Complementary to Kanner's (1943) early findings, various topographies of RRBs are reported in contemporary literature including vocal stereotypy (Lanovaz et al., 2011), self-injurious behaviours (Lundqvist et al., 2009), lining up and arranging objects (Sigafoos et al., 2009), mouthing (Tarbox et al., 2002), and hand flapping (Conroy et al., 2005). People can engage in RRBs for escape, self-stimulation (Goldman et al., 2009), and as a coping mechanism to ameliorate over and under stimulating environments (Rapp & Vollmer, 2005). These behaviours can be enhanced by excitement, boredom, anxiety, social demands, or sensory isolation (Goldman et al., 2009).

Despite the core diagnostic features associated with the condition, a heterogeneity of autism profiles exists within adaptive, cognitive, and language skills (APA, 2013). As such, the level of support an individual needs to integrate into their social environment will vary widely by individual, across environmental contexts, and across the lifespan. For instance, a greater level of support may be required during a time of transition of an individual's life when the social demands significantly increase (e.g., transition from elementary to high school). Supports and interventions should be individually tailored to meet the person's needs and priorities (APA, 2013). Accordingly, the last two decades have given rise to the neurodiversity movement, a social justice, autistic self-advocacy, and civil rights movement which emerged in the late 1990's (Hughes, 2016). The neurodiversity movement asserts that a natural range of diversity occurs in human neurodevelopment (Pellicano & Houting, 2022), and that cognitive diversity is a valuable contributor to society (Chapman, 2021). However, the neurodiversity movement also recognizes that neurocognitive differences encompass strengths as well as weaknesses, which may present challenges for the individual's functioning within their environment (Leadbitter et al., 2021). Therefore, targeted strength-based interventions can be valuable to palliate areas of challenge.

Cognitive Profiles

Along with the neurocognitive diversity among autistic and neurotypical individuals, heterogeneity in cognitive profiles is present across the spectrum and are being recognized in research. Cognitive functioning, or “intelligence”, represents a person’s thinking and reasoning skills and is determined by a wide range of factors (e.g., verbal comprehension, visual spatial/perceptual reasoning skills, working memory, Wechsler, 2014), which together can be useful in identifying patterns of strengths and weaknesses in a person’s cognitive profile. However, overall cognitive functioning is frequently discussed in term intellectual quotient (IQ). Assessing cognitive functioning, or IQ, is important given it’s established relationship with academic achievement for children on the autism spectrum (Mayes & Calhoun, 2008). In addition, gaining insight into the cognitive profiles of autistic children is valuable as IQ is often used as an additional factor, over and above an autism diagnosis, to determine eligibility for community, provincial, federal, and educational programs, as well as school/classroom placement (Billeiter & Froiland, 2022).

Children on the autism spectrum present with cognitive profile ranging from intellectual disability to IQ scores falling in the superior range (i.e., giftedness). Research investigating the occurrence of intellectual disability among autistic children shows varied findings, with estimations ranging from 24% to 75% depending on the study (e.g., Baio et al., 2018; Billeiter & Froiland, 2022; Christensen et al., 2018; Joseph et al., 2002). Autistic children are 12 times more likely to have an IQ score that indicates an intellectual disability (i.e., IQ < 70) and 1.5 times more likely to have IQ scores that fall within the superior range (i.e., IQ > 120) compared to neurotypical children (Billeiter & Froiland, 2022). In addition, the average standard deviation in IQ scores for autistic children is 25.75, compared to the normative sample standard deviation of

15 (Billeiter & Froiland, 2022). Thus, the wide standard deviation (i.e., 1.72 times that of the norm) calls attention to the significant variability of cognitive profiles of children on the autism spectrum, further highlighting the neurocognitive diversity among autistic individuals (Billeiter & Froiland, 2022).

Although the review of an individual's overall IQ gleans important information, the examination of distinct cognitive domains can provide a better representation of their overall cognitive functioning and uncover a detailed profile of strengths and weaknesses (Kuschner et al., 2007), with the goal to provide targeted and suitable interventions. Indeed, evidence of a unique and uneven cognitive profile among autistic children indicates a strength in non-verbal/perceptual skills compared to verbal skills (e.g., Ankenman et al., 2014; Billeiter & Froiland, 2022; Charman et al., 2011; Courchesne et al., 2015; Joseph et al., 2002; Nader et al., 2015; Soulières et al., 2011). The salient strength for non-verbal/perceptual skills over verbal skills may be the results of the distinct cognitive processing styles of autistic persons. As such, the Enhanced Perceptual Functioning model (EPF; Mottron et al., 2001, 2006, 2009) posits that the unique cognitive and behavioural profiles within autism are the result of superior auditory and visual processing abilities (Mukerji et al., 2013). Specifically, the EPF model outlines a set of principles of autistic perception, for example, that locally oriented and featural processing are a default setting, that early atypical behaviours regulate perceptual input (e.g., visual exploratory behaviours – lateral glances), and the presence of enhanced activation of visual perceptual areas and diminished activation of higher-order/social areas of the brain during tasks (regardless of the task having perceptual or social stimuli) (Mottron et al. 2006). In general, EPF principles propose that the cognitive "impairments" and "atypicalities" associated with autism can be more accurately reframed as a different processing system altogether (Mottron et al. 2009).

Accordingly, the Trigger-Threshold-Target model (TTT; Mottron et al., 2014) of autism suggests that cognitive enhancement, such that perceptual materials are preferentially processed over social materials, is due to brain reorganization triggered by a series of genetic mutations.

Taken together, the EFT and TTT models highlight how autistics individuals perceive and experience the world differently and account for the relative strength in visual and auditory processing documented in the literature. Autistic individuals have a greater perceptual capacity in the visual (Remington et al., 2012) and auditory domains (Remington & Fairnie, 2017; Tillman & Swettenham, 2017), and superior visual search skills (Kaldy et al., 2011). Furthermore, in line with the neurodiversity movement, research has shifted to identifying areas of talent and interest of autistic persons. Within the auditory domain, the literature on musical perception reveals that persons on the autism spectrum show enhanced pitch memory (Heaton et al., 1998), musical memory, and melodic perception (Stanutz et al., 2014), and pitch frequency distinction (Bonnel et al., 2010).

Language Profiles

Although a marked strength has been identified for non-verbal/perceptual reasoning skills compared to verbal skills for autistic persons, linguistic profiles are also heterogeneous across the spectrum. Language milestones play a central role in early child development (Paul, 2008) given that they remain relatively consistent regardless of the learned language and cultural factors (Eigsti et al., 2011). The uniformity of language development makes impairments or challenges in attaining typical milestones rather clear to identify. Indeed, one of the first distinguishing symptoms of autism in early childhood is delayed language development (APA, 2013; Pomper et al., 2019). As such, caregivers become concerned if they notice early delays or regression in speech development (Paul, 2008). The first word milestone in typical development emerges at roughly 12 months of age (Schneider et al., 2015), whereas on average, autistic children say their first words around 38 months of age (Howlin, 2003). Additionally, some children may present regression in the use of words at the age of 2 years old (Pickles et al., 2009). Further, the absence of functional and spontaneous speech by age 6 are a significant predictor for the social and adaptive prognosis of autistic children (Szatmari et al., 2003; Venter et al., 1992).

In accordance with the overall heterogeneity across the spectrum, autistic children present with a wide diversity in language development profiles (Tager-Flusberg et al., 2005). Many autistic individuals experience speech onset delay and it is estimated that approximately 30%-50% of autistic children do not have functional speech production (National Autism Association, 2014; Sandiford et al., 2013). Language impairments may range from language delays, poor comprehension of speech (APA, 2013), difficulties with initiation/sustaining conversation, or idiosyncratic use of language (Tager-Flusberg, 1999). While language impairments are prominent among autistic individuals, the DSM-5 does not include them in the diagnostic criteria explicitly, as some children on the autism spectrum follow a typical pattern of language development in some areas (Mottron et al., 2014). For example, a child may show typical articulation and syntax but impairments in comprehension and semantics (Boucher, 2012).

Language delays and impairments of autistic children can be partly explained by challenges in social communication/interactions. Specifically, autistic children demonstrate difficulties in orienting to speech sounds (Lepistö et al., 2005), show a lack of responsiveness to social stimuli (Dawson et al., 1998, 2004), and a lack of spontaneous imitation (Carpenter et al., 2005). Challenges in social interactions can hinder language acquisition and decreases the opportunity for language learning experiences (Vaiouli & Andreou, 2018).

Oral Language. Oral language refers to receptive and expressive language skills (Dynia et al., 2017) that develop prior to a child learning to read (Cronin, 2014). There are several linguistic domains that constitute oral language skills including basic structural skills such as semantics, syntax, morphology, pragmatics, and phonology, and higher-order skills such as inferential language and narrative discourse (Catts et al., 1999; Honig, 2007). Challenges in receptive and expressive oral language skills for autistic children expand across linguistic domains (i.e., semantics, morphology, syntax) and seem to be particularly impaired in pragmatics (understanding of how context contributes to meaning), aligning with the well-documented social impairments associated with autism (Eigsti et al., 2011; Mottron et al., 2014; Westerveld et al., 2016). Some oral language skills are also referred to as emergent literacy skills, such as phonological awareness, as they are necessary precursors to reading success.

Autism and Early Literacy Development

A strong relationship exists between children's oral language skills and future reading abilities (Catts, 1999; Roth et al., 2002), such that difficulties in oral language skills may place children at risk for reading difficulties (Nation & Norbury, 2005; Norbury & Nation, 2011). Given that reading is a language-based skill (Roth et al., 2002) and that autistic children can present with language impairments and difficulties in oral language (Dynia et al., 2014; Smith Gabig, 2010), it is important to investigate precursor skills to reading achievement, including phonological awareness, and to consider the potential of non-verbal stimuli to aid with identifying areas of challenge and to inform instruction and intervention practices.

Phonological Awareness in Autism and Neurotypical Development

Emergent literacy skills encompass the foundational skills that a child will acquire in order to successfully read, write, and orally communicate (Vaiouli & Friesen, 2016).

Phonological awareness is considered one of the best emergent literacy predictors, with a moderately strong correlation with word decoding and reading comprehension (National Early Literacy Panel [NELP], 2008) in neurotypical development (Blachman et al., 1999; Dynia et al., 2017; Moritz et al., 2013). Phonological awareness is defined as a metalinguistic skill referring to the ability to intentionally manipulate and analyse sound structures of spoken language (Hudson et al., 2017; Scarborough & Brady, 2002; Schuele & Boudreau, 2008), which is developed prior to early word reading (Macdonald et al., 2020). It is considered a metalinguistic skill with which a child consciously reflects on how language can be manipulated and thought about (Scarborough & Brady, 2002).

The manipulation and analysis of phonological sound structures can be conducted at several levels, namely at the syllable, subsyllabic (i.e., the division of syllables into onsets and rhymes), and phoneme (i.e., the smallest unit of speech, /k/, /a/, and /t/ in the word cat) levels (Moritz et al., 2013; Scarborough & Brady, 2002). As such, phonological awareness encompasses a range of skills that increase in complexity (Schuele & Boudreau, 2008). For instance, simple phonological awareness skills characteristic of shallow-level knowledge can include dividing words into syllables (e.g., dividing the word "napkin" into two syllables "nap" and "kin") and identifying or generating rhymes (e.g., "sock" and "clock") (Schuele & Boudreau, 2008). Skills indicative of deep-level phonological awareness, also called phonemic awareness, can include segmenting words into sounds (e.g., segmenting "sand" into /sss/, /aaa/, /nnn/, and /d/) and deleting or manipulating phonemes (e.g., what would be left if the /b/ sound was taken away from "bat? "at") (Schuele & Boudreau, 2008). The development of phonological awareness skills follows a typical pattern, beginning at an early age (e.g., syllable awareness develops around age 3) and growing in complexity throughout the late preschool (e.g., onset and rhyme awareness develop around age 4) and school age years (e.g., segmenting words into individual phonemes, Goswami, 2002; Moritz et al., 2013; Scarborough & Brady, 2002). Yet, there is evidence for the emergence of receptive phonemic awareness skills for neurotypical children as young as 2.5 years old (Kenner et al. 2017).

Phonological awareness skills play a prominent role in reading development (Catts, 1989; Catts et al., 1999; Torgesen et al., 1994) such that difficulties with phonological awareness can impact a child's ability to develop necessary reading skills (Layes et al., 2020). Children with deficits in phonological awareness show difficulty manipulating the sound structure of words (Morris et al., 2012), and therefore have trouble segmenting individual or groups of letters into phonemes and blending them to make words (Wagner & Torgesen, 1987). Accordingly, challenges in phonological awareness are one of the most distinguishing characteristics of children with a developmental reading disability, also referred to as dyslexia (Stanovich, 1988; Stone & Brady, 1995; Wagner & Torgesen, 1987). For instance, 73% of children with a reading disability (Morris et al., 2012) and in 69% of children with a language impairment (Justice et al., 2015) show deficits in phonological awareness skills.

As in neurotypical development and specific learning disabilities, phonological awareness skills are a significant predictor for reading achievement of children on the autism spectrum (Dynia et al., 2017). The literature reports mixed findings on the development of phonological awareness skills of preschool autistic children with some studies reporting phonological awareness as an area of challenge (Dynia et al., 2019; Westerveld et al., 2016), while others reporting phonological awareness as a relative strength (Macdonald et al., 2020; Westerveld et al., 2020). However, mixed findings appear to be the result of group matching, such that there are few if any differences between groups matched for verbal and non-verbal cognitive skills;

preschool children on the autism spectrum show comparable phonological awareness skills to non-autistic children when verbal skills (Dynia et al., 2014; Westerveld et al., 2020) and non-verbal skills (Westerveld et al., 2020) are accounted for. Although a review of the literature suggests that group matching has a significant effect on the findings of phonological awareness skills of autistic children, the complexity of the tasks used to measure phonological awareness skills have also been put into question (Westerveld et al., 2017). In view of this concern, investigating alternatives to traditional verbal tasks to assess the phonological awareness abilities of autistic children is a valuable avenue to explore.

Autism and Enhanced Perceptual Processing: Musical Processing

Taken together, the evidence for enhanced perceptual processing of visual and auditory stimuli and the strength in non-verbal over verbal skills for autistic children, suggests that it is fitting to consider the potential of music (i.e., non-verbal stimuli) to aid identifying areas of challenge and to explore the relationship between this non-linguistic predictor and emergent literacy for children on the autism spectrum. It is particularly relevant to examine the music perception of autistic children as, similar to neurotypical youth, youth on the autism spectrum share an affinity for music (Bhatara et al., 2013).

Music

Music holds an important place in the lives of humans as its power is not limited by language, culture, gender, or ability (De Vrines et al., 2015). Music shares a long history with humans as the presence of musical tradition and its evolution has been established through archaeological records reporting the discovery of bone and ivory flutes dating to 35 000 years ago (Conard et al., 2009). Notably, music is present early in human development as mothers interact with their infants through musical approaches (Cirelli et al., 2016), for example though lullabies and playsongs (Trehub & Gudmundsdottir, 2015). Music has also been deemed an integral part of development as mother-infant interactions through musical stimuli lead to enhancements in capacities for social regulation and interaction, emotional bonding, and cognitive flexibility (Cross, 2001).

Music and Autism

Autistic youth appreciate music similarly to neurotypical youth and use music for self-management of mood (e.g., depression) and for a sense of belonging to a wider community (Allen et al., 2009; Allen & Heaton, 2010). For instance, although individuals on the autism spectrum can show difficulty in recognizing and processing their emotions (Kinnaird et al., 2019), also known as alexithymia, they can recognize music-evoked emotions (Heaton et al., 1999; Quintin et al., 2011; Stephenson et al., 2016) and report that listening to music provides a “calming” effects and relieves “tension” (Allen et al., 2009). In addition, autistic children are reported to show a preference for musical over verbal material (Blackstock, 1978; Lim, 2009) and show a greater physiological response to their preferred music compared to neurotypical peers (Hillier at al., 2016).

Further, musical strengths of autistic children have been reported since the early observations of Kanner (1943, 1951) and Sherwin (1953), who describe a special preoccupation and ability for music, exceptional acuity to sound and vibrations, rote memory for melodies, and a preference for singing over speaking. Contemporary research also provides evidence for musical abilities as a relative strength for people on the autism spectrum (Heaton, 2009; Quintin, 2019; also see Applewhite et al., 2022, for a review of music perception and autism), lending support to the EPF and TTT theoretical models suggesting enhanced perceptual processing of auditory stimuli (Mottron et al., 2001, 2006, 2009, 2014). Autistic youth show comparable production and replication of coherent musical melodies to neurotypical peers (Quintin et al., 2013), enhanced musical pitch memory and melodic perception (Heaton et al., 2003; Stanutz et al., 2014), intact rhythm perception abilities (Jamey et al., 2019), intact auditory-motor rhythm synchronization (Tryfon et al., 2017), enhanced distinction and sensitivity between pitch frequencies (Bonnel et al., 2010; Heaton et al., 1999, 2003), enhanced classification of pitch contour (Jiang et al., 2015), and an ability to recognize music-evoked emotions such as happy, sad, or scared (Quintin et al., 2011; Stephenson et al., 2016). In addition, a greater incidence of absolute pitch (when individual tones are recognized without external stimuli) exists among individuals on the autism spectrum (DePape et al., 2012; Mottron et al., 2013) compared to the rare incidence among the general population (1-5 of every 10 000 individuals, Takeuchi & Hulse, 1993).

Music and the Brain

Evidence from neuroimaging research shows that engaging in music over time can lead to cortical changes, specifically in auditory and sensorimotor areas (Bermudez & Zatorre, 2005; Luo et al., 2012). Studies comparing the brain anatomy of musicians and non-musicians reveal that musicians have larger corpus collosum (Schlaug et al., 1995a; Schmithorst & Wilke, 2002), and higher levels of activation in the auditory cortex and motor areas (Lotze et al., 2003; Meister et al., 2005) compared to non-musicians. Fifteen months of musical training resulted in significant changes (voxel size increases) in motor, auditory, frontal, and occipital regions of the brain of 6-year-old children (Hyde et al., 2009). These findings highlight how engaging in musical training can shape brain development and provide neuroscientific evidence indicating that music is a multimodal activity involving the processing of various information simultaneously (i.e., visual, auditory, sensory and motor) (Wan et al., 2010). External stimuli, such as music, can induce cortical reorganization (Schlaug et al., 1995b) and these changes in the brain could transfer to other learning areas (i.e., verbal, visual-spatial, math, Schlaug et al., 2005).

Cognitive transfer is defined as when experiences in one area (e.g., auditory) lead to improvements in another domain thought to be unrelated (e.g., motor) (Carpentier et al., 2016). A limited number of longitudinal studies have shown evidence of cognitive transfer with musical training, such that engaging in musical training for one year resulted in increases in Full Scale IQ scores for 6-year-old children (Schellenberg, 2004) and engaging in 20 days of a musical training computerized program revealed greater gains in measures of verbal intelligence and executive functioning (i.e., inhibition) tasks compared to a control group (visual arts) (Moreno et al., 2011). In addition, Carpentier et al. (2016) provide evidence for potential music-to-language neural transfer effects, showing that English-speaking children aged 4 to 6 years old in a musical training group demonstrated increased information processing capacities in multiple cortices when listening to music notes and French vowels, as well as increased brain signal complexity compared to children in the control group (French language training group).

Music, Language, and Emergent Literacy Skills

As such, significant overlaps have been identified between music, language, and emergent literacy skills as they rely on processing structured sound sequences (Patel, 2003; Patel & Iversen, 2007). Sound sequences can be organized hierarchically in lower-level units, such as musical notes, letters, and phonemes, and higher-level units, such as musical chords, melodies, words, and sentences (Molnar-Szakacs & Overy, 2006). Further, music and language are also processed by overlapping cortical and subcortical regions (i.e., middle and superior temporal gyri and inferior and middle frontal gyri) (Schön et al., 2010). Evidence for music and language neural overlap indicates that music activates language processing areas of the brain (i.e., Broca's area, related to speech production, and Wernicke's area, related to language development) (Koelsch et al., 2002; Maess et al., 2001). Resemblances between music and language are also evident when examining the early developmental period, specifically, when looking at mother-infant communication (Politimou et al., 2019). Adults speak to infants in distinguishing ways such as speaking with higher pitch and exaggerated melodic and rhythmic patterns, which can be referred to as Infant Directed speech or "motherese/parentese" (Fernald, 1985; Fernald & Kuhl, 1987; Ramírez-Esparza et al., 2017), and is recognized across cultures (Hilton et al., 2022). Equally, music also offers a context for communication between infants and their caregivers (e.g., via babbling) (Vaiouli & Andreou, 2018). The prominence of this interaction between a caregiver and infant has lent itself to be described in the literature as "communicative musicality" (Malloch, 1999; Trevarthen & Malloch, 2000). Further, the auditory processing mechanisms necessary for musical perception and phonological awareness are related (Anvari et al., 2002); beat and rhythm perception and production are related to phonological awareness skill in 3- and 4-year-old (Politimou et al., 2019), 5-year-old (Anvari et al., 2002), and 6- to 8- years old children with typical development (David et al., 2007; Eccles et al., 2020; Holliman et al., 2010; Kertesz & Honbolygo, 2021), as well as in 8 to 13 year old children with dyslexia (Huss et al., 2011).

In line with the evidence for a relationship between musical and linguistic processing and emergent literacy skills (Banai et al., 2009; Moritz et al., 2013), Patel (2011) presented the OPERA hypothesis which suggests that musical training can benefit linguistic reading abilities through adaptive plasticity in speech-processing networks. The OPERA hypothesis posits that plasticity in speech-processing networks only occurs as a result of musical training because of overlap in brain networks that process auditory features of music and speech and the following observations: music places higher demands on auditory networks than speech, musical activity elicits strong positive emotion, music reinforces the engagement in shared networks and requires focused attention (Patel, 2011). Overall, the OPERA hypothesis points to shared neural resources by which music and speech processing are related and by which musical training can lead to far transfer effects of improved linguistic processing capacity (Patel, 2011). In addition, Tierney and Kraus (2014) propose the theoretical framework of "Precise Auditory Timing Hypothesis" (PATH) to further elucidate the mechanisms behind the transfer between musical training and early literacy skills (i.e., phonological awareness skills). The PATH framework postulates that music and language rely upon precise timing in the auditory system and that entrainment (i.e., precisely timed joint action) is a core mechanism involved in both (Tierney & Kraus, 2014). Therefore, PATH suggests that musical interventions, with emphasis on entrainment, promote precise timing sensitivity that improves sound perception, leading to the enhancement of phonological skills (Patscheke et al., 2019).

The association between musical and language processing is also highlighted when examining instances of challenges in musical processing. For instance, difficulties with rhythm processing and beat perception are often present for children with a speech/language developmental disorders, such as a developmental language disorder, stuttering, and dyslexia (see Ladányi et al., 2020, for a review) and for children with attention-deficit/hyperactivity disorder (ADHD) (Puyjarinet et al., 2017). Children with a specific language impairment also show challenges in reproducing coherent melodies and matching pitch when singing (Clément et al., 2015). Remarkably, findings showing that musical processing difficulties are associated with several neurodevelopmental conditions (i.e., developmental language disorder, specific learning disorder, ADHD), contrast the literature on musical processing of autistic children, another neurodevelopmental condition, which supports that individuals on the autism spectrum show average or above-average musical production and processing abilities (Heaton, 2009; Quintin, 2019).

Musical Beat and Rhythm Perception and Production and Emergent Literacy

Research on non-linguistic predictors of literacy is growing and demonstrates that musical predictors, such as rhythm perception and production, is an important ability for literacy acquisition (e.g., Eccles et al., 2020; Moritz et al., 2013; Politimou et al., 2019). Rhythm is a musical element, alike with melody, harmony, tempo, and represents one of the most necessary organizational elements of music (Thaut et al., 1999). Rhythm is fundamental to our experience of music and can be defined as “temporally structured sequences of acoustic events” (Large & Snyder, 2009, p. 46). A hierarchical relationship exists among the elements that comprise rhythmic structure (Nave-Blodgett et al., 2021). A fundamental aspect of rhythmic structure is musical beat, which represents the ongoing pulse that occurs at regular intervals in a musical piece (Nave-Blodgett et al., 2021; Toiviainen et al., 2020). Indeed, research provides evidence for beat and rhythm perception as an innate ability **(**Toiviainen et al., 2020); newborn infants as young as 2 days old are able to detect beat violations in rhythmic sound sequences (Winkler et al., 2009) and children between 7 and 15 months old show the capacity to entrain to auditory rhythms (Cirelli et al., 2016).

Numerous studies have investigated the association between phonological awareness and rhythm perception and production due to their overlapping features of timing and segmentation of sounds (Moritz et al., 2013). Rhythm provides linguistic information in music and in speech (Bhatara et al., 2011). However, research on the relationship between beat and rhythm perception and phonological awareness has mostly included neurotypical children and children with a specific learning disorder and shows that rhythm perception and production are important predictors of phonological awareness skills within these populations (Anvari et al., 2002; Politimou et al., 2019; Wolff, 2002). Sensitivity to temporal qualities of musical beat and rhythms and language can begin as early as 4 days old, when newborn infants can discriminate languages based on their rhythmic properties (Mehler et al., 1988; Nazzi et al., 1998; Nazzi & Ramus, 2003) and at 5 months of age (Chang & Trehub, 1977; Demany et al., 1977; Trainor & Cirelli, 2015), when neurotypical infants use rhythm found in language as a cue to access phonological information in speech (Moritz et al., 2013). Investigating the association between phonological awareness and beat/rhythm perception of autistic children would be a valuable endeavour, given their relative strength in rhythm perception abilities (e.g., Jamey et al., 2019; Tryfon et al., 2017).

