Enhancing Communication in Minimally Speaking Autistic Children:

Comparing Augmentative and Alternative Communication Interventions and Expanding Vocabulary Assessment Tools

Angela MacDonald-Prégent

School of Communication Sciences and Disorders

McGill University, Montréal

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General Abstract

Rationale: Approximately 25-30 percent of children on the autism spectrum develop little spoken language, that is, are minimally speaking (Rose et al., 2016; Tager-Flusberg & Kasari, 2013). Teaching these children to use Augmentative and Alternative Communication (AAC) is essential to increase their ability to communicate, promote social inclusion, and improve quality of life (McNaughton et al., 2019). There is empirical support for using AAC to accomplish these outcomes (Dada et al., 2021; Drager & McNaughton, 2010; Leonet et al., 2022; O'Neill et al., 2018; Syriopoulou-Delli & Eleni, 2022), but more research is needed to understand what components (e.g., AAC display, theoretical approach) maximize the rate at which an AAC system is learned. Furthermore, we must expand the options of language assessment tools capable of capturing the full range of this autistic subgroup's communicative repertoire, including AAC use (Kasari et al., 2013a).

Methods: To address these gaps in the literature, in Chapter 1, we tested and compared the effectiveness of two AAC interventions for minimally speaking autistic children that differ in AAC display design (i.e., consistent- versus variable-symbol location) and theoretical approach (naturalistic developmental behavioural versus behavioural only) when delivered by caregivers who were coached remotely via telehealth. In Chapter 2, we modified a caregiver-report assessment tool, MacArthur-Bates Communicative Development Inventory: Words & Gestures, English Long Form (CDI: Words and Gestures; Marchman et al., 2023), to explore how vocabulary size and composition are impacted by considering minimally speaking autistic children's non-spoken, as well as spoken, expressive vocabulary.

Results: In Chapter 1, we demonstrated that both caregiver-implemented AAC interventions significantly, and similarly, increased the frequency and complexity of child AAC use. However, caregivers in the naturalistic developmental behavioural AAC intervention mastered the implementation of their intervention in a shorter period when compared to the caregivers implementing the behavioural only AAC intervention. In Chapter 2, we found that accounting for both spoken and non-spoken communication significantly increased participants reported expressive vocabulary.

Implications/Contributions: In Chapter 1, we added to the literature on AAC interventions by demonstrating that both interventions tested, which differed in display and approach, were equally effective in increasing AAC use. However, we found that an AAC intervention using a naturalistic developmental behavioural approach may be easier for caregivers to learn. In Chapter 2, we demonstrated the value of including both spoken and non-spoken modalities of communication when assessing the expressive vocabulary of minimally speaking autistic children, therefore, expanding the number of language assessment tools adapted for this population.

Résumé

Justification : Entre 25 et 30 pour cent des enfants sur le spectre de l'Autisme sont non-parlants, c'est-à-dire développent peu de langage verbal (Rose et al., 2016 ; Tager-Flusberg & Kasari, 2013). Il est essentiel d'apprendre à ces enfants à utiliser la Communication Améliorée et Alternative (CAA) afin d'augmenter leur capacité à communiquer, de promouvoir leur inclusion sociale et d'améliorer leur qualité de vie (McNaughton et al., 2019). La CAA est soutenue par des études empiriques (Dada et al., 2021 ; Drager & McNaughton, 2010 ; Leonet et al., 2022 ; O'Neill et al., 2018 ; Syriopoulou-Delli & Eleni, 2022), mais des études supplémentaires sont nécessaires pour comprendre quelles composantes (par exemple, concernant l'affichage d'un système de CAA ou l'approche théorique) maximisent le taux d'apprentissage d'un système de la CAA. De plus, il est important d'élargir la gamme d'outils d'évaluation du langage permettant d'identifier l'étendue du répertoire communicatif de ce sous-groupe d'autistes, y compris l'utilisation de la CAA (Kasari et al., 2013a).

***Méthodes* :** Pour remédier à ces lacunes de connaissances, dans le chapitre 1, nous présentons et comparons l'efficacité de deux interventions de CAA pour des enfants autistes non-parlants administrées par des aidants que nous avons formé à distance via télésanté. Ces deux interventions diffèrent quant à l'affichage du système de CAA (c.-à-d., positionnement constant ou variable des symboles) et à l'approche théorique (l'une est comportementale et développementale naturaliste, l'autre uniquement comportementale. Dans le chapitre 2, nous présentons un outil d'évaluation modifié, le *MacArthur-Bates Communicative Development Inventory : Words & Gestures, English Long Form* (CDI :

Words and Gestures; Marchman et al., 2023) rapporté par les aidants. Cela afin d'explorer comment la richesse et la composition du vocabulaire sont affectées par la prise en compte du vocabulaire expressif parlé et non-parlé d'enfants autistes non-parlants.

Résultats : Dans le chapitre 1, nous avons démontré que les deux interventions de CAA administrées par les aidants augmentaient de manière significative et comparable la fréquence et la complexité de l'utilisation de la CAA par l'enfant. Cependant, les aidants de l'intervention de CAA comportementale et développementale naturaliste ont maîtrisé la mise en œuvre de leur intervention plus rapidement que les aidants administrant l'intervention de CAA uniquement comportementale. Dans le chapitre 2, nous avons constaté que la prise en compte de la communication non parlée, en plus de la communication parlée, augmentait de manière significative le vocabulaire expressif rapporté par les participants.

Implications/Contributions : Dans le chapitre 1, nous avons contribué à la littérature sur les interventions de CAA en démontrant que les deux interventions testées, qui différaient dans l'affichage d'un système de CAA et l'approche, étaient comparablement efficaces dans l'incitation à utiliser la CAA. Cependant, nous avons constaté qu'une intervention de CAA utilisant une approche comportementale et développementale naturaliste semblait plus facile à apprendre/accessible pour les aidants. Dans le chapitre 2, nous avons démontré l'intérêt d'inclure les modalités de communication non-parlée lors de l'évaluation du vocabulaire expressif d'enfants autistes non-parlants, et celui d'augmenter le nombre d'outils d'évaluation du langage inclusifs de cette population.

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To my fellow SCSD research students (both past and present) and the members of my lab, thank you for sharing this challenging yet rewarding journey with me. The camaraderie, writing sessions, and countless discussions over tea (or something stronger) have made this process not only bearable but enjoyable. We've laughed, stressed, and celebrated together, and I couldn't have asked for a better group of colleagues to navigate this experience with. Your friendship and support have been a source of strength, and I know the connections we've built will last long beyond our academic pursuits.

To my little Charlie, my brightest star and biggest source of joy. At just three years old, you fill my world with wonder, laughter, and love. Your giggles, curiosity, and boundless energy remind me daily of what's truly important in life. One day, I hope you'll know that I did this not just for myself, but for you -to show you that with passion and perseverance, anything is possible.

To my amazing husband, Dan, my partner-in-crime and the real MVP of this whole PhD saga. From our early days together to almost eight years of marriage (and countless years of you putting up with my antics), you've always been by my side. When we moved to Montreal for your job, I figured, "Hey, why not throw a PhD into the mix?"- and you didn't flinch. You took on bedtime duty, toddler wrangling, and weekend parenting marathons like a pro while I ran off to intervention sessions and burned the midnight oil writing my thesis. Now, as we head to Halifax, I just want to say -thank you for keeping me sane, laughing, and caffeinated through it all. Here's to surviving yet another adventure!

Finally, to my dad, who passed away just three weeks before I embarked on this PhD journey: you taught me everything I know about perseverance and never letting limits. Your belief that no opportunity should be wasted has shaped everything I've done. But perhaps the greatest gift you gave me was your sense of humour -the ability to laugh through even the toughest times and stay relaxed when things get hard. I carried that with me throughout this journey, finding ways to lighten the load when the pressure mounted. This accomplishment is as much yours as it is mine.

Contribution to Original Knowledge

In this thesis, I have made significant contributions to the area of Augmentative and Augmentative Communication assessment tools and intervention knowledge/options for minimally speaking children on the autism spectrum. My research focuses on understanding what components of an AAC intervention (AAC display, theoretical approach) maximize the rate at which an AAC system is learned by minimally speaking autistic children which is an underexplored area.

One of the key contributions of this thesis is comparing an AAC intervention that uses a consistent-symbol location design and a naturalistic developmental behavioural approach against an active control that uses a variable-symbol location design and a behavioural approach. In doing so, I showed that both AAC interventions increased AAC use to a similar degree, at least in minimally speaking autistic children who are emerging communicators, within the timeframe tested (12 weeks). However, I also found that the naturalistic developmental behavioural AAC intervention was mastered by caregivers in a shorter period (approximately 6 one-hour individual coaching sessions) than the behavioural AAC intervention (approximately 12 one-hour individual coaching sessions).

Finally, I created the AAC-modified Communicative Development Inventory: Words and Gestures (AAC-modified CDI: Words and Gestures; MacDonald-Prégent & Nadig, 2024) through some simple additions to the MacArthur-Bates Communicative Development Inventory: Words and Gestures, English Long Form (CDI: Words and Gestures; Marchman et al., 2023). I found that using the AAC-modified CDI: Words and Gestures to account for both spoken and non-spoken communication significantly increased the reported expressive

vocabularies of minimally speaking children. This is the first caregiver report measure to allow for the detailed collection of a child's expressive vocabulary in both spoken and non-spoken forms, providing a more comprehensive understanding of their communication abilities.