Research has increasingly emphasized the potential of rhythm entrainment for several neurological and developmental outcomes. For example, auditory rhythmic cuing (i.e., adjustments in speech rate are targeted using a metronome like pattern of a specific rhythm) has shown to facilitate sensorimotor functioning in autistic people with neurological impairments (Hardy & LaGasse, 2013) and improve speech intelligibility for people with Parkinson’s Disease with severe speech impairments (Thaut et al., 2001). As such, rhythm has been used as a therapeutic element in rehabilitation practices. Evidence from recent studies emphasizes the value of using music with people on the autism spectrum leading to improvements in social, cognitive, behavioural, and emotional domains (see Applewhite et al., 2022, for a review of music interventions and autism). For example, adolescents who engaged in group music making and creating self-reported a significant increase in self-esteem, reduced anxiety, and an increase in positive attitudes towards peers (Hillier et al., 2012). Reported benefits of musical interventions and programs for autistic individuals also include increases in appropriate social behaviours (Kern et al., 2007; Simpson & Keen, 2011), increased social engagement within home and community settings (Geretsegger et al., 2014), improved attention to tasks (De Vrines et al., 2015), and positive outcomes in language gains, including increases in gestural and verbal skills (Lim & Draper, 2011; Warren et al., 2010) and speech repetition ability (Chenausky et al., 2016).

Language and Emergent Literacy Interventions and Autism

Music interventions targeting language and emergent literacy skills of autistic children are particularly relevant to examine given the push for strength-based approaches for remediating areas of challenge. Additionally, music provides an interactive and enjoyable atmosphere for learning (Vaiouli & Friesen, 2016). Accordingly, the music intervention literature emphasizes the positive effects of music on linguistic abilities for autistic children (for review, see Vaiouli & Andreou 2018). For instance, Auditory-Motor Mapping Training (AMMT), an intonation-based therapy, has been examined as an intervention to facilitate speech in minimally verbal children on the autism spectrum. AMMT consists of an intervention that trains the association between sounds and actions with the aim to facilitate speech using music and rhythm (Wan et al., 2011). During the intervention, the therapist uses singing and tapping on drums tuned to the same pitches to target words or phrases (Wan et al., 2011). Following AMMT, children showed improvement in expressive language, specifically, participants improved in their ability to articulate words and phrases (Wan et al., 2011) and increased their vocabulary, which was the case even for minimally verbal autistic children (Chenausky et al., 2016). The music-based technique of Melodic-Based Communication Therapy (MBCT) has also been used to increase verbal communication for autistic children. MBCT uses melody to elicit specific words while adding rhythm (i.e., clapping) (De Vrines et al., 2015). A pilot study on MBCT found that children ages 5 to 7 made stronger gains in verbal communication in a shorter amount of time compared to those in the traditional speech and language therapy control group (Sandiford et al., 2013). Measured outcomes included the number of verbal attempts, the number of new words heard in the home environment, and vocal imitation attempts. Positive findings in musical interventions targeting oral language highlight the growing body of research on the connection between music and language development of autistic children, with musical rhythm proving to be a valuable stimulus in interventions. Other modalities of interventions shown to facilitate expressive language in minimally verbal children on the autism spectrum include didactic approaches, contemporary applied behaviour analysis, social-pragmatic strategies, and augmentative and alternative communication strategies (see Paul, 2008, for a review).

In contrast, the literature on interventions targeting the development of emergent literacy skills, including phonological awareness, of children on the autism spectrum is limited. In addition, there is equally a scarcity of studies investigating the use of music-based intervention for emergent literacy skills for autistic children. The literature on musical intervention for emergent literacy development focuses on population with specific learning disorders (e.g., Cancer & Antonietti, 2022), and provides support for a transfer effect of musical training on phonological skills. While Vaiouli and Friesen (2016) suggest that incorporating re-composed songs, musical storybooks, and song writing into classrooms could encourage literacy development for all children, including autistic children, an absence of evidence-based practice remains for this population.

Overall, literacy instruction for children on the autism spectrum has been largely overlooked in educational research (Kamps et al., 2016). The efficacy of intervention programs aimed at promoting phonological awareness has been well established for neurotypical children (NELP, 2008) but remains to be elucidated for children on the autism spectrum. The relationship between emergent literacy skills and later reading success highlights the importance of targeting the development of these skills for autistic children (Dynia et al., 2014). Thus, an in-depth review of the literature is necessary to aid in establishing evidence-based practice to support in the development of emergent literacy skills for autistic children.

Conclusion

In summary, factors such as autism characteristics, and cognitive ability, and language skills, may play an important role in phonological awareness development (e.g., Dynia et al., 2014; Fleury & Lease, 2018; Nally et al., 2018; Smith Gabig, 2010; Westerveld et al., 2020) and remain to be examined in detail to gain a greater understanding of emergent literacy skill development for autistic children. Further, evidence for enhanced perceptual processing of auditory stimuli and a strength in non-verbal/perceptual reasoning skills for autistic children, suggests that it is fitting to consider the potential of music (i.e., beat perception) to aid identifying areas of challenge and to explore the relationship between this non-linguistic predictor and emergent literacy for children on the autism spectrum.

Chapter 3: Manuscript 1

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Emergent literacy skills and autism: A scoping review of intervention programs

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Abstract

This scoping review summarized the literature on interventions targeting the emergent literacy skills of children on the autism spectrum. Findings across 16 studies highlighted that interventions could be divided into two main categories, namely computer-based interventions and non-computer-based interventions. Overall, results are encouraging and suggest that both intervention modalities can lead to gains in oral and written emergent literacy skills pre to post-intervention for children on the autism spectrum with diverse support needs and developmental profiles. Knowledge gaps and limitations in emergent literacy intervention research for autism include a lack of participant characterization, variable use of emergent literacy terms and measures, and the absence of waitlist comparison groups and follow-up assessments after the end of intervention. Replication studies are needed to gain greater knowledge into evidence-based practice for teaching emergent literacy skills to autistic children.

Keywords: autism spectrum disorder, emergent literacy skills, phonological awareness, word recognition, intervention, children

Emergent Literacy Skills and Autism: A Scoping Review of Intervention Programs

Emergent literacy refers to the development of reading and writing knowledge (Whitehurst & Lonigan, 1998) which is largely learned prior to conventional literacy instruction and before a child becomes a formal reader (Dickinson & McCabe, 2001). Emergent literacy is comprised of several necessary precursors essential to future reading achievement including understanding the connection between oral and written language (Justice & Ezell, 2001) and the underlying phonological structure of a language (Lonigan et al., 1998). The purpose of acquiring emergent literacy skills is, ultimately, to develop an understanding of what you are reading, a concept which is suggested by the prominent reading development theory, the Simple View of Reading (Gough & Tunmer, 1986; Hoover & Gough, 1990). According to this theory, reading comprehension is attained when decoding (which encompasses phonological awareness and word recognition) and listening comprehension are well developed (Hoover & Gough, 1990). As such, two crucial emergent literacy components for reading success for typically developing children are metaphonological skills (i.e., phonological awareness) and word recognition skills (Blachman et al., 1999; Moritz et al., 2013; National Early Literacy Panel [NELP], 2008), which are also referred to as "code-related skills" in the literature (Storch & Whitehurst, 2002) and have been identified as important targets for early intervention (Justice & Ezell, 2001). Therefore, the emergent literacy skills of focus in this review include 1) phonological awareness (oral language) and 2) word recognition skills (written language).

The metalinguistic awareness of phonological elements pertaining to oral language is often referred to as "phonological awareness" or "metaphonological skills", as explained by Scarborough and Brady (2002) who provide a glossary outlining terminology and definitions of emergent literacy terms. Phonological awareness involves the manipulation and analysis of the sound structures of spoken language and includes rhyming, segmentation, categorization, identity, and synthesis/blending (Scarborough & Brady, 2002; Schuele & Boudreau, 2008). As such, tasks assessing phonological awareness exclusively require oral stimuli and do not contain print (Schuele & Boudreau, 2008). While phonological awareness is an essential reading precursor skill, a child must also acquire orthographic knowledge for proficient decoding of written words (Schuele & Boudreau, 2008). The phonological aspect of written word recognition is often referred to as “word recognition skills” (Scarborough & Brady, 2002; Schuele & Boudreau, 2008) or as “phonics” by the National Reading Panel. Word recognition abilities include the alphabet principle (i.e., written graphemes correspond to spoken phonemes), phoneme-grapheme correspondence (e.g., phonemes can be associated with more than one grapheme; F or PH for /f/) and decoding (Scarborough & Brady, 2002). Tasks measuring word recognition abilities involve print stimuli where the child is introduced to the concept that letter symbols represent oral language sounds (Schuele & Boudreau, 2008).

Emergent Literacy Skills and Autism

The presence of a developmental condition, such as autism spectrum disorder (hereinafter referred to as “autism” or “autism spectrum”), is a risk factor for the delayed development of emergent literacy skills (Justice & Pullen, 2003). While autism is characterized by challenges in social communication and interactions and the presence of restricted, repetitive patterns of behaviours, interests, or activities (American Psychiatric Association (APA), 2013), autistic children are also at high risk of developing an impairment in literacy skills (e.g., Henderson et al., 2014; Westerveld et al., 2020). Research suggests that up to 50% of autistic children show difficulties in reading (Nation et al., 2006). As such, much research has focused on attempting to elucidate the reading profiles of autistic children. The multiple deficit model framework proposed by Pennington et al. (2006) posits that comorbidity and behavioural symptoms (such as literacy deficits) within developmental disorders cannot be explained by a single cause, but rather by the interplay of multiple genetic and environmental risk factors (Pennington et al., 2004; Van Bergen et al., 2014). Accordingly, emergent literacy difficulties exhibited by some autistic children could be the result of the multiple factors including 1) autism characteristics (i.e., restricted interests, social-communication deficits), 2) co-occurring language impairments, and 3) co-occurring cognitive impairment (Bailey et al., 2017; Davidson & Weismer, 2014; Westerveld et al., 2018, 2020). Children on the autism spectrum can also present with specific learning disorders (up to 30% depending on the study) (Ibrahim, 2020) and other co-occurring conditions such as an intellectual developmental disorder (30%) (Christensen et al., 2018), attention-deficit-hyperactivity disorder, a mood or anxiety disorder, oppositional defiant disorder (Brookman-Frazee et al., 2018; Chien et al., 2021; Matson & Goldin, 2013; Simonoff et al., 2008), which may also have an impact on emergent literacy development.

Language difficulties are highly prevalent for children on the autism spectrum (APA, 2013; Kjelgaard & Tager-Flusberg, 2001; Pomper et al., 2019). Thirty to 50% of autistic children do not have functional verbal speech (Centre for Disease Control and Prevention, 2014; National Autism Association, 2014; Sandiford et al., 2013). When considering that reading abilities rely heavily on language skills (Nation et al., 2004) as well as the high prevalence rate of language difficulties found in autism, it is possible that language difficulties are a potential source for reading difficulties for some children on the autism spectrum. For example, Westerveld et al. (2016) conducted a systematic review investigating emergent literacy skills of preschool children on the autism spectrum with language skills ranging from severe language impairment to typical/above average language skills. Consistent findings were found among three studies included in their review (Davidson & Weismer, 2014; Dynia et al., 2014; Lanter et al., 2012), which indicated that preschool children on the autism spectrum experience challenges associated with code-related (i.e., phonological components of language) emergent literacy skills (Westerveld et al., 2016). However, when the emergent literacy skills of autistic children and typically developing children were compared, group differences “disappeared” when language ability was controlled for statistically (Dynia et al., 2014). In addition, language skills were a significant statistical predictor of performance on emergent literacy tasks across the three studies for autistic children (i.e., an increase in language skills was associated with an increase in emergent literacy skills). As such, language ability and emergent literacy skills of autistic children are closely related.

Emergent literacy skills are a significant predictor of later reading success in typical development and this is also the case for children on the autism spectrum (Dynia et al., 2017). The efficacy of intervention programs aimed at promoting awareness of the phonological structure of oral language (i.e., phonological awareness training) and the understanding of word recognition (i.e., alphabet principle, decoding, phoneme-grapheme correspondence) or “code-related” instruction has been well established for typically developing children (NELP, 2008) but remains to be elucidated for children on the autism spectrum. Whalon et al. (2009) conducted a review examining the literature on reading instruction for children on the autism spectrum targeting several components of reading. Preliminary findings were promising as they revealed consistent improvements in emergent literacy skills across studies targeting code-focused skills (Whalon et al., 2009). Accordingly, the current scoping review aimed to expand on the review conducted by Whalon et al. (2009) with a specific focus on both oral and written emergent literacy skills; metaphonological and word recognition skills (e.g., basic word reading/decoding).

To date, literacy instruction for children on the autism spectrum has been largely overlooked in educational research (Kamps et al., 2016). Intervention research on emergent literacy skills and autism is lacking compared to similar research efforts for its core features, namely communication and social skills (Nally et al., 2018). The relationship between emergent literacy skills and reading success highlights the importance of targeting the development of these skills for children on the autism spectrum (Dynia et al., 2014). Reading ability leads to enhanced learning opportunities, academic achievement, adaptive skills, social skills, and occupational attainment (Nally et al., 2018; Westerveld et al., 2018). Therefore, it is important to investigate the effectiveness of interventions focusing on the emergent literacy skills of children on the autism spectrum (Dynia et al., 2019).

The purpose of this scoping review is to identify and systematically review interventions targeting the development of emergent literacy skills (i.e., oral = metaphonological and written = word recognition skills) of children on the autism spectrum. Metaphonological skills and word recognition skills have been identified as crucial emergent literacy components for reading success (e.g., NELP, 2008), and as important targets for intervention (Justice & Ezell, 2001), and have therefore been selected as the emergent literacy skills of interest for the current review. Specifically, this scoping review aims to: 1) summarize the literature on interventions targeting the emergent literacy skills of children on the autism spectrum, 2) summarize the characteristics of the participants included in emergent literacy interventions, and 3) highlight knowledge gaps and limitations in emergent literacy intervention research with autism. Overall, this review aims to summarize the extent of the literature on emergent literacy skill interventions in order to provide educators, clinicians, and researchers aiming to increase future reading success of children on the autism spectrum with informed instructional practices for teaching emergent literary skills.

Method

Search Procedure

The framework presented by Arksey and O'Malley's (2005) as well as elements adapted from The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2020) are used in the current review. The search procedure corresponds to stage 1 (identifying the research questions) and stage 2 (identifying relevant studies) from the methodological framework presented by Arksey and O'Malley (2005). A scoping review for peer-reviewed journal articles was conducted on June 24, 2021 following PRISMA guidelines (Page et al., 2020) on PsycINFO (1806 - Ovid), Education Resources Information Centre (ERIC; Proquest), and Web of Science core collection databases. Search terms for PsycINFO (1806 - Ovid) included: 1) exp Autism spectrum disorder, 2) *Intervention, 3)*Training, 4) Program, 5) exp Phonological Awareness, where this term was exploded to include narrower terms *Phonemic Awareness, *Awareness, *Literacy, *Phonology, *Phonemes, * Reading Development, *Reading Readiness, *Rhyme, *Word Recognition, 6) Metaphonological, 7) Phonological Processing, and 8) Phonological Sensitivity. A wide variety of search terms for phonological awareness was explored as the literature uses several terms interchangeably to describe it (Schuele & Boudreau, 2008). The search term "word recognition" was used as an umbrella term to capture studies investigating written language skills and thus, encapsulated the various subskills involved, including decoding, the alphabet principle, and phoneme-grapheme correspondence (see Table 3 for a breakdown of specific subskills skills measured across studies in this review). The search was restricted to age group limits of "childhood". Search terms for

ERIC included: (autism OR ASD) AND ("phonological awareness" OR "phonemic awareness" OR "phonological sensitivity" OR metaphonological OR awareness OR phonemes OR phonetics OR "phonological processing" OR "word recognition") AND (intervention OR training OR program) AND (child* OR kids OR youth). An additional search was conducted on Web of Science core collection database using the same search terms. No date limit was used in the three searches. The reference sections of articles that met inclusion criteria were reviewed to ensure that all relevant articles were captured, as recommended by Arksey & O'Malley (2005).

Inclusion Criteria

Inclusionary criteria relevant to the research questions (stage 3 study selection; Arksey & O'Malley, 2005) were applied during the screening process (Table 1) where studies were required to: a) include participants diagnosed with autism spectrum disorder (15 years and younger), b) employ empirical experimental or quasi-experimental design with quantitative data analysis, c) include a clearly described intervention/training program, d) include a standardized measure to characterize participants, e) include an outcome measure of emergent literacy skills of interest, and f) be published in a peer-reviewed journal in English.

In order to include a broader representation of the literature in this review, studies were eligible for inclusion if the sample consisted of participants identified with autism irrespective of a clinical diagnosis confirmed with autism diagnostic instruments and screeners (e.g., ADOS, ADI-R, SRS, SCQ). In addition, a preliminary exploratory search of the literature showed that limiting the age range to very young children significantly reduced the number of potential studies to be included in the review. Thus, we included a wider age range for participants (15 years and younger; using the age group limit of "childhood" in the databases) to allow for a more comprehensive review of the already limited research published in this area. Studies including a sample of participants with various developmental conditions were eligible for inclusion if the analyses and results of the research were presented separately for participants on the autism spectrum. All studies including a clear description of an intervention/training program (including interventions targeting other abilities together with emergent literacy skills of interest) were eligible to be included.

Study Selection Procedure

The emergent literacy skills of focus in this review as defined by Scarborough and Brady (2002) included: 1) the metalinguistic awareness of phonological concepts (oral language: e.g., phonological/phonemic awareness, code-related skills) and 2) phonological aspects of word recognition (written language: e.g., phonics, alphabet knowledge, decoding, phoneme-grapheme correspondence). The initial electronic search yielded a total of 743 articles. Following the removal of duplicate records using EndNote9 citation software, a total of 655 unique entries were screened by title and abstract as recommended in the PRISMA guidelines (Figure 1; Page et al., 2020). Following the screening of titles and abstracts of articles identified via electronic search, 46 articles were retained for a full-text review and were assessed for inclusion eligibility. All articles were accessed electronically. Of these 46 studies, nine studies were excluded due to the sample not including any participants on the autism spectrum. Ten studies were excluded due to the absence of a pre to post-intervention outcome measure of emergent literacy skills. Furthermore, four studies were excluded due to the absence of administration of a descriptive measure (e.g., autism characteristics, language, adaptive or cognitive skills, etc.). Four studies included a sample with diverse neurodevelopmental conditions but were excluded because they did not report analyses and results separately for participants on the autism spectrum. Two studies were excluded as they only provided sight word instruction without a phonological outcome (Whalon et al., 2009). One study was excluded because it included many participants above the age of 15 years old and another one was excluded as its primary aim was not an intervention study. Exceptionally, one study remained included in the scoping review despite having one participant aged 18 years old as all other participants ranged between 4 and 15 years of age (*n*=30) and this study was deemed to bring valuable data to the current review given its methodological rigor and recent publication date (i.e., 2020). In addition, interventions targeting emergent literacy skills can also be relevant for older autistic adolescents given that difficulties in phonological awareness skills can persist into later years (Nally et al., 2018) and given the high rates of co-occurring intellectual disability within this population (12 times more likely to have and IQ score indicating intellectual disability compared to typical development) (Billeiter & Froiland, 2022), which can have an important impact on reading development. One study was excluded due to its methodological approach (qualitative research design). Lastly, four studies were not peer-reviewed published scientific journal articles (*n* = 3 conference proceedings, *n* = 1 thesis).

Of the 46 studies that were assessed for inclusion eligibility, 10 studies were retained for this scoping review. Next, the reference lists of the 10 retained studies from the electronic search were reviewed via an ancestral search, 10 additional studies were identified of which four articles were retained after review. As highlighted by Arksey & O'Malley (2005), limiting a search to electronic database and ancestral searching holds the potential to miss important articles, as databases may be incomplete, not up to date, and vary in their abstracting services. Therefore, two studies were included from a previous manual search in March of 2020 as they were deemed to be valuable additions to the current review. Following the application of the inclusionary/exclusionary criteria, a final total of 16 articles were included in this scoping review.

Search Procedure and Interrater Reliability

Two independent raters participated in the scoping review search procedure (the first and second author). Following the removal of duplicate records, the first and second author independently completed the scoping review search procedure, including screening of titles, abstracts and full texts, and completing the ancestral searches. Initial screening of titles and abstracts consisted of applying the inclusion criteria to each record. If all information relating to the inclusion criteria could not be deciphered from the title or abstract of a record, that record was retained for full-text review. To calculate interrater reliability (IRR), the total number of agreements (i.e., number of articles identifies by both raters) was divided by the total number of unique records identified for inclusion across both raters (e.g., Gunning et al., 2019). IRR across the articles identified by both raters was 80%. Both raters then applied the inclusion criteria to the 46 full-text articles and agreement of 100% was reached on the 10 included articles from the database search. Following this, the first and second author reviewed the reference sections of the 10 articles identified through the database search, where 100% agreement was reached on the 4 additional articles to include in the final review. The additional two articles identified in a manual search were found by the first author and the second author agreed to their inclusion in the final review.

Data Extraction and Interrater Reliability

Data extraction (stage 4 charting the data; Arksey & O'Malley, 2005) was completed in line with the aims of this scoping review (Table 2). Specifically, each study was summarized and analyzed in terms of (a) authors, (b) design, (c) participants (number/sex/chronological age), (d) descriptive measure of participants, (e) intervention/training program, (f) measure of emergent literacy skills of interest, and (g) relevant results.

The first author completed the data extraction of the 16 included articles of this review with the second author acting as the second rater. Six articles were randomly selected (37.5%) to validate the accuracy of the summaries included in the table (e.g., Watkins et al., 2019). Interrater reliability was calculated across 42 elements (i.e., 6 studies with 7 data extraction questions outlined above), where 100% agreement was obtained on all elements.

Results

The results reported in this scoping review study align with stage 5 (collating, summarizing, and reporting results) of the framework recommended by Arksey & O'Malley (2005). The analysis of findings within a scoping review intends to present an overview of the included studies as opposed to attempting to integrate and assess quality of evidence, as in the case of a systematic review. Accordingly, the results presented below aims to summarize interventions targeting emergent literacy skills within autism research. Further, participant characterization was reviewed across studies in order to obtain a comprehensive representation of the research in this area.

The results of this scoping review present the findings from 16 studies published over a 27-year period, involving 328 participants across eight countries (Table 2). Six studies employed a group design while ten studies employed a single-subject design. Within this review, interventions are categorized into two formats: computer-based interventions (7 studies) and non-computer-based interventions (8 studies); and one study included both a computer-based intervention and a non-computer-based intervention.

Participant Characteristics

The mean chronological age of participants reported across the 16 studies varied between 4 and 11 years old. Of these participants, 84% were identified as male and 16% were identified as female. Studies did not evaluate the impact of chronological age on emergent literacy skills post-intervention; groups were either matched on chronological age or chronological age was used as a covariate in analyses. The 16 studies used diverse standardized descriptive measures to characterize the participants in their samples. Only three out of the 16 studies in this review assessed and validated the autism characteristics of their participants (Heimann et al., 1995; Hudson et al., 2017; Kamps et al., 2016). Of these studies, participants ranged from mild to moderate autism characteristics (Hudson et al., 2017; Kamps et al., 2016) to more severe autism characteristics (Heimann et al., 1995). Thirteen studies did not validate autism characteristics of their participants with a standardized measure but instead used educational codes or a previous diagnosis of autism spectrum disorder by a clinician. Pre-intervention emergent literacy scores and measures for all studies are provided in Table 1.

Mental Age. Four studies included a descriptive measure of mental age for participant characterization (Basil & Reyes, 2003; Heimann et al., 1993, 1995; Tjus et al., 1998). Participants across these studies had a mental age of a minimum of 1 year and maximum of 10 years younger than their chronological age.

Adaptive Ability. Six studies included a measure of adaptive abilities (Arciuli & Bailey, 2019; Bailey et al., 2017; Flores et al., 2004; Grindle et al., 2013; Kamps et al., 2016; Uccheddu et al., 2019). Adaptive functioning levels ranged from moderately low (Arciuli & Bailey, 2019; Bailey et al., 2017; Kamps et al., 2016; Uccheddu et al., 2019) to low (Flores et al, 2004; Grindle et al., 2013) across participants included in these studies.

Cognitive Ability. Only four studies included a measure of cognitive ability to characterize their participants (Flores et al., 2004; Grindle et al., 2013; Nally et al., 2020; Uccheddu et al., 2019). Cognitive functioning full-scale IQ scores ranged from extremely low (Flores et al., 2004), to studies presenting participants with a wide range of cognitive profiles (Grindle et al., 2013; Nally et al., 2020; Ucceddu et al., 2019).

Language Ability. A descriptive measure for language skills was used by nine studies (Arciuli & Bailey, 2019; Bailey et al., 2017; Basil & Reyes, 2003; Beecher & Childre, 2012; Heimann et al., 1995; Joseph, 2018; Kamps et al., 2016; Kimhi et al, 2018; Tjus et al., 1998) to characterize participants. Language abilities of participants varied among studies with some studies reporting average language skills (Arciuli & Bailey, 2019; Bailey et al., 2017), language skills 2 to 4 years below chronological age (Heimann et al., 1995; Tjus et al., 1998), and extremely low language skills (Basil & Rayes, 2003; Beecher & Childre, 2012; Joseph, 2018). Kimhi et al. (2018) reported varying levels of language abilities within the participants in their sample ranging from simple phrases to several compound sentences. Participants in one study also used augmentative and alternative communication (AAC) devices (Johnston et al., 2009).

Co-Occurring Conditions. Of the studies in this review, nine studies did not report or include any information regarding co-occurring conditions in their samples (Arciuli & Bailey, 2019; Grindle et al., 2013; Heimann et al., 1995; Joseph, 2018; Kamps et al., 2016; Kimhi et al., 2018; Nally et al., 2020; Tjus et al., 1998; Uccheddu et al., 2019). One study reported inclusion criteria for participation as having no known co-occurring neurological or genetic disorders (Hudson et al., 2017). Six studies reported the presence of co-occurring disorders for participants on the autism spectrum (Bailey et al., 2017; Basil & Reyes, 2003; Beecher & Childre, 2012; Flores et al., 2004; Heimann et al., 1993; Johnston et al., 2009). Co-occurring conditions from the six studies included the presence of attention deficit hyperactivity disorder (ADHD) (Bailey et al., 2017; Beecher & Childre, 2012; Heimann et al., 1993) and intellectual developmental disabilities (IDD) (Beecher & Childre, 2012; Flores et al., 2004; Heimann et al., 1993), also described as “intellectual impairment of unknown origin” (Basil & Reyes, 2003) and “cognitive delays” (Johnston et al., 2009). Studies also reported co-occurring difficulties including language and articulation difficulties (Bailey et al., 2017) and “perceptual deficits” (Heimann et al., 1993).

Emergent Literacy Skills Interventions

Computer-Based Interventions

Seven of the 16 studies included in this review investigated the effectiveness of computer-based interventions on emergent literacy skills of youth on the autism spectrum (Arciuli & Bailey, 2019; Bailey et al., 2017; Basil & Reyes, 2003; Grindle et al., 2013; Heimann et al., 1993, 1995; Tjus et al., 1998) and revealed relatively consistent positive results despite implementing different programs.

Two studies investigated the efficacy of the ABRACADABRA program (web application with game-based early literacy learning activities) for improving reading accuracy of children on the autism spectrum. The ABRACADABRA program was designed for all children, including at-risk learners (Arciuli & Bailey, 2019; Bailey et al., 2017), and includes literacy activities such as identifying matching sounds, identifying letters corresponding to to audio-recorded phonemes, and matching phonetically segmented words to images. Both studies included participants on the autism spectrum who were assigned to either the intervention group or to a waitlist comparison group who received regular academic instruction. Bailey et al. (2017) delivered the 60-minute intervention program on a one-to-one basis in participants’ homes twice a week over the span of 13 weeks (26 sessions per participant) to the intervention group. Non-computerized extension tasks (i.e., shared reading or spelling games) were also delivered by the experimenters in conjunction with the ABRACADABRA program. Results revealed significant gains pre to post-intervention for children on the autism spectrum in the intervention group compared to children on the autism spectrum in the waitlist comparison group in word level reading accuracy scores, with large gains for the intervention group (Bailey et al., 2017). Further, scores in word level reading accuracy for the waitlist comparison group decreased pre to post-intervention (Bailey et al., 2017). A follow-up study (Arciuli & Bailey, 2019) investigated the efficacy of the ABRACADABRA program when administered by teachers to small groups within a school setting. In this intervention, participants worked on a personal computer, a shared computer, and engaged in small group shared reading. Results revealed similar findings to Bailey et al. (2017), showing significant gains in word level reading accuracy pre to post-intervention for the intervention group compared to the waitlist comparison group, with a large effect size (Arciuli & Bailey, 2019).

Four studies examined the efficacy of a computer software program designed for teaching literacy skills to children with disabilities, originally called “Alpha” (Heimann et al., 1993, 1995) which progressed to a later version named “DeltaMessages” (Basil & Reyes, 2003; Tjus et al., 1998). This program guides learning through immediate multichannel feedback (i.e., voice, animation, video, sign language) (Nelson & Prinz, 1991). The Swedish version of the program was used in three studies (Heimann et al., 1993, 1995; Tjus et al., 1998) and the Castilian and Catalan versions were used in one study (Basil & Reyes, 2003). Heimann et al. (1993) delivered a mean of 23.7 training sessions of approximately 40 minutes (over 11-17 weeks) of the Alpha program to a subgroup of participants on the autism spectrum (n = 7) also included in another study (Heimann et al., 1995). Findings revealed gains in phonological awareness scores for four participants, no progress in phonological awareness scores for two participants, and mixed results for one participant (Heimann et al., 1993). In 1995, Heimann and colleagues published a larger study, which compared the effect of the Alpha program on the phonological awareness skills of children on the autism spectrum (*n* = 11) to children with mixed disabilities (*n* = 9) and typically developing (TD) preschool children (*n* = 10). Results revealed a significant increase in mean scores of phonological awareness pre to post-intervention for children on the autism spectrum and TD children, but a decrease in phonological awareness scores from post-intervention to follow-up for children on the autism spectrum (Heimann et al., 1995). In 1998, Tjus and colleagues investigated the efficacy of the DeltaMessages program in a sample of 13 children on the autism spectrum and found a significant increase in phonological awareness scores pre to post-intervention and at follow-up. Further, greater improvement in phonological awareness scores were found for participants with higher language levels (> 6 years; CPM; Raven et al., 1984) and mental age (≥50th percentile; Reynell Developmental Language Scales; Reynell, 1977). Lastly, Basil et al. (2003) examined the efficacy of the DeltaMessages program for two participants on the autism spectrum and found that one participant showed gains in letters, syllables, and word reading pre to post-intervention. The outcome assessment for the second participant could not be completed due to behavioural difficulties (Basil & Reyes, 2003).

One study was the first to investigate the efficacy of MimioSprout Early Reading (MER), an internet-based reading program, on the early reading skills of four children on the autism spectrum (Grindle et al., 2013). A total of 80 training sessions lasting between 15-20 minutes were delivered to participants and adaptations to the standard teaching procedure (e.g., tutor sitting with child, discrete-trial teaching) were required for all children. Results show an increase in word recognition for three participants (*n* = 1 scored at ceiling) and a general trend of increase on oral and written emergent literacy skills (Grindle et al., 2013). Furthermore, gains in word recognition were maintained for two participants at an 8-week follow-up (Grindle et al., 2013).

Finally, one study compared two formats of the Edmark® Reading Program; table-top instruction and computer-assisted instruction (Nally et al., 2020), on the reading outcomes of 31 children on the autism spectrum. Results revealed a significant difference in word recognition and phonological awareness scores across the two formats with higher gains in the table-top instruction group.

Non-Computer-Based Interventions

Of the 16 studies included in this review, eight investigated the efficacy of non-computer-based interventions on the emergent literacy skills of youth on the autism spectrum (Beecher & Childre, 2012; Flores et al., 2004; Hudson et al., 2017; Johnston et al., 2009; Joseph, 2018; Kamps et al., 2016; Kimhi et al., 2018; Uccheddu et al., 2019) and report consistent positive findings with the exception of one study (Uccheddu et al., 2019).

Three studies examined the efficacy of direct instruction programs to teach letter-sound correspondence to children on the autism spectrum (Flores et al., 2004; Johnston et al., 2009; Joseph, 2018). An adapted direct instruction program taken from the Corrective Reading Word Attack Basics was used in one study (Flores et al., 2004). Flores et al. (2004) found that the participant on the autism spectrum mastered letter-sound identification, sound blending, and decoding skills and that letter-sound correspondence skills generalized to untaught words. The second study compared two conditions (fixed array vs. gradual array) for teaching letter sound correspondence (Johnston et al., 2009). In the fixed array condition, the target letter was immediately presented along with distracter letters and in the gradual array condition, the target letter was first presented alone, after which distracter letters were gradually introduced (Johnston et al., 2009). The mastery criterion established by Johnston and colleagues for both conditions was defined as two consecutive sessions of 80% or higher correct responses. Results from Johnston et al. (2009) revealed that the fixed array condition was effective at reaching the established criterion of the study for both participants, whereas conclusions could not be made regarding the effectiveness of the gradual array condition. The third study examined the effectiveness of a different technique called the "Word Box Method" (Joseph, 2018). The method consisted of placing letters into drawn boxes as each sound of a word is articulated (Joseph, 2018). Findings revealed an increase in phoneme segmentation and word identification skills across all three children on the autism spectrum included in the study.

Five of the eight studies included a reading instruction program as part of their study; with three studies implementing the program in group format (Beecher & Childre, 2012; Kamps et al., 2016; Kimhi et al., 2018), two studies in a one-on-one format (Hudson et al., 2017; Uccheddu et al., 2019). With a small group format, Beecher et al. (2012) explored the effectiveness of a comprehensive reading instruction program on the emergent literacy skills of two children on the autism spectrum with a significant developmental delay and moderate intellectual disability. The program was comprised of the PCI Reading program and teacher designed literacy and language activities and was delivered in small group 55-minute sessions (including 15 minutes of individual instruction). The program was individualized according to student needs and thus integrated additional support such as repetition, visual cues (i.e., pictures and sign language), reinforcement, and systemic prompting. Sign language was an important adaptation made to the program as it is an evidence-based practice used to support language development for children on the autism spectrum and intellectual disability (Beecher et al., 2012). For instance, one participant relied on signs to support memory retrieval of letters.

Findings indicated a gain in letter, letter-sound, and sight word knowledge for both participants pre to post-intervention. Also with a small group format, Kimhi et al. (2018) explored the efficacy of a 6-week naturalistic early literacy intervention for five children on the autism spectrum. The early literacy intervention was based on the national emergent literacy curriculum of the Israeli Ministry of Education (Levin, 2007) and the National Reading Panel's (2008) recommendations to promote literacy among TD children. The intervention was adapted for children on the autism spectrum (i.e., including the use of visual aids and language supports) (Kimhi et al., 2018). Results showed significant pre to post-intervention gains in letter and grapheme-phoneme knowledge for all participants. Further, Kamps et al. (2016) compared the efficacy of the Reading Mastery direct instruction curriculum (*n* = 32) in a group setting to typical reading instruction (*n* = 30). Participants in the Reading Mastery direct instruction curriculum as well as the typical reading instruction group were further divided into small groups (number of participants not specified). Overall, participants with higher scores pre-intervention had higher scores throughout the intervention. Findings revealed an improvement in letter-sound correspondence and word identification scores, with significantly greater improvements for participants in the Reading Mastery intervention group. In addition, all participants improved in word attack scores regardless of group.

As for reading instruction programs implemented in a one-on-one format, Uccheddu et al. (2019) investigated the effectiveness of a 10-session reading program with the presence of a dog (*n* = 5) compared to without (*n* = 4) on the metaphonological skills of children on the autism spectrum. No significant differences were found in metaphonological scores pre to post-intervention between or within groups. However, the primary outcomes targets of this intervention were propensity towards books and motivation to read, and not emergent literacy skills per se. Lastly, the study with largest sample size included in this review (N = 133) examined two literacy interventions designed to improve emergent literacy skills in preschool children on the autism spectrum in a one-on-one format (Hudson et al., 2017). Hudson et al. (2017) compared the efficacy of an interactive book reading treatment (n = 47), a phonological awareness intervention (n = 42), and a “business as usual” control condition (n = 44). Participants in the interactive book reading condition (adapted from the Dialogic Reading procedures; Whitehurst et al., 1988) completed on average 60 sessions of 7 to 15 minutes and those in the phonological awareness condition completed approximately 52 sessions of 7 to 15 minutes. Results demonstrated that all children in the study showed gains in phonological awareness scores, however no significant gains in print knowledge or word reading were found. Pre to post-intervention effects of the phonological awareness treatment on phonological awareness scores were found and this finding remained after controlling for treatment-related classroom literacy activities. Further, pretest negatively predicted gains on emergent literacy skills. Specifically, children with lower skills pre-intervention demonstrated greater gains during the intervention compared to children who began the intervention with higher emergent literacy skills pre-intervention.

Elements of Interventions

The interventions discussed in this review varied in duration, setting, format, and interventionist. The person delivering the computer-based interventions and non-computer-based interventions differed across studies. Three interventions were led by a researcher on the team who was also a professional (i.e., speech pathologist, teacher, special education teacher), eleven by educators or school staff trained by the research team (i.e., teacher, psychologist, behavioural technician), and two by applied behavioural analysis (ABA) therapists. The majority of the interventions were conducted in individual training sessions with 12 studies including interventions delivered on a one-to-one basis (six out of the seven computer-based interventions, five out of the eight non-computer-based interventions and the one study comparing both modalities). Further, 14 studies included interventions held in a school setting, one was held in participant’s homes, and one was held in a community setting.

Outcome Measures of Emergent Literacy Skills

Four of the 16 studies targeted metaphonological skills (oral language) as an outcome variable of their intervention (Heimann et al., 1993, 1995; Tjus et al., 1998; Uccheddu et al., 2019), eight studies targeted the written aspect of emergent literacy skills (Arciuli & Bailey, 2019; Bailey et al., 2017; Basil & Reyes, 2003; Beecher & Childre, 2012; Flores et al., 2004; Johnston et al., 2009; Kamps et al., 2016; Kimhi et al., 2018), and four studies targeted both oral and written emergent literacy components of language as outcome variables (Grindle et al., 2013; Hudson et al., 2017; Joseph, 2018, Nally et al., 2020) (Table 3). Three studies also included an outcome measure for word reading (Heimann et al., 1993, 1995; Tjus et al., 1998) in addition to metaphonological skills. However, the reading outcome measure was not reported in this review as it contained advanced skills in reading above the scope of this review (i.e., sentence reading and comprehension).

Discussion

Summary of Emergent Literacy Skill Interventions

The primary aim of this scoping review was to summarize the literature on emergent literacy skill interventions for children on the autism spectrum. Results revealed that computer-based interventions and non-computer-based interventions were the two most commonly studied types of interventions to target the emergent literacy skills of interest in this review of children on the autism spectrum. Findings across studies examining the use of computer-based interventions revealed significant increases in phonological awareness and word recognition scores pre to post-intervention which suggests that computer-based programs may be a useful tool for promoting oral and written emergent literacy skills for children on the autism spectrum. Adaptations to computer-based interventions based on the child's personal support needs were necessary in some studies and included having a tutor sitting with the child and the use of discrete-trial teaching. Studies exploring the use of non-computer-based interventions, including reading instruction and direct instruction programs, revealed relatively consistent results (with the exception of one study that did not find significant results), showing gains in oral and written emergent literacy skills pre to post-intervention. Parallel to the computer-based interventions, adaptations to the implementation of non-computer-based interventions were needed such as the use of visual aids and language supports.

Based on consistent positive finding across intervention types, it appears that both computer-based interventions and non-computer-based interventions are effective at teaching oral and written emergent literacy skills to children on the autism spectrum. In addition, the person delivering the intervention, the delivery format, and the intervention setting did not have a significant impact on the outcomes of the interventions. Common elements across successful interventions included spanning between 6-24 weeks, with a minimum of a half hour of training per week for at least 7 hours total of intervention time. Interestingly, one study included in this review compared two formats of a reading program; table-top instruction (or non-computer-based intervention) and computer-assisted instruction (Nally et al., 2020) and showed greater gains in oral and written emergent literacy skills in the table-top instruction group. The authors posited that immediate/real-time teacher feedback during the table-top condition and difficulties in generalizing material presented on a computer to paper format could have accounted for these outcomes (Nally et al., 2020). However, despite greater gains in emergent literacy skills in the table-top instruction condition, results from a social validity questionnaire revealed that teachers showed a preference for the computer-assisted instruction modality (Nally et al., 2020). It would thus be important to further compare the advantages and disadvantages of computer-assisted vs. person conducted instruction.

Knowledge Gaps

This review demonstrates that studies investigating the efficacy of interventions targeting the development of emergent literacy skills (i.e., oral = metaphonological and written = word recognition skills) of children on the autism spectrum are limited. At this time, the state of the literature on the topic remains preliminary and thus inadequate to provide evidence-based instructional practices for teaching emergent literary skills to autistic children. Consequently, the following three recommendations are suggested for future studies: 1) to provide detailed participant characterization, 2) to clearly define the use of emergent literacy terms, and 3) to increase rigor of study designs. Recommendation are elaborated in the sections below.

1) Participant Characterization

A primary limitation among the studies included in this review is the lack of participant characterization. The clinical heterogeneity of autism profiles can present as diversity in adaptive, cognitive, and language abilities among others, making it that no two people on the autism spectrum present with the same manifestation of symptoms (APA, 2013; Masi et al., 2017). Therefore, it is important for research to clearly characterize participants using standardized descriptive measures. Ten studies included two or fewer descriptive measures for participants, providing some insight as to how the diverse support needs of children on the autism spectrum impact response to intervention. However, only three studies in this review assessed and validated the autism characteristics of participants using rating scales (i.e., CARS and GARS-2) and a screener (i.e., SRS), putting into question the validity of reported autism diagnoses. Nine studies did not report or include any information regarding co-occurring conditions in their samples. Of the studies who did, analyses did not account for co-occurring conditions as a possible confounding variable. Epidemiological studies suggest that co-occurring conditions are common for people on the autism spectrum, with estimations reported as high as 70% of participants having at least one other psychiatric disorder (e.g., Bookman-Frazee et al., 2018; Ibrahim, 2020; Leyfer et al., 2006; Simonoff et al., 2008). Given that heterogeneity is a hallmark of autism, is it important for co-occurring disorders to be considered in intervention research.

Based on the characterization of participants that was provided across studies included in this review, it appears that children on the autism spectrum with various support needs can benefit from both computer-based and non-computer-based interventions. For instance, the reported autism characteristics of participants ranged from mild to severe, cognitive and language skills ranged from extremely low to average, and adaptive skills ranged from extremely low to low. Reported co-occurring conditions of participants included ADHD, IDD, and language impairments. Notably, no studies reported the presence of a specific learning disorder (e.g., in reading and writing). Upon further examination of results, it seems that participant characteristics could have an effect on intervention outcomes. For example, the only two participants showing no gains in phonological awareness following intervention in the study conducted by Heimann et al. (1993) presented with severe and moderate IDD, while the five other participants showing gains in phonological awareness during intervention and at follow-up presented with cognitive profiles in the low to average range (Heimann et al., 1993). Further, Tjus et al. (1998) found greater improvements in phonological awareness scores with participants who had higher language levels (> 6 years; CPM; Raven et al., 1984) and mental age scores (≥50th percentile; Reynell Developmental Language Scales; Reynell, 1977). Based on qualitative observations, other studies also hypothesized that the mental age of participants could be an important predictor of emergent literacy skills (Heimann et al., 1993, 1995; Kimhi et al., 2018), such that participants with higher mental age scores showed greater progress in emergent literacy skills post-intervention. Therefore, higher developmental level may lead to greater response to intervention. Alternatively, children with lower developmental level may require more intensive intervention for change to occur.

Contrasting findings were presented by two studies showing that baseline/pre-intervention emergent literacy scores positively (Kamps et al., 2016) and negatively (Hudson et al., 2017) predicted gains in emergent literacy skills. Curiously, the participant characteristics of both studies were similar and included children on the autism spectrum with functional verbal communication skills (a minimum of 2-to-3-word phrases or requests), a mean standard score of 81.1 (Kamps et al., 2016) and 81 (Husdon et al., 2017) on the Peabody Picture Vocabulary Test – 4 (PPVT-4; Dunn & Dunn, 2007), and mild autism characteristics. Hudson et al. (2017) indicated that it was unexpected that children with lower emergent literacy skills pre-intervention demonstrated greater gains during the intervention and that they would examine this finding further in future studies.

2) Conceptualization of Emergent Literacy Skills

The variable use of terms in the literature to describe emergent literacy skills is due to multiple factors including the discrepancy among linguistic training across disciplines and the shift of phonological and emergent literacy constructs over time (Scarborough & Brady, 2002). The inconsistent use of terminology causes confusion for practitioners and researchers, hindering communication between professionals in this area (Scarborough & Brady, 2002; Schuele & Boudreau, 2008). Many authors neglect to provide clear definitions of terms, which can lead to errors in interpretation by readers (Scarborough & Brady, 2002). In this review, only four studies (26%) provided precise definitions of their emergent literacy terms in the introduction of the article, and the definition of terminology could be deciphered from the description of the emergent literacy tasks of four other studies. In addition, tasks assessing phonological awareness should exclusively contain oral stimuli and not contain print because phonological awareness involves the manipulation and analysis of sound structures of spoken language (Scarborough & Brady, 2002; Schuele & Boudreau, 2008). However, some measures relying on written language are presented as assessing phonological awareness instead of emergent literacy skills more broadly. For example, the Reading and Writing Analysis Test (TALE; Toro & Cervera, 1991) was used by one study (Basil & Reyes, 2003) to assess the reading of letters, syllables, and words. Although the tasks making up the TALE involve written components of language, the authors describe the TALE as a phonological awareness measure. Likewise, a task using print for understanding grapheme-phoneme relations is labelled as a phonological awareness task in another study (Kimhi et al., 2018). Unclear and imprecise use of emergent literacy terms may lead to inaccurate conclusions and misinterpretation of study results. However, despite these studies not directly assessing phonological awareness, other studies included in this review did find improvements in phonological awareness skills post-intervention.

3) Experimental Design

Sample size is also often a conundrum in intervention research. Horner et al. (2005) proposed a set of standards for evidence-based practice that includes sample size (i.e., at least five studies with a minimum of 20 participants) and methodological design (i.e., studies must have a documented experimental control) criteria. The largest sample sizes of the studies reviewed included 62 and 133 participants. The majority of studies had small sample sizes ranging from one to 23 participants, with seven studies including five participants or fewer. The small sample sizes of included studies could be attributed to the challenges in conducting research with children on the autism spectrum (e.g., recruitment, attrition), particularly when it comes to implementing intervention studies. Nevertheless, further research and replication studies are needed to establish evidence-based practices for teaching emergent literacy skills to children on the autism spectrum.

Of the 16 studies, only four included a control/waitlist comparison group in their study design and found greater gains in the experimental condition compared to the waitlist condition (apart from one study with no significant increase in skills post-intervention), while three studies examined gains in emergent literacy skills by comparing two interventions (e.g., Hudson et al., 2017). Although increases in emergent literacy skills were noted in both interventions across the three studies, each study did identify one intervention in their design that led to greater increases in emergent literacy skills. Further, only seven of the 16 studies included a follow-up assessment to measure whether gains in emergent literacy skills were maintained following the intervention. The inclusion of a waitlist comparison group and of a follow-up assessment when investigating intervention outcomes is necessary to increase methodological rigor. Furthermore, a wide variety of standardized as well as non-standardized outcome measures were present in this review, which limits the ability to compare the impact of interventions across studies. In light of this, findings are limited in generalizability and replicability is needed using consistent and standardized outcome measures.

Future Directions

Although this scoping review is an important first step in summarizing the literature on interventions targeting the oral and written emergent literacy skills of children on the autism spectrum, it is not without limitations. This review process did not account for publication bias, and therefore only reported on peer-reviewed studies that found significant gains in emergent literacy skills post-intervention (apart from one study that showed non-significant findings). Future reviews should consider including gray literature (e.g., non-peer reviewed, dissertations) in order to present a wider representation of the results in this area of research.

Prospective studies should consider examining the efficacy of interventions targeting oral and written emergent literacy skills while comparing different modalities (e.g., computer-based vs. non-computer-based). Considerations for future research also include providing detailed participant characterization, diagnostic validation, and focus on replicating existing studies. Notably, the scoping review did not yield studies assessing the efficacy of leading programs such as Lindamood-Bell Learning Processes (Bell, 1986; Lindamood et al., 1997; Sadoski & Willson, 2006) or the Wilson Reading System (Stebbins et al., 2012; Wilson, 1988), commonly used for children with learning disorders and in the general population. Assessing whether these programs or adaptations of these programs can lead to gains in emergent literacy skills for children on the autism spectrum would be a worthy endeavor. Interventions included in this review mostly reflected general education curriculum (e.g., Kimhi et al., 2017; Nally et al., 2020) or consisted of reading interventions developed for children with various disabilities but adapted for children on the autism spectrum (e.g., Basil & Reyes, 2003; Tjus et al., 1998), and were not specifically developed for autistic children. Preliminary evidence showing that gains in emergent literacy skills is possible for autistic children following general reading interventions is promising, as these interventions are most accessible in schools. Yet, given that adaptations to interventions (e.g., tutor sitting with child, use of visual aids and language support, sign language) based on the child's personal support needs were necessary across studies, future studies should explore alternative types of interventions that adopt a strength-based approach to target the emergent literacy skills of children on the autism spectrum.

The studies included in the current scoping review did not address the incidence of hyperlexia, a special strength in word decoding and recognition alongside difficulties with reading comprehension skills and verbal abilities (Silberberg & Silberberg, 1967), which is estimated to occur among 6-20% of autistic children (Ostrolenk et al., 2017). Children on the autism spectrum with hyperlexia seem to rely on a non-phonological alternative approach when learning to read (Macdonald et al., 2020). As such, they may not benefit from phonological awareness interventions. In fact, following a 6-week intervention period based on a whole-word reading approach, preschool children on the autism spectrum with hyperlexia showed significant gains in reading comprehension that were not observed for typically developing preschool children (Macdonald et al., 2021).

Implications for Practice

An important preliminary finding from this review is that children on the autism spectrum with a wide range of support needs and developmental levels can benefit from interventions targeting the development of both oral and written emergent literacy skills. Implementing computer-based or non-computer-based interventions can lead to improvements in emergent literacy skills regardless of the cognitive, adaptive, and language profiles of the child. Results also suggest that children on the autism spectrum presenting with higher developmental levels may show a slightly greater response to intervention compared to those with lower developmental levels. As such, educators and practitioners are encouraged to set individualized goals for their students and make adaptations to standard intervention/teaching practices in order to accommodate students on the autism spectrum with a broad spectrum of support needs and developmental levels. Moreover, the majority of studies implemented interventions in a school setting, supporting the use of intervention programs within a school curriculum. Results also suggest that small-group delivery format, as well as one-to-one instruction, can lead to gains in emergent literacy skills. Accordingly, findings support the implementation of emergent literacy interventions in group formats, which may be particularly favorable when resources are limited. Group formats also hold the potential to provide secondary benefits by introducing a social component to the intervention.

Conclusion

The development of fundamental emergent literacy skills is critical given the emphasis society places on the use of literacy in academic and daily life (Browder et al., 2009). Children on the autism spectrum experience challenges associated with phonological development (see Westerveld et al., 2016 for a review). Thus, it is important to gain knowledge concerning the literature on intervention programs aimed at promoting oral and written emergent literacy skills for children on the autism spectrum. Results of this scoping review highlight that interventions targeting the development of emergent literacy skills can be divided into two main categories, namely computer-based interventions and non-computer-based interventions. Findings from the current review provide preliminary evidence that children on the autism spectrum with a wide range of support needs and developmental profiles can benefit from both computer-based and non-computer-based interventions targeting oral and written emergent literacy skills. However, results should be interpreted with caution given the identified limitations in inadequate characterization of participants, variable and interchangeable use of emergent literacy terms and measures, and the lack of waitlist comparison groups and follow-up assessments in methodological designs within the studies included in this review. Further large-scale replication studies are needed in order to inform evidence-based practice with the goal to close the gap between research and practice in autism education.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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Appendices

Table 1.