Contribution of Authors

This thesis consists of two manuscripts with an accompanying general introduction, bridging text, and general discussion that were developed through collaborative efforts. The specific contributions of authors involved in each manuscript are detailed below.

Chapter 1

Authors: Angela MacDonald-Prégent and Aparna Nadig

- **Angela MacDonald-Prégent:** Developed the initial concept and framework for the manuscript, conducted the literature review, recruited participants, collected and analyzed data, and wrote the initial manuscript
- **Aparna Nadig:** Provided guidance on the conceptual framework and methodology, provided significant input on the research questions and experimental design, assisted with data interpretation, and critically reviewed and revised the manuscript

Chapter 2

Authors: Angela MacDonald-Prégent, Lauren Mcguinness, Aparna Nadig

- **Angela MacDonald-Prégent:** Developed the initial concept and framework for the manuscript in collaboration with co-authors, conducted the literature review, recruited participants, collected data, completed the re-analysis, assisted with data interpretation, drafted all sections of the initial manuscript apart from the results section, revised and submitted the manuscript for publication

- **Lauren Mcguinness**: Developed the initial concept and framework for the manuscript in collaboration with co-authors, completed the initial analysis, assisted with data interpretation, drafted the result section of the initial manuscript, and critically reviewed and revised the manuscript
- **Aparna Nadig:** Developed the initial concept and framework for the manuscript in collaboration with co-authors, provided guidance on the conceptual framework and methodology, provided significant input on data interpretation, and critically reviewed and revised the manuscript

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List of Key Abbreviations

AAC: Augmentative and Alternative Communication

AAC-modified CDI: Words and Gestures: Augmentative and Alternative Communication Modified MacArthur-Bates Communicative Development Inventory: Words and Gestures, English Long Form

CDI: Words and Gestures: MacArthur-Bates Communicative Development Inventory: Words and Gestures, English Long Form (Marchman et al., 2023)

CSL: consistent-symbol location

CSL-NDBI: naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design

Mod-PECS: modified version of Picture Exchange Communication System

NDBI: naturalistic developmental behavioural intervention

PECS: Picture Exchange Communication System

General Introduction

It is estimated that one in 66 children in Canada is diagnosed with autism (Ofner et al., 2018). Approximately 25-30 percent of these children use little to no spoken language, this is, are minimally speaking (Rose et al., 2016; Tager-Flusberg & Kasari, 2013). Often excluded from autism research up until the mid-2010s (e.g., assessment tools and protocols developed for children on the autism spectrum[1] with stronger language abilities), little was known about this minimally speaking autistic subgroup (Tager-Flusberg & Kasari, 2013). However, over the past decade, we have begun to learn more about the language and communication skills of minimally speaking autistic individuals.

Minimally Speaking Autistic Children – A Heterogenous Autistic Subgroup

A variety of definitions exist to characterize an autistic child as minimally speaking (L. Koegel et al., 2020). Some researchers have defined minimally speaking as a child, three to four years or older, using 20 or fewer different functional spoken words (La Valle et al., 2024; Pizzano et al., 2024) whereas others have defined minimally speaking as the absence of phrase speech (e.g., they do not speak, use single words only, or use at most simple two-word utterances) in a five to six-year-old child (Chen et al., 2023; Maes et al., 2024). Though these definitions may give the appearance of a clear profile, recent findings highlight the heterogeneity of this minimally speaking autistic group. Pizzano et al. (2024) categorized 344

[1] Following recommendations on the use of terminology for autism (Autism Alliance of Canada, 2024; Bottema-Beutel, Kapp, et al., 2021), we use identity-first terms such as “autistic person” or neutral terms such as “person on the autism spectrum.” In addition, we use the terms “spoken” or “speaking” rather than “verbal” due to their preferential acceptance by the autistic community.

minimally speaking children[2] into three profiles based on cognitive, language, play, and autism symptomology. Children falling into the Profile 1 group (n = 206) showed large delays in all areas, including non-verbal cognition and language skills. The Profile 2 group (n = 95) had stronger communication and non-verbal cognition than Profile 1. Finally, Profile 3 (n = 43) featured children who used a larger number of different spoken words and initiated communication more frequently, with non-verbal cognition abilities between those of Profiles 1 and 2.