Inclusion/Exclusion Criteria Used in Screening Articles

Criteria	Inclusion	Exclusion
Population	Sample must include at least one participant on the autism spectrum with a diagnosis of an autism spectrum disorder (using DSM-5/ICD-10 criteria or previous) confirmed with ASD diagnostic instruments (e.g., ADOS, ADI-R; reported scores not required), or professional clinical judgment (e.g., physician, psychologist), or identified as having ASD by their school district and receiving services for ASD through (e.g., an IEP) Analyses/results must be presented separately for participants on the autism spectrum and not included within a mixed sample analysis Participants 15 years of age and younger No sex restriction	Participants with autistic traits (without supporting evidence) Participant age range exceeds 15 years of age
Study Design	Randomized controlled design or quasi-experimental design with or without a comparison group/waitlist control group (no specific inclusion criteria of comparison group necessary). Single-subject designs	Systematic reviews, scoping reviews, and meta-analyses Case studies
Methodological Approach	Quantitative design and data analysis	Qualitative design and data analysis
Intervention/Training Program	Intervention/training program clearly described	No reported intervention/training program or instructional practice Instruction limited to sight words
Descriptive Measure	A minimum of one reported objective standardized measure for participant characterization/description (e.g., autism characteristics, language skills, adaptive skills, cognitive skills, etc.)	No reported objective standardized measure for participant characterization/description
Outcome measure of emergent literacy skills of interest	Pre to post-intervention outcome measure of either and/or both of the following emergent literacy concepts: 1) oral language: metalinguistic awareness of phonological concepts (e.g., phonological/phonemic awareness, code-related skills), or 2) written language: phonological aspects of word recognition (e.g., phonics, alphabetic principle, decoding, phoneme-grapheme correspondence) *Term definitions obtained via Scarborough & Brady (2002)*	No clearly reported outcome measure for emergent literacy skills Outcome measure of speech production/phonology Outcome measure of another oral language linguistic domain (e.g., vocabulary, semantics, pragmatics) Outcome measure of spelling Outcome measure of oral reading fluency
Publication type/date	Peer-reviewed published scientific journal articles, accessible online, published in English No publication date restriction	Conference proceedings, theses/dissertations, books, reports Published in a language other than English

Table 2.

Summary of Studies Included in the Scoping Review

Author (Year), *Design*	Participants	Chronological Age Mean, (SD), range	Descriptive Measure	Intervention/Training Program	EL Measure and Scores	Relevant PS Findings for Participants on the autism spectrum
Arciuli et al. (2019) *Pre to post-intervention*	*N* ASD=23 (23 male)	Intervention group (*N* = 11): 88.18 months, 70-97 Comparison group (*N* = 12):88.75 months, 73-101	VABS-2; PPVT-4; CTOPP-2	ABRACADABRA instruction (web application): game-based early literacy learning activities. 9 weeks. Two sessions a week. LTS=75-90	1) Intervention group WRAT-4 PRE=22.09 (6.52), 15-34; POST=25.18 (7.20), 16-38 2) Comparison group WRAT-4 PRE=19.58 (9.01), 1-37; POST=20.17 (8.64), 2-36	1) sig. main effect of time in word-level reading accuracy** 2) n.s. main effect of group 3) sig. time x group interaction**, large effect size 4) ↑ in word reading accuracy sig. ↑ for intervention group**
Bailey et al. (2017) *Pre to post-intervention*	*N* ASD=20 (18 male)	Intervention group (*N* = 11): 87.18 months (18.65) Comparison group (*N* = 9): 90.22 months (19.72)	VABS-2; PPVT-4; CTOPP-2	ABRACADABRA instruction (web application): game-based early literacy learning activities. 13 weeks. Two sessions a week. LTS=60	1) Intervention group WRAT-4 PRE=25.82 (10.80), 8-43; POST=28.64 (10.21), 13-43 2) Comparison group WRAT-4 PRE=25.33 (12.29), 8-45; POST=24.89 (12.24), 7-47	1) sig. time x group interaction on word- level reading accuracy* with large effect size 2) ↑ pre to post-intervention for intervention group 3) ↓ pre to post-intervention for control group
Basil et al. (2003) *Pre to post-intervention*	*N* ASD=2 (1 male)	11 years, 8-14	BDI; CMMS; PPVT	Delta Messages: multimedia program used for teaching literacy skills. 3 months. Two sessions a week. NTS=24 LTS=30	1) TALE PPT1 Letter errors: T1=14 ; T4=7 Syllable errors: T1=17; T4=13 Word errors: T1=34; T4=21 2) TALE PPT2 could not be assessed	one participant showed gains in PS pre to post-intervention

Beecher et al. (2012) *Multiple baseline*	*N* ASD=2 (2 male)	8.5 years, 7-10	PPVT-III; TOLD (Primary 3 and Intermediate 3)	Individual and sample group comprehensive reading instruction combining PCI Reading Program with literacy and language activities. NTS= approx. 30 LTS=55	1) PPT1 WRMT-R letter knowledge PRE=10 upper, 11 lowercase; POST=25 upper, 25 lowercase; WRMT-R letter-sound knowledge PRE=3; POST=20; Sight word knowledge PRE=3/40, POST=26/40 2) PPT2 WRMT-R letter knowledge PRE=10 upper, 7 lowercase; POST=24 upper, 24 lowercase; WRMT-R letter-sound knowledge PRE=0; POST=22; Sight word knowledge PRE=1/40; POST=36/40	letter, letter-sound, and sight word knowledge ↑ for both participants pre to post-intervention
Flores et al. (2004) *Multiple probe*	*N* ASD=1 (1 male)	7 years	IQ: Differential Abilities Scales; VABS	Adapted Direct Instructions Program taken from: Corrective Reading Word Attack Basics, Decoding A. Three times a week. NTS=NR LTS=NR	Individual letter-sound identification and blending accuracy PRE=0%; POST=100%; FU=87.5%	1) participant mastered letter-sound identification, sound blending, and decoding skills 2) generalization of letter-sound correspondence to untaught words
Grindle et al. (2013) *Pre to post-intervention*	*N* ASD=4 (3 male)	5.25 years, 4-6	SBIS-4; VABS	MimioSprout Early Reading Instruction: internet-based reading instruction. 14 weeks. NTS=80 LTS=15-20	1) PPT1 DIBELS Initial sound: PRE=1; T3=26 Phoneme segmentation PRE=0; T3=13 Letter naming: PRE=20; T3=40 Nonsense words: PRE=6; T3=19 WRAPS PRE=8; T3=48 2) PPT2 DIBELS Initial sound: PRE=9; T2=28 Phoneme segmentation PRE=0; T2=47 Letter naming: PRE=0; T2=21 Nonsense words: PRE=6; T2=25 WRAPS PRE=14; T2=50 3) PPT3 DIBELS Initial sound: PRE=9; T3=31 Phoneme segmentation PRE=12; T3=24 Letter naming: PRE=2; T3=0 Nonsense words: PRE=6; T3=25 WRAPS PRE=28; T3=47 4) PPT4 DIBELS Initial sound: PRE=28; T3=51 Phoneme segmentation PRE=7; T3=23 Letter naming: PRE=3; T3=50 Nonsense words: PRE=23; T3=48 WRAPS PRE=50; T3=50	1) ↑ in word recognition for 3 participants (one participant scoring at ceiling) 2) general trend of skill ↑ on the DIBELS 3) gains in word recognition maintained for two participants at FU

Heimann et al. (1993) *Pre to post-intervention with follow-up*	*N* ASD=7 (6 male)	7.8-13.8 years	CPM	The microcomputer Alpha Program (translated to Swedish). Language learning through multichannel feedback (i.e., voice, animation, video, sign language). 14 weeks. LTS=38-40	1) PPT1 SIPA: no progress 2) PPT2 SIPA: no progress 3) PPT3 SIPA PRE= approx. 20%; POST= approx. 60%; PU= approx.50% 4) PPT4 SIPA PRE= approx. 50% ; POST= approx. 80% ; FU= approx. 80% 5) PPT5 SIPA PRE=0%, POST=4% ; FU=0% 6) PPT6 SIPA PRE=0%, POST=0% ; FU=16% 7) PPT7 SIPA PRE=0%, POST=28% ; FU=16%	1) ↑ in PA for 4 children 2) two children did not show any progress 3) one child displayed a mixed pattern of results, difficult to interpret
Heimann et al. (1995) *Pre to post-intervention with follow-up*	*N* ASD=11 (9 male) *N*=9 Mixed diagnoses *N*=10 TD	9.4 years (2.4), 6.9-13.8	CPM; RDLS; CARS	The microcomputer Alpha Program (translated to Swedish). Language learning through multichannel feedback (i.e., voice, animation, video). Training sessions over 3-4 months ASD NTS=25.6 (7.5); LTS=32 (12.4)	SIPA PRE=.19 (.3); POST=.35 (.4); FU=.24 (.3)	1) sig. ↑ mean scores on PA measures from pre to post-intervention* 2) ↓ in PA score from post-intervention to follow up
Hudson et al. (2017) *Randomized control trial*	*N* ASD = 133 (108 male) Conditions: *n*IBR=47 *n*PAT=42 *n*BAU=44	55.7 months (4.2), 39-69	GARS-2	IBR: Book reading adapted from the Dialogic Reading procedures. Approx. 6 months. IBR NTS=60 (10.57); LTS=7-15 PAT: Lessons consist of a song with a PA element, beginning at the word level and progressing through to the phoneme level. PAT NTS=52 (15.82); LTS=7-15	1) IBR TOPEL PA PRE=75.21 (15.33); POST=83.23 (15.85) TOPEL Print knowledge PRE=103.09 (14.74); POST=105.17 (11.88) WR PRE=109.31 (17.97); POST=109.08 (12.26) 2) PAT TOPEL PA PRE=79.21 (15.22); POST=91.74 (22.65) TOPEL Print knowledge PRE=102.73 (15.57) ; POST=103.64 (15.30) WR PRE=110.55 (16.82) ; POST=112.64 (20.10) 3) BAU TOPEL PA PRE=77.88 (18.94); POST=82.11 (17.96) TOPEL Print knowledge PRE=106.14 (13.92) ; POST=105.36 (10.15) WR PRE=112.30 (17.52) ; POST=114.16 (20.85)	1) whole sample growth (model 1): all children in study ↑ in gains in PA**, no significant gains in PK or WR 2) effect of interventions (model 2): PAT effect on PA score** ↑ 3) pretest negatively predicted gains 4) controlling for treatment-related classroom literacy activities (model 3): PAT effect on PA score** ↑ remains

Johnston et al. (2009) *Within subject alternating treatment*	*N* ASD=2 (2 male)	4-5 years	LAP-R	Comparison of fixed vs. gradual array to teach letter-sound correspondence. NTS= approx. 5-13 LTS=10	Identification of letter sounds: 1) PPT1 Baseline=0%; Maintenance=87% 2) PPT 2 Baseline=0-20%; Maintenance=96%	1) fixed array effective at reaching established criterion 2) not possible to draw conclusions regarding effectiveness of gradual array
Joseph (2018) *Multiple baseline*	*N* ASD=3 (2 male)	7.33 years (0.58), 7-8	DIBELS	Word box method: placing letters into drawn boxes as each sound of the word is articulated. NTS= approx. 35 LTS= 30	1)PPT1 PSW PRE=0 (0), 0-0; POST=35.9 (26.5), 0-63 WRP PRE=4.1 (2.0); POST=12.9 (2.5) 2)PPT2 PSW PRE=15 (0), 15-15; POST=35.3 (6.7), 35-48 WRP PRE=5.6 (1.7); POST=11.8 (2.8) 3)PPT3 PSW PRE=.25 (.5), 0-1; POST=44.2 (19.7), 0-63 WRP PRE=1.4 (1.4); POST=12 (3.9)	↑ in phoneme segmentation and word identification skills across all three participants
Kamps et al. (2016) *Quasi-experimental non-equivalent group*	*N* ASD=62 (53 males)	Intervention group (*N* = 32): 67.9 months (4.7), 62-80 Comparison group (*N* = 30): 68.9 months (5), 62-82	PPVT-4; SRS; VABS; CARS	The Reading Mastery Direct Instruction Curriculum in small groups with peers. NTS= approx. 169 LTS=30	1) Intervention Group: DIBELS Nonsense words: T1=7.66 (8.7); T6=47.97 (33.4) WRMT word identification: T1=6.66 (9.4); T3=34.67 (15.3); word attack: T1=1.59 (2.9); T3=12.43 (9.4) 2) Comparison group: DIBELS Nonsense words: T1=16.57 (15); T6=51.79 (36.4) WRMT word identification: T1=8.83 (11.16); T3=36.25 (18.8); word attack: T1=2.52 (4.2); T3=14.07(11.5)	1) sig. effect of time**, intervention*, and time x intervention* for nonsense word reading 2) ppts in intervention saw greater ↑ in nonsense word reading scores 3) sig. effect of time**, intervention*, and time x intervention* for word identification 4) ppts in intervention saw greater ↑ in word identification scores 5) n.s. group diff. on word attack, sig. effect of time**. All ppts regardless of group saw ↑ in word attack scores
Kimhi et al. (2018) *Pre to post-intervention*	*N* ASD=5 (4 male)	82.2 months (8.04), 69-88	PPVT-3	Levin's national reading curriculum to promote early literacy skills adapted to the ASD population including visual aids, language supports, and individualized modification of tasks. 6 weeks.	1)PPT1 PALS PRE=18 ; POST=22 DS PRE=22, POST=27 2)PPT2 PALS PRE=0 ; POST=0 DS PRE=22 ; POST= 27 3) PPT3 PALS PRE=0 ; POST=0 DS PRE=22 ; POST=27 4) PPT4 PALS PRE=8 ; POST=22 DS PRE=27 ; POST=27 5) PPT5 PALS PRE=0 ; POST=22 DS PRE=22 ; POST=27	1) sig. ↑ pre to post-intervention group difference for letter knowledge* 2) sig. ↑ pre to post-intervention group difference for grapheme-phoneme knowledge*

Nally et al. (2020) *Pre to post-intervention*	*N* ASD=31 (26 male)	Table-top instruction (TTI) condition (*N* = 16): 8.01 years (1.7) Computer assisted instruction (CAI) condition (*N* = 15): 9.08 years (4.1)	CELF-4; ABIQ	Edmark Reading Program (ERP): reading curriculum. TTI vs. CAI conditions. 10 weeks. NTS=50 LTS=10	1) TTI condition post-intervention: WIAT-II word reading 64.7 (1.43); non-word reading 68.2 (.76) DIBELS first sound fluency 5.75 (1.08); letter naming fluency 25.14 (1.01); phoneme segmentation 7.19 (1.73) NARA-II reading accuracy 77.07 (1.17) 2) CAI condition post-intervention: WIAT-II word reading 62.5 (1.66); non-word reading 67.24 (2.66) DIBELS first sound fluency 1.22 (1.26); letter naming fluency 22.90 (1.18); phoneme segmentation 3.93 (2.01) NARA-II reading accuracy 74.58 (1.37)	1) TTI scored ↑ on reading accuracy than CAI at post-intervention 2) TTI scored ↑ on first sound fluency subtest than CAI at post-intervention 3) n.s. difference in word/non word reading, letter naming fluency, and phoneme segmentation between groups at post-test
Tjus et al. (1998) *Pre to post-intervention with follow-up*	*N* ASD=13 (10 male)	9.8 years (2), 4.11-11.11	CPM; RDLS	Delta Messages (Swedish version): multimedia program used for teaching literacy skills. 13.5 weeks. NTS=15 LTS=15-30	SIPA PRE=-0.8 (7.3); POST=4.6 (6.1); FU=5.1 (6.4)	1) sig. ↑ mean scores on PA measures from pre to post-intervention* and at FU* 2) ↑ improvements in PPTS with language level of >6 3) ↑ improvements in PPTS with mental age >50th %
Uccheddu et al. (2019) *Pre to post-intervention*	*N* ASD=9 (7 male)	Intervention group (*N* = 5): 6-11 Comparison group (*N* = 4): 6-10	WISC-IV; VABS	Reading program with a dog. NTS=10 LTS= approx. 30	1) Intervention group: recognition T0=30; T1=26.6; phonemic T0=35; T1=35; segmentation T0=37.5; T1=35; deletion T0=21.2 ; T1=35 2) Comparison group: recognition T0=30; T1=50; phonemic T0=50; T1=50; segmentation T0=27.5; T1=30; deletion T0=27.5 ; T1=50	n.s. difference in metaphonological competence pre to post-intervention between or within groups

Note: Age, Behavioural Measure Scores, and intervention columns indicate mean (standard deviation), and range, if available
Abbreviations: ABIQ= Abbreviated Battery Intelligence Quotient; ASD=autism spectrum disorder; BAU=no treatment business-as-usual condition; BDI=Battelle Development Inventory; CARS=Childhood Autism Rating Scale; CELF=Clinical Evaluation of Language Fundamentals – Preschool; CMMS=Columbia Mental Maturity Scale; CPM=Raven's Coloured Progressive Matrices; CROWD= completion, recall, open-ended, wh-questions, and distancing prompts; CTOPP=Comprehensive Test of Phonological Processing; DIBELS=Dynamic Indicators of Basic Early Literacy Skills; DS=decoding skills; EL=emergent literacy; FU=follow-up assessment score; GARS= Gilliam Autism Rating Scale; IBR=interactive book reading treatment condition; KBIT=Kaufman Brief Intelligence Test; LAP-R=Learning Accomplishment Profile – Revised; LTS=lengths of training sessions in minutes; NARA= Neale Analysis of Reading Ability; NR= not reported; n.s.=not significant; NTS=number of training sessions; PA=phonological awareness; PALS=phonological awareness literacy screening; PAT=phonological awareness treatment condition; PEER=prompt, evaluate, expand, and repeat prompts; POST=post-intervention program score; PPT=participant; PPVT=Peabody Picture Vocabulary Test; PRE=pre-intervention program score; PSW=phoneme segmentation words; RDLS=Reynell Developmental Language Scales; SBIS=Stanford Binet Intelligence Scale; SIPA=Swedish Instrument of Phonological Awareness; SRS=Social Responsiveness Scale; T=time; TALE=Reading and Writing Analysis Test; TD=typically developing; TOLD=Test of Language Development; TOPEL= phonological awareness subtest of the Test of Preschool Early Literacy; VABS-2=Vineland Adaptive Behaviour Scales; WIAT= Wechsler Individual Achievement Test; WISC=Wechsler Intelligence Scale for Children; WR=word reading as measured by the Woodcock-Johnson III Tests of Achievement letter-word identification subtest; WRAPS= Word Recognition and Phonics Skills Test; WRAT=Wide Range Achievement Test; WRMT=The Woodcock Reading Mastery Test; WRP=word recognition performance
Symbols: ↑=increase/greater; ↓=less/reduced; *Statistically significant gains pre to post-intervention program reported at p < .05; **Statistically significant gains pre to post-intervention program reported at p < .01.

Table 3.

Emergent Literacy Skill Outcome Measures Used in Included Studies

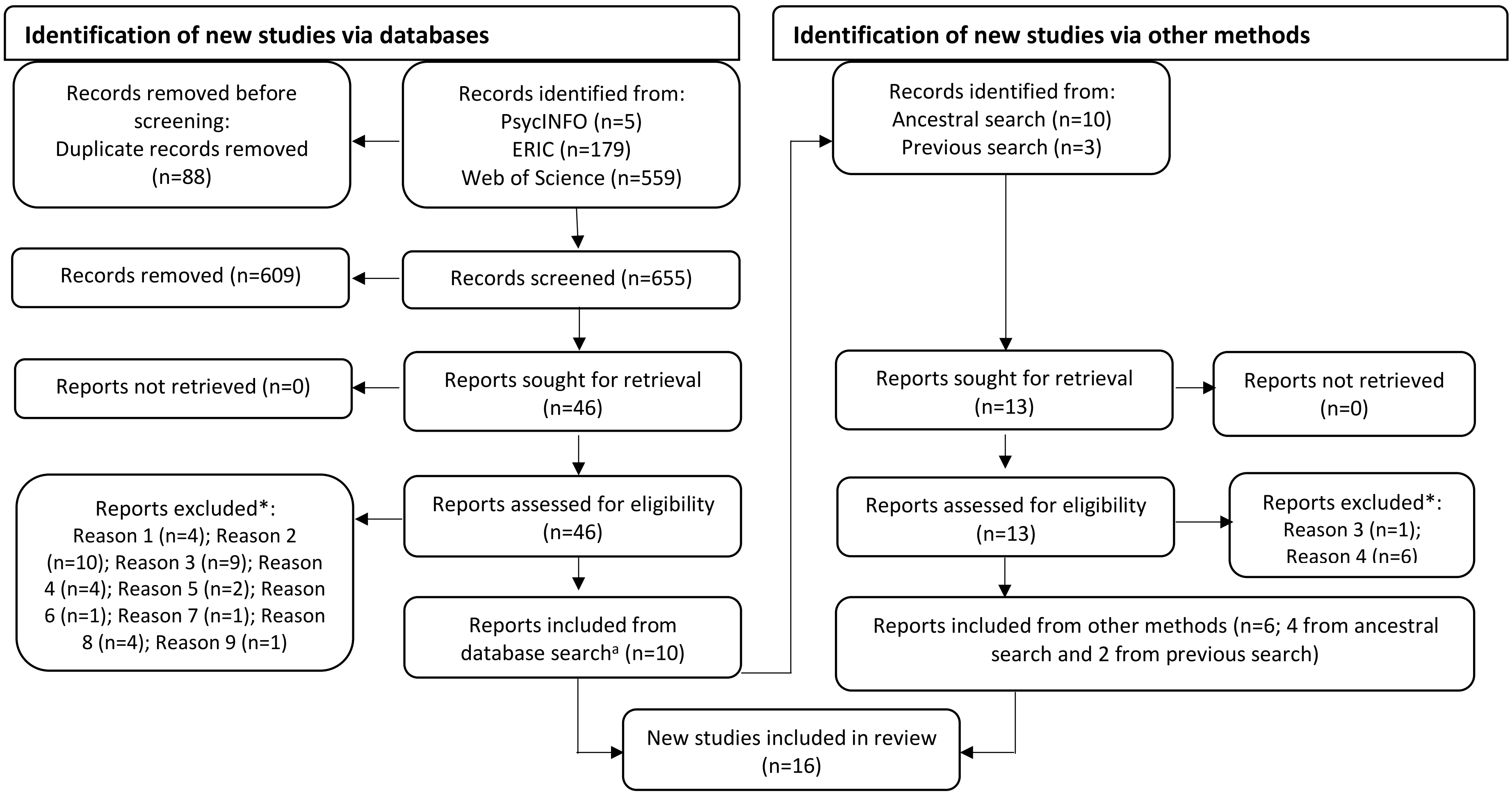
Task/Measure	Skills of Interest	Study
Oral Language: Metaphonological Skills		
Swedish Instrument of Phonological Awareness	Sound synthesis and segmentation	Heimann et al. (1993), (1995); Tjus et al. (1998)
MCF	Recognition, fluidity, phonemes, segmentation, and letter deletion	Uccheddu et al. (2019)
DIBELS Initial Sound Fluency and Phonemic Segmentation subtests	Metaphonological skills	Grindle et al. (2013); Nally et al. (2020)
TOPEL	Elision and blending	Hudson et al. (2017)
Words presented orally and students asked to say sounds in the words within 20 seconds	Phoneme segmentation	Joseph (2018)
Written Language: Word Recognition Skills		
WRAT-4	Letter naming and word decoding	Arciuli & Bailey (2019); Bailey et al. (2017)
TALE	Reading of letters, syllables, and words	Basil & Reyes (2003)
WRMT-R	Letter identification and letter-sound knowledge	Beecher & Childre (2012)
PCI Reading Program	Sight word knowledge	Beecher & Childre (2012)
Probes to assess letter-sound correspondence	Letter-sound identification, discrimination, blending, and decoding	Flores et al. (2004); Johnston et al. (2009)
WRMT-III	Word recognition and decoding	Kamps et al. (2016)
DIBELS Nonsense Word Fluency subtest	Letter-sound correspondence	Kamps et al. (2016); Grindle et al. (2013)
Alphabet ruler embedded with consecutive alphabet letters	Decoding skills and letter-sound correspondence	Kimhi et al. (2018)
WRAPS	Word recognition	Grindle et al. (2013)
WJIII	Word reading	Hudson et al. (2017)

WIAT-II	Word reading and decoding	Nally et al. (2020)
Words presented on index cards and participants asked to read the word within 2 seconds	Word recognition	Joseph (2018)

Note. DIBELS= Dynamic Indicators of Basic Early Literacy Skills; MCF= The Metaphonological Competence Test (Marotta et al., 2008); PCI Reading Program (PCI, 2007); Swedish standardized instrument of phonological awareness (Tornéus et al., 1984); TALE= The Reading and Writing Analysis Test (Toro & Cervera, 1991); TOPEL= The Test of Preschool Early Literacy, Phonological Awareness and Print Knowledge subtests (Lonigan et al., 2007); WIAT-II= Wechsler Individual Achievement Test – second edition, Word reading and Pseudoword Decoding subtests; WJIII= The Woodcock-Johnson III Tests of Achievement, Letter-Word Identification subtest (Woodcock et al., 2001); WRAPS= The Word Recognition and Phonics Skills Test (Carver & Moseley, 1994); WRAT-4= The Word Reading subtest of the Wide Range achievement Test – fourth edition (Wilkinson & Robertson, 2006); WRMT-III= The Word Identification and Word Attack subtests of the Woodcock Reading Mastery Test – third edition (Woodcock et al., 2001); WRMT-R= The Supplementary Letter Checklist of the Woodcock Reading Mastery Test – revised (Woodcock, 1998).

Figure 1

Study Retrieval and Selection Process as Adapted from the PRISMA Guidelines (Page et al., 2020)



Note. *Reasons for exclusion: participant sample includes a mix of diagnoses or statistical analyses are not presented separately for autism (Reason 1); emergent literacy skills of interest not used as an outcome measure (Reason 2); sample does not include any participants on the autism spectrum (Reason 3); study does not include a standardized characterization measure of participants (Reason 4); studies providing only sight word instruction (Reason 5); not an intervention study (Reason 6); qualitative research design (Reason 7); not a peer-reviewed empirical study (Reason 8); participants above age restriction (Reason 9).
[a]An ancestral search of reference lists was conducted of the 10 studies included from the database search, where 10 additional studies were identified for review.

Bridge Between Manuscripts – Chapter 3 and Chapter 4

The scoping review presented in Chapter 3 aimed to summarize the extent of the literature on interventions targeting important oral and written emergent literacy skills of children on the autism spectrum, to summarize the characteristics of the participants included in emergent literacy interventions, and to highlight knowledge gaps and limitations in emergent literacy intervention research with autism. Results from the scoping review provided preliminary evidence that children on the autism spectrum with heterogeneous developmental profiles can benefit from computer-based and non-computer-based interventions targeting emergent literacy skills. Yet, the scoping review revealed important knowledge gaps in the literature on emergent literacy and autism including insufficient characterization of participants, inconsistent use of emergent literacy terms and measures, and flaws in methodological design. As such, findings from the literature review informed the methodology of Manuscript 2.

The scoping review revealed that a substantial limitation within the field of emergent literacy and autism is insufficient characterization of participants included in the studies, which limits the potential insight that could be gained in terms of the effect of individual characteristics on response to intervention. More specifically, only a small percentage of studies validated the autism characteristics of participants, putting into question the validity of autism diagnoses and consequently the conclusions that can be drawn from the results. Based on this important limitation, Manuscript 2 (Chapter 4) validates the autism characteristics of all participants included in the study through standardized measures and parental screening questionnaires such as the Social Responsiveness Scale - 2 (SRS-2; Constantino & Gruber, 2012), the Autism-Spectrum Quotient screener questionnaire (AQ; Baron-Cohen et al., 2001), or through the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2; Lord et al., 2012).

Another important knowledge gap identified through the scoping review was the inconsistent and vague use of emergent literacy terminology within the field as well as, among some studies, the incongruity between the emergent literacy skill of interest and the tasks used to measure this skill. In order to elucidate the interpretation of research, Manuscript 2 provides a clear operational definition of the emergent literacy skill of interest, phonological awareness, in the introduction. In addition, Manuscript 2 carefully considered the task used to measure phonological awareness by taking into account the heterogeneity of cognitive, receptive and expressive language profiles of children on the autism spectrum. The NEPSY-II (Korman et al., 2007) Phonological Processing subtest was chosen as it contains non-verbal and verbal items which makes it a useful measure for children with a wide range of abilities by minimizing the participant's use of expressive language. Further, the NEPSY-II (Korman et al., 2007) is standardized with clinical subgroups and recommended for children with exceptionalities including autism (Brooks et al., 2009).

Finally, the scoping review also revealed an overall weakness in methodological rigor in the field of emergent literacy and autism. For instance, studies placed limited emphasis on potential predictors that could have an effect on emergent literacy skills development of children on the autism spectrum. Select studies included in the review hypothesized that mental age could play an important role in emergent literacy development for autistic children. Previous investigations of phonological awareness in preschool and school age children on the autism spectrum showed comparable phonological awareness skills to non-autistic children when accounting for language (Dynia et al., 2014; Westerveld et al., 2020) and non-verbal cognitive ability (Westerveld et al., 2020). Thus, Manuscript 2 includes non-autistic school-aged children as a comparison group matched on chronological age, verbal and non-verbal/perceptual reasoning cognitive skills in order to account for possible confounding variables which could significantly impact results. Based on these findings, the overall aim of Manuscript 2 was to gain a greater understanding of phonological awareness development of children on the autism spectrum. Specifically, Manuscript 2 investigated the phonological awareness skills of school age autistic children compared to non-autistic children and explored the role of cognitive skills and autism characteristics on phonological awareness abilities, as outlined in Chapter 4. Chapter 4 places particular emphasis on characterizing and validating the autism diagnoses of the children included in the study through diverse standardized measures and screening questionnaires and ensuring that heterogeneous cognitive profiles and autistic traits are represented.

Chapter 4: Manuscript 2

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Phonological awareness skills of school age autistic children and the role of perceptual reasoning skills

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Abstract

This study aimed to investigate the phonological awareness (PA) skills of school age autistic children (age range = 6–12) in two parts: 1) comparing their performance on a PA task to non-autistic children with groups matched on chronological age, verbal and non-verbal cognitive skills, and 2) exploring the role of cognitive skills and autism characteristics on PA skills. Results revealed that the groups did not differ in their PA skills (study 1) and that perceptual reasoning skills are associated with the PA skills of autistic participants (study 2). Results highlight the role of non-verbal cognitive skills in literacy development for autistic children and suggest that their perceptual reasoning abilities likely contribute a great deal when learning to read.

Keywords: phonological awareness, autism spectrum disorder, early literacy, perceptual reasoning skills

Phonological awareness skills of school age autistic children and the role of perceptual reasoning skills

Phonological awareness (PA) is a metalinguistic skill that represents the ability to analyse and manipulate the sound structures of spoken language (Hudson et al., 2017; Scarborough & Brady, 2002; Schuele & Boudreau, 2008). The manipulation and analysis of phonological sound structures of oral language can be conducted at several levels, namely at the syllable, subsyllabic (i.e., the division of syllables into onsets and rhymes), and phoneme (i.e., the smallest unit of speech, /k/, /a/, and /t/ in the word cat) levels (Moritz et al., 2013; Scarborough & Brady, 2002). Research shows that the typical development of PA skills follows a common pattern, beginning at an early age (e.g., syllable awareness develops around age 3) and growing in complexity throughout the late preschool (e.g., onset and rime awareness develop around age 4) and school age years (e.g., segmenting words into individual phonemes) (Goswami, 2002; Moritz et al., 2013; Scarborough & Brady, 2002). A child's understanding of the phonological structure of spoken words can be displayed and assessed in various ways. Scarborough and Brady (2002) describe detailed PA assessment methods (see Table 1).

Table 1

Examples of Phonological Awareness Assessment Methods as Described in Scarborough and Brady (2002)

PA Assessment Methods	Example
Rhyming	Which of these words rhymes with *cat*: *seal, hat, five*? *Hat*
Segmentation	Say a little bit of *snake*. /s/,
Categorization	*door…pan…duck…*Which one doesn't belong? *Pan*
Identity	Tell me the last sound in *fish. /sh/*

Synthesis/blending	*car…tune…*What do you get when you say them together? *Cartoon*
Manipulation	Say *winter* without the *ter* part. *Win*

Phonological awareness is considered one of the strongest emergent literacy predictors with a moderately strong correlation with word decoding (r = 0.40) (National Early Literacy Panel [NELP], 2008) in typical development (Blachman et al., 1999; Dynia et al., 2017), signifying that it is a necessary precursor essential to future reading success (Whitehurst & Lonigan, 1998). Reading is a crucial skill to acquire as it leads to enhanced future learning opportunities, academic achievement, adaptive skills, social skills, and occupational attainment (Nally et al., 2018; Westerveld et al., 2018). Thus, developing reading precursor skills, such as PA, is critical given the emphasis society places on the use of literacy in academics and daily life (Browder et al., 2009).

Numerous studies over the last four decades have established that PA plays a prominent role in reading development (Catts, 1989; Catts et al., 1999; Torgesen et al., 1994), consistently finding that difficulties with PA are one of the most distinguishing features that characterize children with a developmental reading disability (also known as dyslexia) (Stanovich, 1988; Stone & Brady, 1995; Wagner & Torgesen, 1987). More recently, research showed that deficits in PA were present in around 73% of a sample of 279 children with a reading disability (Morris et al., 2012) and in 69% of a sample of 218 children with a language impairment (Justice et al., 2015). Children with deficits in PA have difficulty manipulating the sound structure of words (Morris et al., 2012), therefore, they have trouble segmenting individual or groups of letters into phonemes and blending them to make words (Wagner & Torgesen, 1987). In turn, difficulties with PA can impact a child's ability to develop necessary reading skills (Layes et al., 2020).

Phonological Awareness Skills and Autism

The reading profiles of children who have received a diagnosis of autism spectrum disorder, a neurodevelopmental condition characterized by challenges in social communication/interaction and repetitive behaviours and restricted interests (American Psychiatric Association (APA), 2013), present with considerable variability across reading outcomes (e.g., Davidson & Ellis Weismer, 2014; Henderson et al., 2014; Nation et al. , 2006; Westerveld et al., 2018, 2016). For instance, it is estimated that between 6-20% of autistic children present with hyperlexia (Ostrolenk et al., 2017), which is described as a strength in word decoding and recognition alongside difficulties with reading comprehension skills and verbal abilities (Silberberg & Silberberg, 1967). Yet, some autistic children present with difficulties in decoding (Nation et al., 2006) and word reading abilities (Westerveld et al., 2018). Autistic children thus present with a variety of reading profiles.

Phonological Awareness Skills of Preschool Autistic Children

Phonological awareness skills are a significant predictor for reading achievement of preschool aged autistic children (Dynia et al., 2017). Autistic children may be particularly susceptible to impairments in PA skills as it has been suggested that PA skills develop through socially mediated learning (Davidson & Ellis Weismer, 2014; Dynia et al., 2019). Furthermore, there is a high prevalence of reading disorders co-occurring with autism (Ibrahim, 2020). Autistic children either demonstrate difficulties with PA (Dynia et al., 2019, 2017, 2014; Westerveld et al., 2016), typical PA (Macdonald et al., 2020), or a relative strength for PA (Fleury & Lease, 2018; Westerveld et al., 2020).

Preschool autistic children perform similarly to non-autistic children on PA tasks when groups are matched on language skills and non-verbal cognitive skills (Westerveld et al., 2020).

Although, a few studies show similar PA skills between preschool autistic and non-autistic children even when groups are not matched on verbal or non-verbal cognitive skills (Fleury & Lease, 2018; Macdonald et al., 2020). Preschool autistic children show challenges in PA skills compared to non-autistic children when groups are not matched on non-verbal cognitive skills (Dynia et al., 2019) and language skills (Dynia et al., 2019, 2017, 2014).

Overall, inconsistent findings among studies investigating the PA skills of preschool autistic children compared to non-autistic children appear to be the result of controlling for cognitive skills, such that there are few if any differences between groups matched for verbal and non-verbal cognitive skills.

Phonological Awareness Skills of School Age Autistic Children

There is a growing body of studies that have investigated PA in school age autistic children and found impairments in PA skills within this age group (Nally et al., 2018; Smith Gabig, 2010); although caution should be taken when interpreting these results given the absence of group matching on language and cognitive skills. Similar to findings from the preschool literature, school age autistic children showed lower performance on a PA task compared to non-autistic children when groups were not matched for cognitive or language skills (Smith Gabig, 2010). In addition, school age autistic children between the ages of 6-17 years old show difficulty in PA skills, with 67% of the sample obtaining floor level scores on the PA task (Nally et al. 2018).

The Role of Cognitive Skills and Autism Characteristics on the Phonological Awareness Skills of Autistic Children

Linguistic abilities are considered an important underpinning in reading development, as the association between verbal skills and literacy skills has been well documented in typical development (e.g., Catts et al., 1999; Cornwall, 1992; Macdonald et al., 2020; McArthur et al., 2000; Roth et al., 2002). However, this may not be the case for autistic children. Evidence of a common developmental pathway exists within the cognitive profile of autistic children, showing discrepantly higher non-verbal/perceptual skills compared to verbal skills (Ankenman et al., 2014; Charman et al., 2011; Courchesne et al., 2015; Joseph et al., 2002; Nader et al., 2015; Soulières et al., 2011). The marked strength for non-verbal/perceptual skills over verbal skills may be the results of the distinct cognitive styles of autistic persons. For instance, the Enhanced Perceptual Functioning model (EPF; Mottron et al., 2001, 2006, 2009) posits that autistic cognitive profiles can be characterized by superior representations of locally oriented and featural information and enhanced activation of perceptual brain areas during task performance (e.g., visuospatial, language, working memory tasks). Similarly, the Trigger-Threshold-Target model (TTT; Mottron et al., 2014) of autism suggests that cognitive enhancement, such that perceptual materials are preferentially processed over social materials, is due to brain reorganization triggered by a series of genetic mutations. Together, the EFT and TTT models highlight how persons on the autism spectrum perceive and experience the world differently and account for the relative strength in visual and auditory processing documented in the literature, such as superior visual search skills (Kaldy et al., 2011), musical memory and melodic perception (Heaton, 2003; Stanutz et al., 2014), and pitch frequency distinction (Bonnel et al., 2010). As such, investigating if PA skills are related to verbal skills, as in the case of typical development, or other skills (i.e., non-verbal skills) due to the distinct cognitive styles of autistic persons, is needed to elucidate correlates of literacy development for autistic children.

Indeed, various factors may play an important role in PA development of autistic children such as autism characteristics, language skills, and cognitive skills (e.g., Dynia et al., 2014;

Fleury & Lease, 2018; Nally et al., 2018; Smith Gabig, 2010; Westerveld et al., 2020). Autistic children show comparable performance on PA tasks to non-autistic children when accounting for verbal skills (Dynia et al., 2014; Westerveld et al., 2020) and non-verbal skills (Westerveld et al., 2020). Furthermore, verbal skills (Nally et al., 2018), non-verbal skills (Jokel et al., 2020) and general cognitive skills (Fleury & Lease, 2018) are associated with PA. Specifically, non-verbal (visual-spatial/perceptual reasoning) cognitive skills are a predictor for oral language abilities among autistic children (Wodka et al., 2013) and may even account for the heterogeneity in language profiles (Kjelgaard & Tager-Flusberg, 2001).

In addition, some studies show a relationship between autism characteristics and oral language skills such that greater social impairment is related to delayed acquisition of oral language (Wodka et al., 2013). However, social skills are not a significant predictor of PA skills (Dynia et al., 2019), and repetitive behaviours/sensory interests do not seem related to oral language skills (Wodka et al., 2013) of autistic children. Overall, it is pertinent to continue to investigate the impact of autism characteristics and verbal and non-verbal cognitive skills on the PA skills of autistic children to understand which factors influence their learning.

The overall aim of this study is to extend prior research on the PA skills of preschool children to school age autistic children. In addition, we will examine the relationship between PA skills and cognitive and autism characteristic to understand how autistic children best learn in the context of literacy development. This objective is informed by the neurodiversity movement, which posits that a natural range of diversity occurs in human neurodevelopment (Pellicano & Houting, 2022) while recognizing that neurocognitive differences encompass strengths as well as weaknesses, which may present challenges for the individual's functioning within their environment (Leadbitter et al., 2021). Thus, findings could help to improve academic outcomes for autistic children by providing insight into possible mechanisms underlying phonological awareness development for school age children who present with a wide range of support needs (Davidson & Ellis Weismer, 2014; Wodka et al., 2013), while considering autistic developmental trajectories and natural developmental processes to inform targeted strength-based interventions to palliate areas of challenge (Leadbitter et al., 2021).

Given the heterogeneity of cognitive, receptive, and expressive language profiles of autistic children, we used the NEPSY-II's Phonological Processing subtest (Korman et al., 2007) to measure PA because it minimizes the participant's use of expressive language. The NEPSY-II is standardized with clinical subgroups and recommended for children with exceptionalities including intellectual disability and autism (Brooks et al., 2009). The Phonological Processing subtest contains non-verbal and verbal items which makes it a useful measure for children with a wide range of abilities.

Study Objectives and Hypotheses

Study 1

The objective of the first study is to compare the PA skills of school age autistic children to non-autistic children, using a PA task commonly used in clinical practice and recommended for use with autistic children. Based on findings from previous investigations on PA, mainly in preschool age autistic children showing comparable PA skills to non-autistic children when accounting for language (Dynia et al., 2014; Westerveld et al., 2020) and non-verbal cognitive skills (Westerveld et al., 2020), we hypothesized that there would be no difference in performance on the PA task between school age autistic children compared to non-autisitc children. Study 1 includes a preliminary exploration of the relationship between cognitive skills, autism characteristics, and PA skills of autistic and non-autistic children, which is explored in greater depth in study 2.

Study 2

Given the uneven cognitive profile of autistic children, the link between non-verbal skills and PA skills (Jokel et al., 2020), and the mixed findings reported across behavioural studies regarding the role of general autism characteristics and oral language on PA skills (e.g., Dynia et al., 2019 vs. Wodka et al., 2013), the objective of the second study is to explore the relationship between verbal and non-verbal cognitive skills and autism characteristics (social communication/interaction and repetitive behaviours/restricted interests) and PA skills of autistic children across a wide spectrum of cognitive skills.

STUDY 1

Methodology

Participants in the current study represent a subset of participants from a larger study where behavioural and neurophysiological measures were collected for autistic and non-autistic children who participated in a Summer Social Science Research camp at Simon Fraser university in Burnaby, British Columbia, Canada. Ethical approval was granted by the Office of Research Ethics at the Simon Fraser University (SFU).

Participants

A total of 32 participants (n = 9 females) between the ages of 6 and 12 (M = 9, SD = 1.64) including 18 autistic and 14 non-autistic participants were included in study 1. Exclusion criteria included individuals with a co-occurring intellectual disability (IQ < 70). Participant characteristics of the autistic and non-autistic groups are reported in Table 2. Independent t-tests were used to investigate if the autistic and non-autistic groups differed on the experimental measure of PA skills, and on group characteristics of chronological age, autism characteristics and verbal and non-verbal cognitive skills. Univariate effects were evaluated at a Bonferroni corrected alpha level of .008 (.05/6). The autistic and non-autistic groups were matched on chronological age, the Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II; Wechsler, 2011) Vocabulary and Matrix Reasoning subtests, but differed in terms of autism characteristics.

Table 2

Study 1 Participant Characteristics of Autistic and Non-Autistic Groups

Variables	Autistic Group (*N*=18, 2 females)			Non-Autistic Group (*N*=14, 7 females)				
	M	*SD*	Range	*M*	*SD*	Range	*p*	*d*
Age	9.78	1.71	6–12	8.97	1.49	6–11	.17	.51
SRS-2	72	8	58–87	49	9	39–69	.00*	2.7
AQ	33	5	24–41	15	6	5–30	.00*	3.3
WASI-II VC	100	12	79–143	102	8	88–128	.63	.20
WASI-II MR	106	8	85–131	114	12	85–140	.21	.80
NEPSY-II PA	11	3	4–17	11	2	7–15	.96	0

Note. Means (*M*), standard deviations (*SD*), age (in years), Social Responsiveness Scale, 2nd edition (SRS-2) total t-scores, Autism-Spectrum Quotient (AQ) total score, Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II), Vocabulary (VC), Matrix reasoning (MR), WASI-II VC and MR presented in standard scores. NEPSY-II Phonological Processing subtest (PA).
Second last column denotes a *t*-test (p) comparing group differences in means for each variable, and last column denotes Cohen's *d* effect size.
*Bonferroni corrected alpha level of .008 (.05/6).

Measures and Group Characteristics

Autism Inclusionary Criteria. Children in the autistic group received a standardized clinical diagnosis of autism spectrum disorder from a qualified pediatrician, psychologist, or psychiatrist associated with the provincial government funded autism assessment network, or through a qualified private clinician. All diagnoses were based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-5; APA, 2013) using the Autism Diagnostic Interview–

Revised (ADI-R; Rutter et al. 2003), and Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999). A clinical autism assessment report or a Ministry of Child and Family Development autism funding eligibility form, which requires a clinical autism assessment, was provided by the parents to confirm diagnosis. In addition, autism characteristics were measured through parent report on two parent questionnaires; the Social Responsiveness Scale - 2 (SRS-2; Constantino & Gruber, 2012) and the Autism-Spectrum Quotient screener questionnaire (AQ; Baron-Cohen et al., 2001). A total score of ≥32 on the AQ and a t-score ≥60 on the SRS-2 were used as cut-off scores indicative of autism characteristics. The SRS-2 and AQ questionnaires were administered to both the parents of autistic and non-autistic children.

Two participants with a prior diagnosis of autism from a clinician met criteria on either the SRS-2 or the AQ, but not both, obtaining scores slightly below clinical cut-off scores on either one of these questionnaires. All analyses were repeated excluding the 2 participants in the autism group to assess whether the pattern of results differed for analyses conduced with and without these 2 participants. Given that the pattern of results did not differ with and without these 2 participants and that we obtained evidence of diagnosis of autism by a clinician, these participants were retained in the autism group. All other 16 autistic participants scored in the elevated range for autism on the SRS-2 or the AQ. All non-autistic participants (n = 14) scored below the clinical cut-off score of 32 on the AQ, indicating few signs of autism. All but 2 non-autistic participants obtained scores below the clinical cut-off t-score of 60 on the SRS-2. Analyses were repeated excluding these 2 non-autistic participants and patterns of results did not differ. Thus, these 2 participants were retained in the non-autistic group.

Study Exclusion. The original sample comprised 48 participants; however, 13 participants were excluded due to incomplete data, extreme scores (outliers identified through assessment of boxplots) and being in the process of an autism assessment (unable to assign them to either group), and 3 participants in the non-autistic group were removed from the study as they obtained scores indicative of autism characteristics on both autism screening questionnaires. The final sample included in the analyses consisted of 32 children (n = 9 females) including 18 autistic children and 14 non-autistic children.

Co-Occurring Conditions. Twelve participants in the autistic group presented with one or more co-occurring conditions other than autism spectrum disorder which included attention-deficit-hyperactivity disorder (n = 7), specific learning disorder (n = 1), and anxiety (n = 7). Two participants in the non-autistic group presented with an anxiety disorder. All participants were able to complete the measures in this study.

Autism Characteristics. There was a statistically significant difference with a large effect size in autism characteristics between groups on the SRS-2, $t(30) = -7.49$, $p = .00$, $d = 2.7$, and the AQ, $t(30) = -8.84$, $p = .00$, $d = 3.3$, with the autistic group having statistically significant higher scores, indicating more autism traits, than the non-autistic group (see Table 2).

Age and Sex. There was no statistically significant difference in chronological age between the autistic and non-autistic groups, $t(30) = -1.41$, $p = .17$, $d = .51$. Chi-square analyses revealed statistically significant sex difference between the autistic and non-autistic groups. The autistic group was primarily composed of males (N=16, 88%) and the non-autistic group was equally composed of males and females (N=7, 50%). The discrepancy in sex distribution within our sample reflects the fact that autism is more commonly identified in males than in females at a ratio of 4:1 (CDC, 2018).

Cognitive Skills. The Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II; Wechsler, 2011) was used as a fast and reliable measure of cognitive skills including verbal

(Vocabulary subtest) and non-verbal skills, specifically, perceptual reasoning skills[3] (Matrix Reasoning subtest). Total raw scores are transformed into t-scores, and we converted those into standard scores where the mean is 100 and the standard deviation is 15. There was no statistically significant difference in verbal skills, $t(30) = .483$, $p = .63$, $d = .2$., and non-verbal cognitive skills, $t(30) = 1.29$, $p = .95$, $d = .8$., between the autistic and non-autistic groups. Levene's test revealed that perceptual reasoning skills violated the assumption of homogeneity of variance and was therefore interpreted using the equal variances not assumed test statistic.

Phonological Awareness

Phonological awareness skills were measured using the Phonological Processing subtest of the NEPSY-II (Korman et al., 2007). This subtest can be administered to participants from 3 to 16 years of age. The Phonological Processing subtest is comprised of non-verbal items (receptive), measuring word segment recognition, which require participants to identify words from word segments by pointing to pictures (e.g., the participant is asked to choose between 3 pictures to match "do-g"). This subtest also included verbal items (expressive), measuring phonological segmentation, that assess the ability to manipulate sounds and syllables in spoken words. These items ask participants to repeat a word and then to create a new word by omitting or substituting a syllable or phoneme (e.g., "coat", now say it again but don't say /k/, "oat"). Higher scores on the NEPSY-II Phonological Processing subtest indicate stronger PA skills. Raw scores are transformed into standardized scores, where the mean is 10 and the standard deviation is 3.

[3] The term "non-verbal" cognitive skills is used to refer to the specific non-verbal skill of perceptual reasoning, as measured by the Matrix Reasoning subtest of the WASI-II (Wechsler, 2011). As such, the terms "non-verbal cognitive skills" and "perceptual reasoning skills" may be used interchangeably.

Results

Participants in the autistic group performed similarly (*M* = 10.56, *SD* = 3.28) to the participants in the non-autistic group (*M* = 10.5, *SD* = 1.99) on the PA measure. This difference, -.06, BCa 95% CI [-2.09, 1.98], was not significant, $t(30) = -.056$, $p = .96$, $d = 0$ (Table 2). These results revealed that the autistic and non-autistic groups did not differ in their PA skills.

The Relationship Between Cognitive Skills, Autism Characteristics and PA skills

Autistic Group. Spearman correlation analyses were used to investigate the relationship between PA skills and verbal and non-verbal cognitive skills and autism characteristics (i.e., SRS-2 total t-score) (Table 3). Results revealed a statistically significant positive and moderate correlation, with Bonferonni correction for multiple comparisons applied, between PA and perceptual reasoning skills, $r_s = .615$, $p < .01$, within the autism group. There was no relationship between PA skills and either verbal cognitive skills or autism characteristics, within the autism group.

Non-Autistic Group. Spearman correlation analyses did not reveal a relationship between PA skills and either verbal, non-verbal skills, or autism characteristics, within the non-autistic group.

Table 3

Correlations Between Phonological Awareness (PA) Skills, Cognitive Skills and Autism Characteristics within the Autistic and Non-Autistic Groups

	NEPSY-II PA (PA) correlation with:		
	WASI-II VC (Verbal)	WASI-II MR (Non-verbal)	SRS-2
Autistic Group	.391	.615*	-.116
Non-Autistic Group	.333	.403	-.427

Note. NEPSY-II Phonological Processing subtest (PA), Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II), Vocabulary (VC), Matrix reasoning (MR), Social Responsiveness Scale, 2nd edition (SRS-2) total t-scores.

*Bonferroni corrected alpha level of .017 (.05/3).

Discussion

The aim of study 1 was to compare the PA skills of school age autistic children to non-autistic children, using a PA task commonly used in clinical practice and recommended to use with autistic children. Specifically, this study aimed to extend prior research on the PA skills of preschool children to school age autistic children matched with non-autistic peers. We hypothesized that autistic and non-autistic children would not differ in their scores on the PA task. Results supported our hypothesis and found that the autistic and non-autistic groups had similar performance on the PA task. Study 1 provided a preliminary investigation of the relationship between cognitive skills, autism characteristics and PA skills of autistic children and non-autistic children. Findings revealed a positive relationship between perceptual reasoning skills and PA skills for autistic children. No relationship was found between cognitive skills and PA skills for typically developing children.

Given the cognitive profile of autistic children in study 1, results seem most applicable to autistic children requiring a low level of support, who often complete school in mainstream education. As such, findings from study 1 may be limited to children with low support needs and may not generalize to those with high support needs, who often complete school in specialized education. Thus, we investigate the relationship between PA, cognitive skills, and autism characteristics in study 2, which includes participants with low and high support needs across the spectrum.

STUDY 2

Methodology

The participant sample in study 2 includes the autistic participants from study 1 (*n* = 18) combined with an additional 21 autistic participants recruited separately, for a total of 35 participants. The 21 additional autistic participants were recruited at an elementary school in Montreal, Quebec, Canada for autistic children and children with other neurodevelopmental conditions. While study 1 excluded participants with a co-occurring intellectual disability (IQ < 70), study 2 includes participants with a wide range of cognitive skills in order to be representative of the heterogeneity of cognitive profiles across the spectrum. Ethical approval was granted by McGill University's Research Ethics Board. Informed consent was obtained from parents and teachers, and assent was obtained from child participants.

Participants

A total of 35 autistic participants (*n* = 4 females) between the ages of 6 and 12 years old (*M* = 9.6, *SD* = 1.54) were included in study 2. Participant characteristics are reported in Table 4. All variables fell within conventional limits of normality (i.e., skewness and kurtosis absolute value smaller than 1.96) (Field, 2013).

Table 4

Study 2 Autistic Participant Characteristics

Variables	*n*	*M*	*SD*	Range
Age	35	9.6	1.54	6–12
SRS-2 Total	35	72	9	55–87
SRS-2 RRB	35	71	9	58–90
SRS-2 SCI	35	71	9	54–89
AQ Total	18	33	5	24–41
SCQ Total	20	19	6	2–27
ADOS-2	11	9	1	7–10
WASI-II VC	35	90	15	55–143
WASI-II MR	35	95	12	63–132

NEPSY-II PA	35	8	4	1–17

Note. Means (M), standard deviations (SD), age (in years), Social Responsiveness Scale, 2nd edition (SRS-2) total t-scores, Restricted Interests and Repetitive Behaviour or Autistic Mannerisms (RRB), Social Communication and Interaction (SCI), Autism-Spectrum Quotient (AQ) total score, Social Communication Questionnaire (SCQ) raw scores, Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2) comparison score, Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II), Vocabulary (VC), Matrix reasoning (MR), WASI VC and MR presented in standard scores. NEPSY-II Phonological Processing subtest (PA).

Measures

The measures used in study 2 overlap with those used in study 1. The Phonological Processing subtest of the NEPSY-II (Korman et al., 2007) was used to measure phonological awareness skills, The Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II; Wechsler, 2011) was used to measure cognitive skills including verbal (Vocabulary subtest) and non-verbal/perceptual reasoning skills (Matrix Reasoning subtest), and the Social Responsiveness Scale - 2 (SRS-2; Constantino & Gruber, 2012) and Autism-Spectrum Quotient screener questionnaire (AQ; Baron-Cohen et al., 2001) were used to measure autism characteristics. Two additional measures were used to measure autism characteritics in a subset of participants in study 2 including the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2; Lord et al., 2012) and the Social Communication Questionnaire (SCQ; Rutter et al., 2003).

The ADOS-2 is a semi structured, standardized assessment of communication, social interaction, play, and restricted and repetitive behaviours. Autism criterion is met by obtaining a comparison score in the moderate to high range and a classification of autism spectrum/autism. The SCQ-Lifetime (focus on the child’s entire developmental history) version of the screening questionnaire was used for parent and the SCQ-Current version for teachers. Parental report scores were used in analyses and teacher report was used in cases where parental report was not obtained.

Autism Characteristics and Study Exclusion. All participants had a prior diagnosis of autism from a clinician (e.g., pediatrician, psychiatrist, psychologist) or had a Québec Education Ministry code indicating that the participant had been identified as having autism by a clinician (Lazoff et al., 2010). Autism characteristics were measured through additional screening questionnaires (i.e., SRS-2, Constantino & Gruber, 2012; AQ, Baron-Cohen et al., 2001; SCQ, Rutter et al., 2003) and a standardized assessment instruments (i.e., ADOS-2, Lord et al., 2012). Participants who obtained scores below the cut-off score of 60 on the SRS-2 scored above the clinical cut-off on either AQ (32), SCQ (15), or met criteria for a clinical diagnosis on the ADOS-2.

The original sample for study 2 comprised of 39 participants; however, 2 participants were excluded due to incomplete data and 2 participants were excluded because they did not meet criteria on either the SRS-2 or the AQ, obtaining scores slightly below cut-off scores on these questionnaires, and SCQ and ADOS-2 scores were not available for those participants. The final sample included in the analyses consisted of 35 autistic children (*n* = 4 females).

Co-Occurring Conditions. Seventeen participants presented with one or more co-occurring conditions other than autism which included attention-deficit-hyperactivity disorder (*n* = 10), global developmental delay (*n* = 2), specific learning disorder (*n* = 2), intellectual disability (*n* = 1), and anxiety (*n* = 7). All participants in the sample were able to complete the measures.

Results

Pearson correlation analyses were used to investigate the relationship between PA skills and verbal and non-verbal/perceptual reasoning cognitive skills and autism characteristics (i.e., restricted interests/repetitive behaviours [RRB], and social communication and interactions

[SCI]) (Table 5). Results revealed a statistically significant positive and large correlation between PA and verbal, r = .725, p < .001, and perceptual reasoning, r = .837, p < .001, cognitive skills with Bonferonni correction for multiple comparisons applied. In addition, there was a negative moderate correlation between the RRB subscale of autism characteristics and PA skills, r = -.392, p = .02. However, the relationship between the RRB subscale and PA skills was not significant when Bonferonni correction was applied. There was no relationship between the SCI subscale of autism characteristics and PA skills.

Table 5

Correlations Between Phonological Awareness (PA) Skills, Cognitive Skills and Autism Characteristics

Variable	PA	Verbal	Non-verbal	RRB	SCI
NEPSY-II PA (PA)	-	.725†	.837†	-.392*	.041
WASI-II VC (Verbal)		-	.734†	-.153	.130
WASI-II MR (Non-verbal)			-	-.292	.223
SRS-2 RRB (RRB)				-	.444**
SRS-2 SCI (SCI)					-

Note. NEPSY-II Phonological Processing subtest (PA), Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II), Vocabulary (VC), Matrix reasoning (MR), Social Responsiveness Scale, 2nd edition (SRS-2) total t-scores, Restricted Interests and Repetitive Behaviour or Autistic Mannerisms (RRB), Social Communication and Interaction (SCI).
*Significant without Bonferroni correction, p <.05.
**Significant without Bonferroni correction, p <.01.
†Significant with Bonferroni corrected alpha level of .005 (.05/10).

Predictors of Phonological Awareness Skills

We performed a regression analysis in order to assess the predictive impact of cognitive skills (verbal and non-verbal) and autism characteristics (RRB and SCI) on PA skills of autistic children, where PA skills was considered as the dependent variable (Table 6). Results revealed a significant overall regression model, $F(4, 30) = 23.63$, $p = .00$, $R^2=.76$. The R^2 value suggests that 76% of the variance in PA skills is attributed to verbal and non-verbal cognitive skills, RRB, and SCI. Of the four predictors, perceptual reasoning skills was the only significant predictor of PA skills, $\beta = .62$, $t = 4.23$, $p=.000$, for autistic participants; suggesting that an increase of 1 (standard score) on the PA task is associated with an increase of .23 (standard score) on the WASI-II Matrix Reasoning task.

Table 6

Regression Analysis Predicting Phonological Awareness from Autism Characteristics, Verbal and Non-Verbal Cognitive Skills

Predictor	Phonological Awareness				
	B	SE B	β	*t*	*p*
WASI-II VC (Verbal)	.08	.04	.26	1.91	.066
WASI-II MR (Non-verbal)	.23	.06	.62	4.23	.000
SRS-2 RRB (RRB)	-.07	.05	-.14	-1.23	.227
SRS-2 SCI (SCI)	-.03	.05	-.07	-.62	.538

Note. Unstandardized beta (B), standard error for unstandardized beta (SE B), standardized beta (β), Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II) Vocabulary (VC), Matrix Reasoning (MR), Social Responsiveness Scale, 2nd edition (SRS-2) total t-scores, Restricted Interests and Repetitive Behaviour or Autistic Mannerisms (RRB), Social Communication and Interaction (SCI).

Discussion

The aim of study 2 was to examine the contribution of verbal and non-verbal cognitive skills and autism characteristics to the PA skills of children with low and high support needs across the autism spectrum. Children with a wide range of support needs, including broad levels of cognitive skills and autism characteristics, were included in study 2 in order to assess whether the findings of study 1 that apply mainly to children in mainstream education settings generalize to children in specialized education as well.

In typical development, reading is considered a language-based skill (Catts et al., 1999; McArthur et al., 2000; Roth et al., 2002). However, many autistic children experience the world differently and show a strength for non-verbal/perceptual skills (e.g., visual and auditory processing) over verbal skills (Ankenman et al., 2014; Charman et al., 2011), which is also highlighted by the EPF (Mottron et al., 2001, 2006, 2009) and TTT (Mottron et al., 2014) theoretical models. Therefore, we investigated if PA skills were related to verbal skills, as in the case of typical development (e.g., Roth et al., 2002), or other skills (i.e., perceptual reasoning skills) due to the distinct cognitive styles of autistic persons. Findings from the current study showed that perceptual reasoning skills, but not verbal skills or autism characteristics, are associated with PA skills of autistic children. Results highlight the central role of non-verbal cognitive skills in literacy development for autistic children and suggest that their enhanced perceptual processing abilities likely contribute a great deal when learning to read.

General Discussion

The current study investigated an important emergent literacy skill, phonological awareness (PA), among autistic children with a wide range of cognitive skills, autism characteristics, and co-occurring conditions, in two parts. Study 1 compared the PA skills of school age autistic children to non-autistic children, with groups matched on chronological age, verbal and non-verbal cognitive skills. Study 1 also conducted a preliminary investigation into the relationship between cognitive skills, autism characteristics and PA skills for autistic and non-autistic children. Study 2 examined the contribution of verbal and non-verbal cognitive skills and autism characteristics on performance on the PA task of children with low and high support needs across the spectrum. Including children with heterogeneous abilities in study 2 allows for findings to be as representative as possible of the developmental profiles found across the spectrum and in different educational settings.

Overall, results from study 1 and 2 can be summarized into three main findings: i) we found no significant difference in PA skills between autistic and non-autistic children (study 1), ii) the PA skills of autistic children are associated with their perceptual reasoning skills (studies 1 & 2), while the two are not correlated for non-autistic children (study 1), and iii) we found no significant correlation between PA skills and verbal cognitive skills or autism characteristics for both autistic and non-autistic children (studies 1 & 2).

Autistic Children Show Similar PA Skills to Non-Autistic Children

The first main finding (study 1) supported our hypothesis showing that autistic and non-autistic children showed similar PA skills. School age autistic and non-autistic children did not differ in their performance on the PA task when groups were matched on chronological age, verbal and non-verbal cognitive skills. Scores obtained by both groups were within the normative average on the NEPSY-II. Results are consistent with previous studies on PA skills with preschool children that indicate no difference in PA skills between autistic children and non-autistic children when verbal and non-verbal skills are accounted for (e.g., Westerveld et al., 2020) but are not consistent with research showing that autistic children have challenges in PA skills compared to non-autistic children (Dynia et al., 2019, 2017, 2014). Our finding supports the notion that inconsistencies in the literature on PA skills of preschool autistic children appear to be the result of the lack of controlling for cognitive skills and group matching, such that there are few if any differences between groups matched for verbal and non-verbal cognitive skills.

Further, our finding showing that children in the autistic and non-autistic groups did not differ in their PA skills expands the extensive research on PA skills of preschool autistic children to school age children who have begun to receive formal literacy instruction in school. To our knowledge, only a few studies have investigated the PA skills of school age autistic children and found deficits in PA skills within this age group (e.g., Nally et al., 2018; Smith Gabig, 2010). Yet, group matching on language and cognitive skills was absent, although the autistic and non-autistic groups were matched on chronological age (Smith Gabig, 2010). Our finding suggests that differences in PA skills reported in previous studies may be related to verbal and non-verbal skills, which were not controlled for in previous studies. Overall, our results indicate that autistic and non-autistic children show similar PA skills during the school age period of development, after receiving years of formal reading instruction.

PA Skills are Associated with Perceptual Reasoning Skills of Autistic Children

The second main finding showed that PA skills are positively associated with the perceptual reasoning skills of autistic children with low (study 1) or low to high support needs (study 2), although not for non-autistic children (study 1). Autistic children with higher perceptual reasoning skills had better performance on the PA task compared to those with lower perceptual reasoning skills. Although autistic children in study 1 performed in the normative range of the NEPSY-II PA subtest (NEPSY-II: $M = 11$, $SD = 3$, range = 4 – 17) and autistic children in study 2 performed approximately one standard deviation below the PA subtests normative range (NEPSY-II: $M = 8$, $SD = 4$, range = 1 – 17), the association between PA and perceptual reasoning skills remained for autistic children despite their higher level of support needs (with study 2 including children with a wider range of support needs). Results did not reveal an association between PA and perceptual reasoning skills for non-autistic children.

Given that the autistic and non-autistic groups did not differ in their PA skills, the second main finding suggests that perceptual reasoning skills play a greater role in literacy development for autistic children as compared to non-autistic children. The Enhanced Perceptual Functioning (EPF; Mottron et al., 2001, 2006, 2009) and the Trigger-Threshold-Target (TTT; Mottron et al., 2014) models of autistic cognitive profiles account for the relative strength in non-verbal/perceptual skills (visual and auditory) as compared to verbal skills for persons on the autism spectrum, which has been well documented in the literature (Ankenman et al., 2014; Charman et al., 2011; Courchesne et al., 2015; Joseph et al., 2002; Nader et al., 2015; Soulières et al., 2011). Taken together, enhanced perceptual processing could be contributing to literacy skill acquisition of autistic children.

Our finding leads us to question the trajectory of reading development for autistic children, particularly when considering the diversity of reading profiles across the spectrum ranging from marked difficulties to enhanced skills, as in the context of hyperlexia (i.e., a special strength in word decoding/recognition accompanied by difficulties with reading comprehension and with verbal skills) (Silberberg & Silberberg, 1967). For instance, preschool age autistic children with hyperlexia demonstrate advanced word reading skills compared to autistic children without hyperlexia and non-autistic children, but do not significantly differ in terms of PA skills (Macdonald et al., 2020), suggesting that preschool autistic children who present with a hyperlexic profile may employ a non-phonological alternative approach when learning to read (Macdonald et al., 2020). The current study did not measure the presence of hyperlexia within our sample of participants which limits our understanding of distinct reading profiles, although our findings suggest that this alternative approach to reading may capitalize on strengths for perceptual processing that are more closely related to non-verbal than verbal cognitive skills. Future studies examining the reading profiles of school age autistic children should include measures of reading skills, such as reading comprehension and word reading, to clarify the presence of hyperlexia in order to elucidate the trajectory of reading development for older autistic children following formal reading instruction. Next steps in this line of research could also include assessing the relationship between PA skills and basic reading and reading comprehension skills of autistic children, while accounting for cognitive skills.

No Significant Relationship Between PA skills and Verbal Skills or Autism Characteristics for Autistic and Non-Autistic Children

The third main finding revealed no statistically significant relationship between PA skills and verbal cognitive skills or autism characteristics for autistic and non-autistic children (studies 1 & 2). Although PA and verbal cognitive skills were significantly correlated for autistic children in study 2 (and not in study 1), further investigation revealed that verbal skills were not a significant predictor for PA skills of autistic children when non-verbal cognitive skills were also included in a regression model (study 2). This finding further illustrates the importance of perceptual reasoning skills over verbal skills for autistic children when it comes to learning to read.

Our finding of no significant association between PA and verbal skills for non-autistic children is not consistent with findings that show a link between reading skills and oral language in typical development. Yet, previous studies showing that PA and verbal/language skills are closely related in typical development mostly focus on the preschool age period (e.g., Catts et al., 1999; Macdonald et al., 2020; Roth et al., 2002), with few studies investigating the link between these two for older children. Thus, it is possible that the chronological age of the participants included in this study (children between 6 and 12 years old) could explain the lack of a significant association between PA and verbal skills within the non-autistic group, such that a significant association between the two is no longer present in the school age years. In addition, the result showing no significant association between PA and verbal skills for non-autistic children could also potentially be explained by the nature of the task used to measure PA (NEPSY-II Phonological Processing subtest). The PA task contains receptive (early items) and expressive (later items) questions which increase in difficulty. The expressive items require the child to manipulate sounds and syllables in spoken words, a reasoning skill that requires mental reasoning, a process that is arguably more akin with abilities required for the Matrix Reasoning task (i.e., visual-spatial/perceptual reasoning) compared to the Vocabulary task (i.e., word knowledge) on the WASI-II (although PA and non-verbal skills were also not correlated for the non-autistic group). Lastly, the lack of association between PA and verbal skills may also be explained by the limitations in the current study such as a small sample size and the fact that non-autistic children included in study 1 had strong verbal cognitive scores (standard score range = 88 – 128), with few participants falling below the low average range.

Similar to previous studies investigating the association between PA skills and autism characteristics (e.g., Dynia et al., 2019; Macdonald et al., 2020; Wodka et al., 2013), the current study did not find an association between PA skills and autism characteristics across the repetitive behaviour (RRB) and social communication (SCI) domains within the autistic and non-autistic groups. Whereas a negative correlation between PA skills and the RRB subscale of autism characteristics was found in study 2, the correlation was no longer significant when Bonferroni correction for multiple comparisons was applied. Additionally, RRB was not a significant predictor for PA skills of autistic children when further analysis was conducted using a regression. Further, our results are not consistent with findings from Nally et al. (2018) showing that more autism characteristics predicted increased reading deficits. Instead, we found that perceptual reasoning skills seem to play a more important role than autism characteristics in literacy skills development.

Implications

Our findings provide insight into the mechanisms underlying an important aspect of literacy development (i.e., phonological awareness) in school age autistic children who present with a wide range of support needs, cognitive profiles, autism characteristics and co-occurring conditions. Our finding that autistic children show similar PA skills to non-autistic children and showing the importance of perceptual reasoning skills in literacy development for autistic children align within the neurodiversity framework, which emphasizes the importance of considering the environment goodness-of-fit and individual developmental trajectories when creating and implementing intervention programs (Leadbitter et al., 2021). Through highlighting the contribution of perceptual reasoning skills to literacy development, results support the use of strength-based approaches to reading instruction for autistic children such as using non-verbal aids like accompanying visual or auditory stimuli (i.e., music, pictures). Using non-verbal aids during reading instruction could also be useful for all children in the classroom regardless of a diagnosis. While the task used to measure perceptual processing included in this study primarily involved visual processing skills, it is important to recognize that not all autistic children will benefit from visual approaches to reading interventions given the heterogeneity of profiles across the spectrum. Findings support the need for further research on multimedia (e.g., combination of text, graphics, audio, and video) reading interventions for autistic children that incorporate the individual's relative perceptual learning strengths.

Conclusion

This study contributes to a better understanding of the development of PA skills in school age autistic children with a wide range of support needs, cognitive profiles, and autism characteristics. Results reveal that autistic children show comparable PA skills to that of non-autistic children (matched on chronological age, verbal and non-verbal cognitive skills) and highlight the contribution of perceptual reasoning skills to PA skills of autistic children. This study expands the existing research with preschool age autistic children to school age autistic children. Overall, findings hold important educational implications for autistic children and help inform instructional interventions targeting literacy skills by suggesting a need for approaches that capitalize on the strength in perceptual processing while relying less on verbal skills when teaching autistic children to read.

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Bridge Between Manuscripts – Chapter 4 and Chapter 5

The overall aim of Manuscript 2 (Chapter 4) was to extend and clarify prior research on the phonological awareness skills of preschool children, to school age autistic children in two parts. First, Manuscript 2 compared the phonological awareness skills of school age autistic children to non-autistic children, matched on chronological age, verbal, and non-verbal/perceptual reasoning skills. Second, Manuscript 2 investigated the role of verbal and non-verbal cognitive skills and autism characteristics on phonological awareness task performance of autistic children across a wide range of cognitive skills.

Findings from Chapter 4 assisted to elucidate the development of phonological awareness abilities in school age autistic children compared to non-autistic peers and highlighted the contribution of perceptual reasoning skills on phonological awareness. Specifically, findings show that phonological awareness is a relative strength in the learning profiles of autistic children, such that there is no significant difference in the phonological awareness skills between autistic and non-autistic children. Furthermore, non-verbal cognitive skills, specifically, perceptual reasoning skills, and not verbal abilities or autism characteristics predict phonological awareness task performance for autistic children. Findings substantiate the importance of considering the contribution of perceptual reasoning skills on emergent literacy skills, putting into question the current screening measures used to assess phonological awareness which often use verbal tasks. Based on findings from Manuscript 2, the overall objective of Manuscript 3 was to explore the relationship between musical beat perception, a perceptual and non-verbal stimulus, and phonological awareness skills for autistic children. Previous research supporting the link between musical beat and rhythm perception/production abilities and phonological awareness have predominantly included neurotypical children or children with a specific learning disorder with average cognitive skills. To our knowledge, no study has investigated the association between beat perception and phonological awareness abilities of autistic children, which is particularly relevant given some autistic children showing heightened musical interests and abilities. Thus, Manuscript 3 aimed to investigate the use of an enjoyable, non-academic, and non-verbal stimulus as a potential screening tool for the early literacy skills of autistic children with a wide range of cognitive skills, as outlined in Chapter 5.

Chapter 5: Manuscript 3

The manuscript in this chapter was originally submitted for publication in March 2022 and is currently under review.

Links between musical beat perception and phonological skills for autistic children

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Abstract

Exploring non-linguistic predictors of early literacy, such as musical beat perception, is valuable for children who present with language difficulties and diverse support needs. Studies on the musical abilities of children on the autism spectrum show that they have average or above-average musical production and auditory processing abilities. This study aimed to investigate the use of a non-verbal stimuli (musical beat) as a potential screening tool for the early literacy skills of children on the autism spectrum with a wide range of cognitive abilities, by exploring the relationship between musical beat perception and phonological awareness skills. A total of 21 autistic children between the ages of 6 to 11 years old (*M* = 8.9, *SD* = 1.5) with full scale IQs ranging from 52 to 105 (*M* = 74, *SD* = 16) completed a beat perception task. Results revealed that phonological awareness and beat perception are positively correlated for children on the autism spectrum. Findings lend support to the use of beat and rhythm perception as a screening tool for early literacy skills for children with diverse support needs as an alternative to traditional verbal tasks that tend to underestimate the potential of children on the autism spectrum.

Keywords: autism, beat perception, rhythm perception, phonological awareness, early literacy

Links between musical beat perception and phonological skills for autistic children

Gaining a greater understanding of linguistic predictors of literacy acquisition has been a topic of focus for many years. The vast research in this field has led to the discovery of linguistic abilities that play a significant role in literacy development such as alphabet knowledge, oral language, concepts about print, and rapid naming of letters or digits (National Early Literacy Panel [NELP], 2008). Among the strongest predictors of literacy acquisition is phonological awareness, which has a moderately strong correlation with word decoding (r = 0.40) (NELP, 2008) in typical development (Blachman et al., 1999; Dynia et al., 2017; Moritz et al., 2013). Phonological awareness is defined as a metalinguistic skill referring to the ability to intentionally manipulate and analyse sound structures of spoken language (Hudson et al., 2017; Scarborough & Brady, 2002; Schuele & Boudreau, 2008). Examples of phonological awareness skills can include but are not limited to synthesis/blending ("What word does it make when you say these together: /st/…/ik/?" *Stick*) and manipulation ("What's left if you leave out the /n/ in band?" *Bad*) (Scarborough & Brady, 2002).

Research on non-linguistic predictors of literacy is growing and suggests that musical predictors, such as rhythm perception and production, are important abilities for literacy acquisition (e.g., Eccles et al., 2020; Moritz et al., 2013; Politimou et al., 2019). Here, we investigated beat perception, which is a fundamental component of rhythm perception. Studies investigating the link between literacy development and musical beat and rhythm perception and production have mostly focused on typical development (e.g., Anvari et al., 2002; Eccles et al., 2020; Politimou et al., 2019). Yet, exploring non-linguistic predictors may be particularly important for populations who present with diverse support needs, such as children on the autism spectrum. Autism spectrum disorder (hereinafter referred to as autism) is a neurodevelopmental condition of childhood onset characterized by challenges in social communication and interactions, as well as the presence of restricted, repetitive patterns of behaviours, interests, or activities (American Psychiatric Association (APA), 2013). The core features of autism, in addition to the commonly associated co-occurring conditions such as intellectual developmental disorder, attention-deficit-hyperactivity disorder, and specific learning disorder (e.g., Christensen et al., 2018; Ibrahim, 2020; Mannion & Leader, 2013) can impact the development of literacy skills (Bailey et al., 2017).

As in the case of typical development, phonological awareness is a significant linguistic predictor for reading achievement of children on the autism spectrum (Dynia et al., 2017). Phonological awareness is a complex emergent literacy skill as it necessitates the synthesis of many abilities, including language, speech and auditory processing skills (Eccles et al., 2020; Patscheke et al., 2016).

Music, Language Processing, and Literacy

Important overlaps are found between music, language, and early literacy abilities such that all three domains rely on processing structured sound sequences (Patel, 2003; Patel & Iversen, 2007). Music and language are organized hierarchically in lower level (i.e., musical notes & phonemes) and higher-level (i.e., musical chords & sentences) units (Degé & Schwarzer, 2011; Molnar-Szakacs & Overy, 2006). The overlap in shared basic processing mechanisms is described by Patel (2008) as the “shared sound category learning hypothesis” (i.e., sounds, music and speech, are organized into discrete categories which benefits memory) (McMullen & Saffran, 2004). Music and language both also engage similar cognitive processes, such as attention and memory (Patel et al., 1998). Musical processing activates language areas of the brain including Broca’s area (related to speech production) and Wernicke’s area (related to language comprehension) (Koelsch et al., 2002; Maess et al., 2001), providing evidence of neural overlap for music and language processing.

Given the established relationship between speech processing and reading (Banai et al., 2009; Moritz et al., 2013), theoretical frameworks have been developed to support literacy development through musical training. Patel (2011) presented the OPERA hypothesis which proposes that musical training benefits speech processing through adaptive plasticity in speech-processing networks. Plasticity occurs when there are “Overlaps (overlap in brain networks that process auditory features of music and speech), Precision (music places higher demands on networks than speech), Emotion (musical activity elicits strong positive emotion), Repetition (music reinforces the engagement in shared networks), and Attention (music requires focused attention)” (Patel, 2011). Thus, the OPERA hypothesis suggests shared neural resources by which music and speech processing are related and by which musical training can lead to far transfer effects of improved language processing capacity (Patel, 2011). To further explain the mechanisms behind the transfer between musical training and early literacy skills (i.e., phonological awareness skills), Tierney and Kraus (2014) propose the theoretical framework of “precise auditory timing hypothesis” (PATH). PATH suggests that music and language rely upon precise timing in the auditory system and that entrainment (i.e., precisely timed joint action) is a core mechanism involved in both (Tierney & Kraus, 2014). Therefore, PATH suggests that musical interventions, with emphasis on entrainment, promote precise timing sensitivity that improves sound perception, leading to the enhancement of phonological skills (Patscheke et al., 2019).

Beat and Rhythm Perception and Production and Phonological Awareness

Rhythm is one of the most essential organizational elements of music (Thaut et al., 1999) and can be defined as the division of time through distinct order and patterns of events (Hardy & LaGasse, 2013). Rhythmic structure is comprised of many elements, such as beat and meter, in which a hierarchical relationship exists (Nave-Blodgett et al., 2021). For instance, musical beat is a fundamental aspect of musical rhythm and is defined as an ongoing pulse that occurs at regular intervals in a musical piece (Toiviainen et al., 2020). Musical beat can be innately extracted from the rhythmic structure, which combines different patterns and durations of notes (Hardy and Lagasse, 2013; Toiviainen et al., 2020). The next level in the rhythmic structure is called meter, which describes a pattern in the musical piece where some beats are emphasized and in turn are perceived as more salient (Large & Snyder, 2009; Nave-Blodgett et al., 2021).

Rhythm perception and production play a crucial role in learning, development, and performance, as the timing of movement is important in several motor and cognitive functions (Thaut et al., 1999). Many studies have investigated the connection between phonological awareness and rhythm perception and production due to their overlapping features of timing and segmentation of sounds (Moritz et al., 2013). Rhythm also provides linguistic information in music and speech (Bhatara et al., 2011).

Empirical evidence shows that the sensitivity to temporal qualities of musical beat, rhythm and language begins in infancy. Extracting beat and rhythm from our auditory environment (whether music or language) is an innate ability (Toiviainen et al., 2020). For instance, infants as young as 5 months old can perceive differences in musical rhythmic patterns (Chang & Trehub, 1977; Demany et al., 1977; Trainor & Cirelli, 2015). By the age of 5, children are able to identify beat misalignment (e.g., when the tempo of the beat is 10% too fast or too slow) in a musical excerpt (Einarson & Trainor, 2016). Electroencephalogram (EEG) studies show that newborn infants between 2 and 3 days old are able to detect beat violations in a rhythmic sound sequence (Winkler et al., 2009) and children between 7 and 15 months old show the capacity to entrain to auditory rhythms (Cirelli et al., 2016), supporting the idea that beat perception is innate. Further, evidence from developmental research shows that infants use rhythm found in language as a cue to access phonological information in speech (Moritz et al., 2013). Specifically, newborn infants as young as 4 days old can discriminate languages based on their rhythmic properties (Mehler et al., 1988; Nazzi et al., 1998; Nazzi & Ramus, 2003).

A key commonality of phonological awareness, beat and rhythm perception is that they all require temporal processing (Moritz et al., 2013). Rhythm provides a temporal organizational structure for the perception and processing of music and language (Patscheke et al., 2019). For example, phonological segmentation tasks require the participant to process and manipulate the time intervals between speech sounds (e.g., pronounce phonemes or syllables more closely together) (Moritz et al., 2013). Accordingly, beat and rhythm perception tasks also require participants to process and manipulate time intervals with musical sounds (Iversen & Patel, 2008; Moritz et al., 2013). Bonacina et al. (2020) showed that rhythmic production predicted phonological awareness in a sample of 55 typically developing children between the ages of 5 and 8 years old. They suggest that the rhythmic production task used in their study contains similar processes to phonological awareness, such that the task required participants to integrate, attend to, and manipulate the temporal information of sounds (Bonacina et al., 2020).

Research on the association between beat and rhythm perception and production and phonological awareness has mostly included children with typical development and specific learning disorders and shows that beat perception seems innate, and that rhythm perception and production, which rely on beat perception, are important predictors of phonological awareness skills within these populations. Indeed, beat and rhythm perception and production are related to phonological awareness skill in 3 and 4 year old (Politimou et al., 2019), 5 year old (Anvari et al., 2002), and 6 to 8 years old children with typical development (David et al., 2007; Eccles et al., 2020; Holliman et al., 2010; Kertesz & Honbolygo, 2021), as well as in 8 to 13 year old children with dyslexia (Huss et al., 2011). Anvari et al. (2002) thus suggested that auditory processing mechanisms necessary for musical perception and phonological awareness are related, providing supporting evidence for the connection between early literacy and musical skills.

Indeed, rhythm perception and production and phonological awareness have been linked to reading acquisition, as both speech perception and reading proficiency are affected by temporal cues (Overy et al., 2003; Wolff, 2002). Youth between the ages of 10 and 16 years old with a reading disorder show greater difficulties with phonological awareness and temporal processing compared to those with typical reading abilities (Wolff, 2002) and children with dyslexia between 7 and 11 years old demonstrate more difficulties with musical aptitude tests (involving rapid temporal processing) compared to children without dyslexia (Overy et al., 2003). Further, children aged 7 to 11 with a reading disorder show significant improvements in phonological segmentation and spelling skills following a 15-week musical intervention compared to a waitlist control period (oral individual reading with instructor) (Overy, 2003), which again lends support to the link between reading and beat and rhythmic skills.

Music and Autism

It is particularly relevant to examine music perception, and specifically, rhythm perception of autistic children as, similar to typically developing youth, autistic youth share an affinity for music (Bhatara et al., 2013). Music is also valued by autistic youth in comparable ways to those reported by their typically developing peers such as for mood management (i.e., self-management of depression) and social affiliation (i.e., using music for a sense of belonging to a wider community) (Allen et al., 2009; Allen & Heaton, 2010). Early observations of autistic children by Kanner (1943, 1951) and Sherwin (1953) describe a special preoccupation and ability for music, exceptional acuity to sound and vibrations, rote memory for melodies, and a preference for singing over speaking. More recently, research provides evidence for musical abilities as a relative strength for people on the autism spectrum (Heaton, 2009; Quintin, 2019), moving towards a strength-based characterization of the condition (Mottron et al., 2006). Additionally, people on the autism spectrum have demonstrated strength in perceiving and processing musical stimuli, including enhanced musical memory and melodic perception (Heaton, 2003; Stanutz et al., 2014), distinguishing between pitch frequencies (Bonnel et al., 2010), producing and replicating coherent musical melodies (Quintin et al., 2013), recognizing music-evoked emotions (Quintin et al., 2011; Stephenson et al., 2016), showing intact rhythm perception abilities (Jamey et al., 2019), and simple and complex meter perception (DePape et al., 2012).

Rationale

This study aims to investigate the use of an enjoyable, non-academic, and non-verbal stimuli as a potential screening tool for the early literacy skills of autistic children with a wide range of cognitive abilities. Studies supporting the relationship between beat and rhythm perception and production abilities and phonological awareness have predominantly included participants with typical development or specific learning disorders with average cognitive abilities. To our knowledge, no study has investigated the link between beat or rhythm perception and phonological awareness abilities of children on the autism spectrum, which may be especially pertinent given their musical interests and abilities. Epidemiological studies indicate that intellectual disability and autism covary at rates of approximately 30% (Christensen et al., 2018), and for this reason, investigating the association between beat perception, which is a fundamental element in the rhythmic structure hierarchy, and phonological awareness for children with varying levels of cognitive abilities and autism characteristics is needed to extend the applicability of findings. Thus, in order to represent the heterogeneity of cognitive profile found among autistic children and to examine the theoretical implications underlying musical beat perception within this population, participants with a wide range of cognitive abilities are included in this study.

Objectives and Hypotheses

The first objective of this study is to investigate the relationship between beat perception and phonological awareness of autistic children. We hypothesized that beat perception performance would be positively correlated with phonological awareness skills of autistic children, given that a link has been found between beat and rhythm perception and production and phonological awareness abilities in populations with typical development (e.g., Anvari et al., 2002; Bonacina et al., 2020; Eccles et al., 2020; Moritz et al., 2013) and specific learning disorders (e.g., Overy et al., 2003; Wolff, 2002).

The second objective of this study was to explore whether beat perception skills are associated to heterogeneity across the autism profile by assessing whether beat perception is related to verbal and non-verbal cognitive skills, and autism characteristics. Exploring the relationship between beat perception, which is closely related to rhythm perception, and phonological awareness skills of autistic children holds important educational implication by helping to inform potential early literacy screening tools as well as musical interventions targeting reading outcomes.

Method

Participants

A total of 21 participants on the autism spectrum (*n* = 3 females) between the ages of 6 to 11 years old (*M* = 8.9, *SD* = 1.45) were included in this study. Participants were recruited at an elementary school for autistic children and other neurodevelopmental conditions. Ethical approval was granted by the University Research Ethics Board. Informed consent was obtained from parents and teachers, and assent obtained from child participants. Participant characteristics can be found in Table 1. All variables fell within conventional limits of normality (Field, 2013).

Table 1

Participant Characteristics

Variables	*M*	*SD*	Range
Age	8.9	1.45	6–11
NEPSY-II Phonological Awareness	6	4	1–12
Beat Perception –Total Accuracy (%)	51	17	15–90
Beat Perception – HiFA ratio	.07	.33	-.7–.8
Years of practice of a musical instrument or singing	.60	1	0–4
Years of formal music theory training	.27	.7	0–2
Number of instruments played	.07	.27	0–1
SRS-2 Total	70	10	55–87
SCQ Total	19	6	2–27
ADOS-2[1]	9	1	7–10
WASI-II PRI [2]	85	18	55–120
WASI-II VCI[2]	70	18	47–110
WASI-II FSIQ[2]	74	16	52–105

Note. Means (*M*), standard deviations (*SD*), age (in years), Hits – False Alarm (HiFA), Social Responsiveness Scale 2nd edition (SRS-2) total t-scores, Social Communication Questionnaire (SCQ) raw scores, Autism Diagnostic Observation Schedule 2nd Edition (ADOS-2) comparison score, Wechsler Abbreviated Scale of Intelligence 2nd Edition (WASI-II) used for perceptual reasoning index (PRI), verbal comprehension index (VCI), and full scale IQ (FSIQ), presented in standard scores.

1. ADOS-2: *n* = 11.
2. The Wechsler Intelligence Scale for Children, 5th Edition (WISC-V) was used to obtain verbal, non-verbal and FSIQ standard scores for one participant.

Autism Eligibility Measures. All participants included in this study had an Education Ministry code indicating that the student had been identified as having autism by a qualified professional (e.g., pediatrician, psychiatrist, psychologist) (Lazoff et al., 2010). Autism characteristics were also measured through parent or teacher report on the Social Responsiveness Scale-2 (SRS-2; Constantino& Gruber, 2012) and the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). The SCQ-Lifetime (focus on the child's entire developmental history) version of the questionnaire was used for parents and the SCQ-Current version for teachers. Parental report scores were used in analyses for both the SRS-2 and SCQ questionnaires and teacher report was used in cases where parental report was not obtained. The Autism Diagnostic Observation Schedule – Second Edition (ADOS-2, Lord et al., 2012) was administered last in a separate session, which 11 participants were able to complete before COVID-19 lock down. The ADOS-2 is a semi structured, standardized assessment of communication, social interaction, play, and restricted and repetitive behaviours.

All of the participants who completed an ADOS-2 in this study (n = 11) met criteria by obtaining a comparison score in the moderate to high range and a classification of autism spectrum/autism on modules 1, 2, or 3. The remaining participants included in this study (n = 10) met criteria for autism on at least the SRS-2 (cut-off score of 60) or the SCQ (cut-off score of 15).

Study Exclusion. A total of 36 participants were originally recruited to participate in this study. Of the initial sample, 6 participants were excluded due to missing ASD confirmation and 7 participants were removed because they were not able to complete the WASI-II or WISC-V before the COVID-19 lockdown. Finally, two participants were removed due to not understanding the beat perception task (see beat perception section below for details). The final sample included in the analyses comprised 21 participants.

Co-Occurring Conditions. Eight participants presented with co-occurring conditions other than autism spectrum disorder which included attention-deficit-hyperactivity disorder, language impairment, specific learning disorder, anxiety, and mild intellectual developmental disorder. All participants were able to complete the measures in this study.

Cognitive Abilities. The Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II; Wechsler, 2011) was used as a measure of cognitive functioning including non-verbal (perceptual reasoning: block design and matrix reasoning subtests), and verbal (verbal comprehension index; vocabulary and similarities subtests) skills. The expressive language level of all participants was high enough to answer all questions verbally, including the participants with a language impairment. To note, the Wechsler Intelligence Scale for Children, 5th Edition (WISC-V; Wechsler, 2014) was used as a measure of verbal (verbal comprehension index) and non-verbal (visual spatial index) skills for one participant in the sample, as the WASI-II was not available for this participant. These assessments are normed and standardized for individuals of 6 to 16 (WISC-V) and 6 to 90 (WASI-II) years old. Total raw scores are transformed into standard scores, where the mean is 100 and the standard deviation is 15.

Hearing Screening. A demographic questionnaire was completed by parents to rule out the contribution of hearing loss or impairment. In addition, each participant completed the practice portion of the beat perception task where they were asked if they could hear the stimuli and gave responses to the trials. Hearing loss or impairment was not indicated for any of the participants included in this study and all participants were able to complete the practice session of the beat perception task.

Musical Experience. Parents were asked to fill out a short questionnaire on their child's previous musical training and experience based on the Musical Training Subscale of the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen, Gingras, Musil, & Stewart, 2014) and adapted for parent report. Three specific questions were analysed in order to gain an understanding of participants' previous musical experience: "*For how many years has your child practiced a musical instrument or singing on a daily basis?*", "*How many years has your child been formally trained in music theory?*" and *"How many musical instruments (not including singing or voice) can your child play?"*. Data was reported for the above three questions as per previous research on musical skills of children on the autism spectrum (Quintin et al., 2011). Participants had minimal experience in playing a musical instrument/singing and in formal music theory training.

Experimental Measures

Phonological Awareness

Phonological awareness skills were measured using the Phonological Processing subtest of the NEPSY-II (Korman et al., 2007). The NEPSY-II (Korman et al., 2007) is standardized with clinical subgroups and recommended for children with exceptionalities including intellectual disability and autism (Brooks et al., 2009). It contains non-verbal and verbal items which makes it a useful measure for children with a wide range of abilities and can be administered to participants from 3 to 16 years of age. The Phonological Processing subtest contains non-verbal (receptive) items that assess word segment recognition by requiring the participant to identify words from word segments by pointing to pictures (e.g., the participant is asked to choose between 3 pictures to match "do-g"). The subtest also contains verbal items (expressive) that assess the ability to manipulate sounds and syllables in spoken words by requiring the participant to repeat a word and then to create a new word by omitting or substituting a syllable or phoneme (e.g., “coat”, now say it again but don’t say /k/, “oat”). Higher scores on the NEPSY-II Phonological Processing subtest indicate stronger phonological awareness skills. Raw scores are transformed into standardized scores, where the mean is 10 and the standard deviation is 3.

Beat Perception

Musical beat perception was measured using an adapted version of the Beat Alignment Test (BAT; Iversen & Patel, 2008) presented on a computer with EPrime 3. Participants were asked to listen to short musical excerpts with overlaid beeps (ON or OFF the musical beat, which can also be referred to as musical tempo). In the ON beat condition, beeps are in synchrony to the musical beat. In the OFF beat condition, beeps are 10 milliseconds too fast or too slow compared to the musical beat. Musical excerpts in the current task contained isochronous beat tracks (beats occurring at regular time intervals). Following each trial, participants were asked to choose whether the beeps matched the musical beat via a yes/no force-choice response.

The BAT (Iversen & Patel, 2008) is innovative as it solely requires participants to perceive the beat of the music without placing an additional demand to engage in overt synchronization (Iversen & Patel, 2008). Thus, the BAT (Iversen & Patel, 2008) was deemed to be an appropriate starting point to measure rhythm perception given that musical beat is a fundamental aspect of musical rhythm (Toiviainen et al., 2020). We chose the BAT instead of typical rhythm perception tasks, which require participants to discriminate between two musical sequences played consecutively (Iversen & Patel, 2008), thus placing a high demand on auditory working memory. The BAT is easily understood independently of the musical experience of participants (Iversen & Patel, 2008).

The performance of all participants was analysed by calculating Hits (number of correct responses for ON-beat trials/number of ON-beat trials) minus False Alarms (number of incorrect responses for OFF-beat trials/number of OFF-beat trials) (HiFA as per Tillman et al., 2009). The HiFA ratio accounts for the identification of a response bias (i.e., always responding with yes/no as a true bias or due to participants not understanding the task). Following the review of HiFA scores for all participants, two participants were identified as having a response bias towards the ON beat condition (100% of responding by clicking the yes forced choice response) or not understanding the task and were therefore removed from the study. Analyses were conducted using both the HiFA ratio and the percent accuracy score and revealed no difference in results. Therefore, we report results in terms of percent accuracy in order to facilitate interpretation of performance on this task.

Results

Paired sample t-tests were conducted to assess performance on the beat perception task comparing the ON beat and OFF beat conditions. Results revealed a statistically significant difference in performance between the ON and OFF beat conditions, $t(20) = 2.24$, $p = .03$. Participants were more accurate in identifying when the beeps matched the musical beat in the ON beat condition (% accuracy: $M = 59$, $SD = 22$, range = 10–90) compared to when the beeps did not match the musical beat in the OFF beat condition (% accuracy: $M = 43$, $SD = 24$, range = 0–90). This performance accuracy difference between conditions is consistent with what was found with typically developing adults (Iversen & Patel, 2008). However, low percentage accuracy rates across conditions indicate that the overall task was challenging.

The Relationship Between Musical Beat Perception and Phonological Awareness

Pearson correlation analyses were used to investigate the relationship between phonological awareness skills and musical beat perception across task conditions (Table 2).

Results revealed a statistically significant large positive correlation between phonological awareness skills and overall beat perception, $r = .550$, $p = .01$. Higher scores in phonological awareness skills are related to a more accurate performance on the musical beat perception task. In addition, analyses revealed a small positive correlation between phonological awareness skills and performance on the OFF beat condition, $r = .491$, $p = .02$. There was no relationship between the ON beat condition and phonological awareness abilities. The relationship between beat perception and phonological awareness remained significant when evaluated at Bonferroni corrected alpha level of .016 (.05/3), however, the correlation between the OFF beat condition and phonological awareness was no longer significant.

Table 2

Correlations Between Phonological Awareness and Musical Beat Perception

Variables	Beat Perception Overall Response Accuracy	ON Beat Accuracy	OFF Beat Accuracy
NEPSY-II Phonological awareness	.550**	.306	.491*

$^*p < .05$, $^{**}p < .01$.

The Relationship Between Musical Beat Perception, Cognitive Ability, and Autism Characteristics

Pearson correlation analyses were used to explore the relationship between musical beat perception and verbal/non-verbal cognitive abilities and autism characteristics (i.e., restricted interests/repetitive behaviours [RRB], and social communication and interactions [SCI]). The correlation matrix did not reveal a significant relationship between cognitive ability, autism characteristics and rhythm perception (Table 3). In addition, further examination of scatter plots did not reveal a pattern in the data between beat perception, cognitive ability and autism characteristics.

Table 3

Correlations Between Musical Beat Perception, Cognitive Ability, and Autism Characteristics

Variable	WASI-II VCI[1] (Verbal)	WASI-II PRI[1] (Non-verbal)	SRS-2 RRB	SRS-2 SCI
Beat Perception Overall Response Accuracy	.261	.390	-.310	-.393

Note. Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II) verbal comprehension index (VCI) and perceptual reasoning index (PRI), Social Responsiveness Scale 2nd edition (SRS-2) total t-scores: Restricted Interests and Repetitive Behaviour or Autistic Mannerisms (RRB), Social Communication and Interaction (SCI).
$^*p < .05$, $^{**}p < .01$.

1. The WISC-V was used to obtain verbal and non-verbal standard scores for one participant.

Discussion

The current study explored the relationship between phonological awareness skills and musical beat perception, a fundamental pre-requisite to rhythm perception, of children on the autism spectrum with a wide range of cognitive abilities, autism characteristics, and co-occurring conditions. The aim was to gauge the potential of musical beat perception, an enjoyable, non-academic, and non-verbal stimuli, as a screening tool for early literacy skills of children on the autism spectrum with diverse support needs. The present study also investigated the link between beat perception skills and level of severity with variables such as verbal and non-verbal cognitive abilities, and autism characteristics including restricted interests/repetitive behaviours and social communication and interaction. Including a sample of participants with heterogeneous abilities and characteristics allows for findings to be as representative as possible of the developmental profiles found across the spectrum and in the classroom. Results from this study can be summarized into three main findings: i) a positive correlation between phonological awareness skills and overall performance on the musical beat perception task, ii) a positive correlation between phonological awareness skills and the OFF beat condition of the task, and iii) no statistically significant relationship between performance on the beat perception task and cognitive ability or autism characteristics. We measured beat perception using the BAT (Iversen & Patel, 2008), where participants were presented with short musical excerpts with overlaid beeps (ON or OFF the musical beat) and asked to choose whether the beeps matched the musical beat. This task measured the fundamental aspect of rhythm perception, musical beat perception, and offered an appropriate choice of measure for participants with heterogenous cognitive skills compared to traditional rhythm discrimination tasks which place a high demand on auditory working memory skills.

Beat Perception Skills and Phonological Awareness Are Associated for Autistic Children

The first main finding supported our hypothesis showing that beat perception abilities were positively correlated with the phonological awareness skills of children on the autism spectrum. Higher scores in phonological awareness skills were associated with a more accurate performance on the beat perception task. Accordingly, participants with lower scores in phonological awareness had more difficulty matching the musical beat to the musical rhythm. A common auditory mechanism may underlie PA and beat perception (Patel, 2003, 2008). Music and language are processed by overlapping cortical and subcortical regions (i.e., middle and superior temporal gyri and inferior and middle frontal gyri) (Schön et al., 2010), and phonological awareness, beat and rhythm processing require temporal processing (Moritz et al., 2013; Nave-Blodgett et al., 2021). Our result showing a positive correlation between phonological awareness and beat perception suggest that both may also stem from common auditory mechanisms for children on the autism spectrum.

Further, our finding showing a positive correlation between beat perception and phonological awareness skills of children on the autism spectrum is consistent with previous studies of children with typical development reporting a link between rhythmic abilities (perception and production skills) and phonological awareness (e.g., Bonacina et al., 2020; Eccles et al., 2020, Mortiz et al., 2013). Eccles et al. (2020) propose that the association between rhythm perception and phonological awareness holds significant clinical implications for the assessment of phonological awareness skills, as typical screening tools rely heavily on linguistic stimuli. Obtaining an accurate assessment of early literacy skills is imperative when entering school in order to provide the necessary educational supports to students (Eccles et al., 2020) and standardized verbal early literacy measures have the potential to over/underestimate the phonological awareness skills of a child, particularly when a student presents with language difficulties (Eccles et al., 2020; Patscheke et al., 2016). Language difficulties are inherent to autism (APA, 2013; Pomper et al., 2019). Approximately 30%-50% of children on the autism spectrum do not have functional verbal speech (CDC, 2014; National Autism Association, 2014; Sandiford et al., 2013). Further, language deficits may range from language delays, poor comprehension of speech (APA, 2013), difficulties with initiation/sustaining conversation, or idiosyncratic use of language (Tager-Flusberg, 1999). Challenges in receptive and expressive oral language skills for children on the autism spectrum expand across linguistic domains (i.e., semantics, morphology, syntax) and may be particularly impaired in pragmatics (understanding of how context contributes to meaning) given the social impairments associated with autism (Eigsti et al., 2011; Westerveld et al., 2016). Therefore, the results from the current study are particularly important given the high rate of language difficulties of children on the autism spectrum and suggest an alternative to traditional verbal tasks that tend to underestimate the potential of children on the autism spectrum. Beat and likely rhythm perception tasks could thus be used as a proxy to assess phonological awareness.

The second main finding showed that phonological awareness skills and performance on the OFF beat condition of the experimental task were positively correlated, although this finding was not significant when Bonferroni correction was applied. There was no statistically significant relationship between phonological awareness abilities and performance on the ON beat condition. Participants with high phonological awareness skills were more accurate in their performance on the OFF beat trials compared to those with lower phonological awareness skills. It appears phonological awareness skills are related to performance on the musical beat perception task, especially during the more challenging trials (OFF beat trials). On the less challenging trials of the task (ON beat trials), phonological awareness abilities do not play as significant of a role in performance accuracy. Phonological awareness is as a metalinguistic skill that encompasses the ability to understand, attend to, analyse and manipulate sound structures in spoken language (Hudson et al., 2017; Scarborough & Brady, 2002; Schuele & Boudreau, 2008). Accordingly, participants with higher phonological awareness skills (i.e., metalinguistic skills) are more in tune to the timing and segmentation of sounds, which enables increased accuracy when analysing the more challenging OFF beat trials of the task (where the beep did not match the musical beat). Indeed, analyses also revealed that participants were more accurate in identifying when the beeps matched the musical beat in the ON beat condition compared to when the beeps did not match the musical beat in the OFF beat condition, suggesting that the OFF beat condition was more difficult.

No Association Between Beat Perception and Cognitive Skills or Autism Characteristics

The third main findings showed no statistically significant relationship between beat perception and verbal or non-verbal cognitive ability and autism characteristics. This result is consistent with a previous study that found that rhythm discrimination of autistic children did not have a significant relationship with verbal or non-verbal cognitive ability (Jamey et al., 2019). A larger sample size may hold the potential for more statistical power to detect a relationship among non-verbal cognitive ability and beat perception skills for children on the autism spectrum, for whom an association between global musical perception and non-verbal skills has been previously reported (Chowdhury et al., 2017; Quintin et al., 2013). An association between auditory rhythm perception and visual spatial frequency discrimination is also present in typical development (Sherman et al., 2013). Future studies should explore this relationship further to better understand the role of cognitive abilities on rhythm perception of autistic children. Alternatively, beat and rhythm perception may be independent of cognitive abilities, which is what our findings indicate.

Similar to Jamey et al. (2019) who investigated rhythm discrimination skills, the current study did not find an association between beat perception abilities and autism characteristics across the repetitive behaviour and social communication domains. The severity of autism characteristics does not seem to play an important role for beat and rhythm perception abilities. This result is encouraging as it suggests that beat and rhythm perception tasks hold the potential to be a valuable early literacy screening tool for children with autism characteristics that span across the spectrum.

Future Directions and Implications

In addition to increasing sample size, future studies should include more than one task to measure beat perception abilities and tasks that measure both beat and rhythm perception in order to expand on the current findings and capture different aspects of rhythm perception in addition to beat perception (e.g., meter). Although the participants could complete the beat perception task, low percentage accuracy rates across the OFF and ON beat conditions indicate that the overall task was challenging, which warrants the use of alternative tasks in future research, although we had chosen this task because of its simplicity.

Despite these limitations, our findings have important clinical and educational implications for school-aged children on the autism spectrum who present with heterogeneous cognitive profiles, autism characteristics, and one or more co-occurring conditions that can negatively impact early literacy development. Our findings support the use of beat, and possibly rhythm perception tasks as screening measures for children at risk for a reading disorder, as has been previously suggested (e.g., Moritz et al., 2013). Musical beat and rhythm perception tasks could be especially suitable given that they can be used across multilinguistic settings and in areas where standardized norms are not always available for assessments measures (Eccles et al., 2020; Wilsenach, 2016). As such, we suggest that beat and rhythm perception screening tasks can also be used to assess for potential difficulties with phonological awareness across developmental profiles, notably children who present with heterogeneous cognitive abilities and autism characteristics.

In addition, the current results help to inform music intervention research by emphasizing the potential of beat and rhythmic training as a valuable tool for linguistic and reading outcomes. For instance, we suggest the use of rhythm-based musical training interventions to target emergent literacy skills (i.e., phonological awareness). In the typical development population, rhythm production and perception skills gained through music interventions are thought to play a central role in improving phonological awareness (Moritz et al., 2013) and training through musical enrichment programs has been linked to gains in neural processing related to reading and language skills (Kraus et al., 2014). Given that phonological awareness is a predictor for reading ability (Carson et al., 2000), future steps would warrant an investigation as to whether rhythm-based musical interventions can serve as a developmentally appropriate non-academic activity to aid in remediating reading disability (Overy et al., 2003) of autistic children. Autistic children also make greater gains in expressive vocabulary following melodic intonation therapy than traditional speech and language therapy (Chenausky et al., 2016), which could be mediated by improvements in phonological awareness associated with rhythmic entrainment in melodic intonation therapy. As such, gains in literacy may also result from rhythmic entrainment.

Conclusions

Results provide exploratory evidence that phonological awareness and beat perception abilities are positively correlated for autistic children Further, phonological awareness skills seem to be especially important when the complexity of beat perception tasks increases. Phonological awareness and beat and rhythm perception may underlie a common auditory mechanism in the typical population, which seems to also be the case for autistic children. This study has expanded on findings from previous research with populations with typical development and specific learning disorders by showing that a relationship between beat perception and phonological awareness abilities is also present for children on the autism spectrum. In addition, results indicate that autism characteristics are not associated with beat perception abilities. In contrast with a large body of research highlighting deficits and impairments of individuals on the autism spectrum, the current study is innovative in its focus on utilizing the strengths and interests (music) of this population to remediate areas of challenge. Beat and rhythm perception tasks may thus represent a proxy to assess phonological awareness because musical tasks offer an alternative to traditional verbal tasks that tend to underestimate the potential of children on the autism spectrum.

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Chapter 6: Discussion

Rationale

We learn to read with the ultimate goal to comprehend or understand text. This goal is highlighted in a prominent reading development theory, the Simple View of Reading (Gough & Tunmer, 1986; Hoover & Gough, 1990). The Simple View of Reading posits that reading comprehension is the main purpose when learning to read, and that reading comprehension is attained when decoding (which encompasses phonological awareness) and listening comprehension are developed (Hoover & Gough, 1990). Accordingly, reading comprehension is one of the main areas of research on literacy and autism and shows that some autistic children experience challenges in reading comprehension (Davidson & Ellis Weismer, 2014; Henderson et al., 2014; Nation et al., 2006), as well as in decoding (Nation et al., 2006), and word reading abilities (Westerveld et al., 2018).

Yet, efforts to uncover the underlying mechanisms to reading comprehension development of autistic children are lacking and remain a valuable area to explore as evidence indicates that reading challenges in later childhood can be identified during emergent literacy development (Davidson & Ellis Weismer, 2014). Early identification and intervention focused on difficulties in precursor skills to reading comprehension could lead to a reduction in reading difficulties as a child progresses through school. Therefore, investigations into one of the first necessary skills in learning to read, phonological awareness, is appropriate for preliminary research. Phonological awareness is considered one of the most robust emergent literacy predictors for later reading abilities, such as for word decoding and reading comprehension (National Early Literacy Panel, NELP, 2008) in typical development, and is also a significant predictor for reading developmental of autistic children (Dynia et al., 2017).

This dissertation aimed to advance our knowledge of the development of phonological awareness skills for school age autistic children by providing insight into literacy development of children who present with a wide range of support needs, cognitive profiles, autism characteristics and co-occurring conditions. Findings indicate for the potential of an alternative and strength-based approach with music to identify literacy skill difficulties among autistic children. The manuscripts that compose this dissertation placed particular emphasis on exploring the emergent literacy skills of autistic children with heterogeneous cognitive profiles with the aim to reflect, as much as possible, the wide range of abilities present across the spectrum.

Emergent Literacy Skills of School Age Autistic Children: Findings and Contributions from Manuscripts 1 and 2

A first objective of the current dissertation was to explore the literature on intervention programs targeting the emergent literacy skills (phonological awareness and word recognition) of autistic children to determine knowledge gaps within the field and to inform study methodology of the subsequent manuscripts included in this dissertation. Manuscript 1 accomplished this objective by summarizing emergent literacy interventions for autistic children, identifying the characteristics of the participants included in emergent literacy interventions, and by highlighting knowledge gaps and limitations in emergent literacy intervention research with autism. Although results showed that computer-based and non-computer-based interventions can lead to significant increases in phonological awareness or word recognition skills, adaptations to the implementation of the original intervention were required across numerous studies to account for the child’s individual support needs, such as the use of visual aids, language supports, and 1:1 teaching. This finding demonstrates the importance of investigating the relationship between areas of strength for autistic children and early literacy to lead to interventions that utilize a strength-based approach to target the development of emergent literacy skills, without the need for additional adaptations. This finding therefore informs the rational for manuscript 3, which explored the link between musical beat perception (a relative strength for autistic children) and phonological awareness.

Manuscript 1 suggests that the current state of the literature on emergent literacy skill interventions and autism is preliminary and thus inadequate to provide evidence-based instructional practices for teaching emergent literary skills to autistic children. Knowledge gaps identified through the scoping review informed the recommendations for future studies to provide detailed characterization of participant included in studies, to clearly define the use of emergent literacy terms, and to increase the overall rigor of study designs. As such, the recommendations outlined in manuscript 1 were considered for manuscripts 2 and 3.

The second objective of this dissertation was to clarify the development of phonological awareness skills for school age autistic children. Manuscript 2 accomplished this objective through comparing the phonological awareness abilities of autistic children to non-autistic children, matched on chronological age, verbal and non-verbal cognitive skills, and by exploring the relationship between individual differences in cognitive skills and autism traits and phonological awareness skills. The limited previous studies investigating the phonological awareness skills of school age autistic children did not match groups on cognitive or language skills (e.g., Nally et al., 2018; Smith Gabig, 2010), although the autism and non-autistic groups were matched on chronological age in one study (Smith Gabig, 2010). Nally et al. (2018) did not have a neurotypical comparison group in their study, but instead divided autistic children into two groups based on chronological age (group 1: 3:30-5:10 years; group 2: 6:00-17:3 years). Both studies showed difficulties in phonological awareness skills for school age autistic children

(Nally et al., 2018; Smith Gabig, 2010). In addition, the preschool literature remains unclear, showing inconsistent findings among studies based on whether participant groups were matched or not on verbal and non-verbal cognitive skills. Therefore, manuscript 2 is a valuable contribution to the school age literature on the phonological awareness skills of autistic children as the study design includes group matching across chronological age and verbal and non-verbal/perceptual reasoning cognitive skills and thus, aimed to clarify the discrepancies among previous studies in the field. The hypothesis in manuscript 2 was that there would be no significant difference in performance on the phonological awareness task between autistic and non-autistic children. Results supported the hypothesis showing that the autistic and non-autistic groups showed comparable performance on the phonological awareness task and were consistent with the preschool studies showing similar phonological awareness abilities between autistic and non-autistic children when matched on verbal and non-verbal skills (e.g., Westerveld et al., 2020). Results contrast the literature suggesting that autistic children show phonological awareness difficulties compared to non-autistic children (e.g., Dynia et al., 2019, 2017; Nally et al., 2018; Smith Gabig, 2010). Our findings further substantiate the notion that inconsistencies in the literature on phonological awareness skills of preschool autistic children appear to be the result of controlling for individual variables and group matching, such that there are few differences between groups who have similar verbal and non-verbal cognitive skills. Overall, results indicate that autistic and non-autistic children show comparable phonological awareness skills during the school age period of development, after beginning formal reading instruction.

Furthermore, manuscript 2 examined and contrasted the role of verbal and non-verbal/perceptual reasoning cognitive skills and autism characteristics (social communication/interaction and repetitive behaviours/restricted interests) on phonological awareness task performance of autistic children. The contribution of verbal skills, non-verbal skills, and autism characteristics to phonological awareness were explored given the mixed findings as to the predictive role of autism characteristics on phonological awareness skills (e.g., Dynia et al., 2019 vs. Wodka et al., 2013) and due to evidence for a unique and uneven cognitive profile among autistic children, such that perceptual reasoning skills are a strength compared to verbal skills (Ankenman et al., 2014; Charman et al., 2011; Courchesne et al., 2015). Results revealed that only perceptual reasoning skills, and not verbal cognitive skills, are a positive predictor for the phonological awareness skills for autistic children and are not significantly correlated for non-autistic children and that there is no statistically significant relationship between autism characteristics and phonological awareness for either group. Results from manuscript 2 support findings from previous studies showing no association between phonological awareness skills and autism characteristics across the repetitive behaviour (RRB) and social communication (SCI) domains (Dynia et al., 2019; Macdonald et al., 2020; Wodka et al., 2013), and are distinct from one study which shows that greater autism characteristics predict increases in reading difficulties (Nally et al., 2018).

Overall, findings from manuscript 2 contribute to the literature by clarifying that the phonological awareness skills of school age autistic children are comparable to non-autistic children and by suggesting that perceptual reasoning skills play a greater role in literacy development for children on the autism spectrum compared to non-autistic children. The Enhanced Perceptual Functioning (EPF; Mottron et al., 2001, 2006, 2009) and the Trigger-Threshold-Target model (TTT; Mottron et al., 2014) models of autistic cognitive profiles account for the relative strength in non-verbal/perceptual skills (visual and auditory) compared to verbal skills for persons on the autism spectrum. Taken together with results from manuscript 2, it appears that autistic children utilize visual and auditory stimuli in their environment when learning to read and, thus, their enhanced perceptual processing could be a significant contributor to early literacy skill acquisition. The importance of considering the role of perceptual reasoning skills on phonological awareness abilities for autistic children elicits us to question the current phonological awareness screening measures using verbal tasks. Phonological awareness assessment methods often require the child to have sufficient expressive/oral language in order to rhyme (*Can you tell me a word that rhymes with sock?*), segment (*Tell me all the little sounds you hear in blimp. /b/, /l/, /i/, /m/, /p/.*), blend (*What word does it make when you say these together: /s/, /p/, /u/, /n/? Spoon*), and manipulate (*What's left when you leave out the /n/ in band? Bad*) sounds (Scarborough & Brady, 2002). Collectively, manuscripts 1 and 2 contribute to the growing body of research on emergent literacy skills and autism by highlighting the importance of investigating the relationship between areas of strength for autistic children and early literacy to inform intervention practices (manuscript 1), all while considering the role of perceptual skills, perhaps even over verbal skills, for the reading development of autistic children (manuscript 2) and its implication for the current phonological awareness assessment methods.

Musical Beat Perception and Emergent Literacy Skills of Autistic Children: Findings and Contributions from Manuscript 3

Thus, the final objective of this dissertation was to explore the relationship between a non-verbal area of strength for autistic children and phonological awareness skills. Manuscript 3 met this objective through examining the link between musical beat perception and phonological awareness for autistic children with a wide range of cognitive skills. Beat perception, a fundamental element of rhythm perception, is the topic of a growing body of research suggesting that non-linguistic, musical predictors, are informative of literacy acquisition in neurotypical development (Eccles et al., 2020; Politimou et al., 2019) due to the necessity for temporal processing required for both music and reading (Moritz et al., 2013). The relationship between rhythm perception and phonological awareness has only been researched for neurotypical populations or for individuals with specific learning disorders with average cognitive abilities. Manuscript 3 contributes to the literature as it is the first study, to our knowledge, to explore this connection for autistic children, which is particularly relevant given their relative strength in musical processing (as described in Chapter 2). The Phonological Processing subtest of the NEPSY-II (Korman et al., 2007) was used to assess phonological awareness skills. Although this subtest does contain verbal (expressive) items, it also contains non-verbal (receptive) items. In addition, the clinical validity and utility of the Phonological Processing subtest of the NEPSY-II has been specifically studied for autistic children and children with an intellectual disability and showed large effect sizes (d=1.10 and d=1.68, respectively) indicating that this subtest is able to identify challenges in phonological awareness for these populations (Brooks et al., 2009). Therefore, the NEPSY-II Phonological Processing subtest was deemed as an appropriate measure of phonological awareness for this dissertation. An adapted version of the Beat Alignment Test (BAT; Iversen & Patel, 2008) was chosen as the measure of musical beat perception as it solely requires participants to perceive the beat of the music without placing an additional demand to engage in overt synchronization and is easily understood independently of the musical experience of participants (Iversen & Patel, 2008).

The hypothesis in manuscript 3 was that beat perception performance would be positively correlated with phonological awareness skills of autistic children. Results from manuscript 3 supported the hypothesis showing that beat perception abilities were positively correlated with the phonological awareness skills of children on the autism spectrum and revealed that phonological awareness skills and performance on the OFF beat condition of the experimental task (more challenging trials of the task) were positively correlated. Manuscript 3 contributes to the literature by suggesting that beat perception and phonological awareness skills stem from a common auditory mechanism for autistic children, complimenting findings from neurotypical research (Patel, 2003, 2008). Manuscript 3 also explored whether beat perception skills were related to verbal and non-verbal cognitive skills, and autism characteristics. Results revealed that there was no statistically significant relationship between beat perception and verbal or non-verbal cognitive ability and autism characteristics. Although we would have expected a relationship between non-verbal cognitive ability and beat perception skills for autistic children, given reports from previous studies on the topic (Chowdhury et al., 2017; Quintin et al., 2013), we hypothesize that a larger sample size is needed to detect a significant relationship.

Manuscript 3 contributes to the literature as being the first study to explore the relationship between beat perception and phonological awareness for autistic children, which has previously been explored for other populations. As such, preliminary findings indicate that continued investigation into the use of musical perception as a tool to identify reading challenges for autistic children is a valuable avenue for research to explore.

Clinical and Educational Implications

Clinically, findings from the present dissertation are in line with work showing that cognitive skills develop differently for autistic individuals (e.g., Nader et al., 2015; Soulières et al., 2011), and this is likely having an impact on learning and reading development. In turn, increased knowledge of the unique cognitive profile of autistic children should lead to adaptation to the curriculum and consideration of the environment goodness-of-fit to meet their learning profiles (Leadbitter et al., 2021). This implication was further highlighted by findings in manuscript 1, which encouraged educators and practitioners to set individualized goals for their students and make adaptations to standard intervention/teaching practices to accommodate students on the autism spectrum with a broad spectrum of support needs and developmental levels.

Findings across the manuscripts in the present dissertation reveal that autism characteristics do not seem to play an important role in phonological awareness skills or musical perception abilities. This finding is promising as it suggests that having high levels of autism characteristics does not impact a child's ability in learning to read or in processing musical beat. Nation et al. (2006) suggest that autistic students may rely on visual cues as a primary strategy when reading words. Accordingly, the present results underscoring the contribution of perceptual reasoning skills to early literacy development support the use of strength-based approaches to reading instruction for autistic children such as using non-verbal aids like accompanying visual or auditory stimuli (i.e., music and pictures). In addition, findings from the present dissertation expand on previous recommendations of using beat perception as a screening measure for children at risk for a reading disorder (e.g., Moritz et al., 2013) to autistic children who may be experiencing reading challenges. Non-verbal perceptual tasks, such as beat/rhythm perception tasks may offer an alternative and appropriate way to screen for phonological awareness abilities for children with a wide range of developmental profiles. The link between beat perception and phonological awareness established when using a computer-based beat perception task in manuscript 3 is promising, as it compliments findings in manuscript 1 showing that computer-based interventions can lead to improvements in emergent literacy skills of autistic children. Therefore, computer administered musical perceptions tasks should continue to be examined in prospective studies.

Limitations and Future Directions

The generalization of the current findings could be strengthened with a larger sample size of participants included across the studies. This limitation was also noted following a review of the literature in manuscript 1, showing that most studies included in the scoping review had small sample sizes ranging from one to 23 participants, with seven studies including five participants or less. Sample size is often a challenge when conducting research with specific populations, including autistic children. In addition, the relatively smaller sample sizes in manuscript 2 and 3 can be attributed to the time and resources involved in obtaining detailed participant characterization. For instance, validation of an autism diagnosis, over and above a prior diagnosis from a clinician or Québec Education Ministry code, was achieved through one or more standardized measures and questionnaires (i.e., Social Responsiveness Scale – Second edition, Constantino & Gruber, 2012; Autism-Spectrum Quotient, Baron-Cohen et al., 2001; Social Communication Questionnaire, Rutter et al., 2003) and the administration of the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2, Lord et al., 2012) across empirical studies included in this dissertation. Validating the autism spectrum disorder diagnosis and characteristics for each participant was a challenging but essential goal within this dissertation to increase generalizability of findings and to address a knowledge gap identified in manuscript 1, where only 3 studies in the review validated the autism characteristics of their samples. Despite the small sample sizes, manuscript 2 and 3 provide valuable insight into phonological awareness development of school age autistic children and the relationship between a non-linguistic predictor (beat perception) and emergent literacy skills for this population.

Manuscripts within this dissertation did not include specific standardized measures of reading skills, which limited the ability to measure the presence of hyperlexia within the sample of participants included in the studies. Given that the presence of hyperlexia among autistic children is estimated to be between 6-20% (Ostrolenk et al., 2017), future studies examining the emergent literacy profiles of school age autistic children should include measures of reading skills to gain insight into distinct reading profiles. In addition, although we had chosen the beat perception task because of its simplicity, low percentage accuracy rates across the OFF and ON beat conditions indicated that the overall task was challenging for the children included in manuscript 3. Future studies should include more than one task to measure beat perception abilities and tasks that measure both beat and rhythm perception in order to expand on the current findings and capture different aspects of rhythm perception in addition to beat perception (e.g., meter). Lastly, a noteworthy limitation of the present dissertation was the absence of representatives of the autism community. Autistic persons or stakeholders (e.g., parents of autistic children) perspectives would have been a valuable contribution to the conceptualization, design, and methodology of this dissertation.

Due to the Coronavirus pandemic, this dissertation was unable to include the rhythm-based musical intervention which was halfway complete at the time of the onset of the pandemic. However, findings from the current dissertation help to inform music intervention research by emphasizing the potential of rhythmic training as a valuable tool for linguistic and reading outcomes. For instance, we suggest the use of rhythm-based musical training interventions to target emergent literacy skills (i.e., phonological awareness). In neurotypical development, rhythm and beat production and perception skills gained through music interventions are thought to play a central role in improving phonological awareness (Moritz et al., 2013). For example, engaging in rhythmic/sensorimotor entrainment training resulted in improvements in phonological awareness (Maróti et al., 2019). Moreover, Degé and Schwarzer (2011) compared the effect of a musical training program to a phonological training program on the phonological awareness skills of preschool children, children in both the musical program and the phonological training program show significant improvements in phonological awareness skills (Degé & Schwarzer, 2011), highlighting the positive impact and far transfer effect that musical training can have on early literacy abilities. Following musical training in kindergarten, longitudinal results indicate that rhythm production ability is related to phonological skills in both kindergarten and in second grade and that children who receive musical training show greater improvement in phonological awareness skills at the end of kindergarten compared to those with less musical training (Mortiz et al., 2013). Accordingly, rhythm sensitivity (Mortiz et al., 2013), and possibly beat perception (Kertesz & Honbolygo, 2021), seem to be pre-cursors to early literacy skill acquisition.

Musical intervention and programs for autistic individuals show benefits across several skills, including increases in appropriate social behaviours (Kern et al., 2007; Simpson & Keen, 2011), increased social engagement within home and community settings (Geretsegger et al., 2014), improved attention to tasks (De Vrines et al., 2015), and positive outcomes in language gains, including increases in gestural and verbal skills (Lim & Draper, 2011; Warren et al., 2010) and speech repetition ability (Chenausky et al., 2016). Given that phonological awareness is a predictor for reading ability (Carson et al., 2000), and is positively related to the beat perception abilities of autistic children (manuscript 3), future steps would warrant an investigation as to whether beat/rhythm-based musical interventions can serve as a developmentally appropriate non-academic and non-verbal activity to aid in remediating reading difficulties (Overy et al., 2003) of children on the autism spectrum which may also generalize to other students with or without special education needs. The engaging quality that music holds for children is an important tool to be utilized, as engagement facilitates learning (Wolf et al., 2000). Findings may lead to direct applications to foster positive inclusion of students on the autism spectrum or other learning differences in educational and community settings.

Chapter 7: Final Summary and Conclusion

The overall aim of this dissertation was to elucidate the development of phonological awareness (PA) skills of school age children on the autism spectrum with heterogeneous cognitive profiles and autistic trait, given the mixed findings in the literature. Specifically, the scoping review and two empirical studies that make up the present dissertation aimed to advance our knowledge on phonological awareness development for school age autistic children and prompted the exploration into strength-based skills, such as musical beat perception, to identify potential challenges in emergent literacy skills for this population.

The objectives were met through the three manuscripts within this dissertation. Manuscript 1 consisted of a scoping review of the literature on interventions targeting the foundational emergent literacy skills of phonological awareness and word recognition for autistic children. As such, Manuscript 1 provided an overview of current practices used for teaching emergent literacy skills to autistic children and set the groundwork for the subsequent two empirical manuscripts by identifying knowledge gaps in participant characterization, definitions of emergent literacy terms used in research, and study designs. Next, Manuscript 2 compared the PA skills of autistic children to non-autistic children and explored the relationships among cognitive skills, autism traits and PA skills. Finally, Manuscript 3 explored the relationship between musical beat perception and PA skills of autistic children.

Findings from Manuscript 1 highlighted the need for further investigation into interventions which utilize the strengths and interests of autistic children to establish evidence-based practice for teaching emergent literacy skills. Results from Manuscript 2 clarified previous investigations into the PA skills of autistic children by showing that non-verbal/perceptual reasoning skills, and not autism characteristics or verbal skills, play a significant role in PA development. This dissertation also included the first investigation into the relationship between a non-linguistic predictor and PA for autistic children (Manuscript 3) and revealed that akin to neurotypical development, beat perception skills are related to emergent literacy development for autistic children. Together, findings hold important educational implications for autistic children (as detailed in Chapter 6) and help inform instructional practices and potential screening tools targeting early literacy skills by suggesting a need for approaches that capitalize on the strength in perceptual processing while relying less on verbal skills.

Complete Bibliography

This reference list includes all references cited throughout the non-manuscript sections of the thesis.

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