Haebig et al. (2021) found that minimally speaking autistic children produce a significantly higher percentage of verbs when compared to typically developing children with vocabularies of a similar size.[3] Butler et al. (2023) also noted verb prominence in the vocabulary of these children. Moreover, they observed that as minimally speaking autistic children's expressive vocabularies increased in size, their proportion of nouns and verbs remained stable. The new words (e.g., yes, please, all done) they acquired often belonged to lexical categories other than nouns and verbs. This is counter to what is commonly seen in typical early expressive language development, where the proportion of nouns and verbs increases as vocabulary size grows in what Bates et al., (1994) referred to as the first and second "waves of lexical re-organization". **The composition and assessment of expressive vocabulary in these children will be the focus of Chapter 2.**

[2] 20 or less different spoken words during a 10-minute caregiver-child interaction video was used as the definition of *minimally speaking* for this study.

[3] It is important to note that lexical composition percentages in the Haebig et al. (2021) samples (both autism and typically developing) were based on a particularly small number of words, so proportions could be heavily influenced by only one or two words.

Other research has highlighted the use of nongenerative language (i.e., immediate or delayed rote repetitions of words or phrases heard in their environment) as a salient feature of the spoken production of many minimally speaking autistic children. A study by Maes et al. (2024) showed that minimally speaking children produced significantly more nongenerative language than spontaneous language and found that they produced significantly more nongenerative language compared to children on the autism spectrum who were verbally fluent.

In terms of receptive language, Chen et al. (2023) found that minimally speaking autistic children demonstrate significantly lower abilities when compared with the normative sample of standardized language assessments. Furthermore, the delay in receptive understanding relative to age-based norms was larger in older minimally speaking adolescents in comparison to minimally speaking children in their sample. A significant discrepancy was found between the minimally speaking autistic group's expressive and receptive skills whereby receptive skills were significantly higher. However, this group effect was driven by 25 percent of the sample. Therefore, a majority of the sample (i.e., 75 percent) showed no significant differences between receptive and expressive language, highlighting the equally pronounced receptive and expressive difficulties experienced by most of the children and youth within this autistic subgroup.

Challenges in Spoken Language Comprehension and Production Among Minimally Verbal Autistic Children: Exploring the Underlying Causes

Currently, there is no unified theory explaining why minimally speaking children on the autism spectrum experience significant difficulties understanding and/or producing spoken language. However, given the heterogeneity of profiles in this autistic subgroup, there likely are multiple explanations — some of which we are only just beginning to understand, while many remain unknown. The following provides an overview of the current understanding.

First, widespread difficulties in receptive language could be accounted for, at least in part, by co-occurring non-verbal cognitive difficulties. Many studies in the literature have reported that a majority of minimally speaking autistic participants have non-verbal cognitive abilities below a standard score of 70 (i.e., extremely low) [Bal et al., 2016; Slušná et al., 2021]. However, other studies have reported areas of relative strength in visually based cognitive tasks such as pattern recognition [as measured on the Raven's Colored Progressive Matrices (Raven, 1998) or the block design subtest of the Weschler Preschool and Primary Scales of Intelligence (Wechsler, 2012)] and visual search tasks such as the Children's Embedded Figures Test (Karp & Konstadt, 1963) where performance is similar to neurotypical controls (Courchesne et al., 2015, 2019).

Second, there is also very preliminary evidence that receptive spoken language difficulties seen in minimally speaking autistic individuals could be associated with difficulties in perceiving and/or processing auditory stimuli. Research suggests that many people on the autism spectrum, not just those who are minimally speaking, process

auditory information differently from neurotypicals (O'Connor, 2012). These auditory processing difficulties can manifest in various ways, such as challenges with perceiving pitch, loudness, or prosody, and they are more likely to occur when processing complex stimuli like speech as opposed to non-speech sound (O'Connor, 2012).

Schwartz et al. (2020b, 2020a) completed two studies examining the neural responses of minimally speaking and low verbal autistic individuals to salient nonspeech and speech stimuli. First, Schwartz et al. (2020b) found that minimally speaking and low-verbal autistic individuals showed no significant difference in their early latency Mismatch Response (MMR) when hearing their name versus a stranger's name in a multi-speaker setting similar to a cocktail party. In contrast, a significant difference in neural responses was observed in verbally fluent autistic individuals and neurotypical participants, aligning with similar findings from Nijhof et al. (2018). The authors suggest that this distinct pattern in minimally speaking autistic individuals may indicate difficulties in discriminating and organizing linguistic information in complex auditory environments.

Furthermore, exploratory post-hoc analyses by Schwartz et al. (2020a) revealed that more time spent engaging in atypical auditory behaviors (e.g., covering or cupping their ear with their hand to avoid or amplify sound) was significantly associated with a weaker Mismatch Negativity (MMN) neural response (i.e., shorter MMN waveform) to non-speech sounds. Schwartz et al. also found that these minimally speaking autistic individuals exhibited significantly more atypical auditory behaviors compared to verbally fluent autistic individuals. These behaviors were negatively correlated with their receptive vocabulary abilities. Taken together, these findings suggest a potential link between increased atypical

auditory behaviors in minimally speaking autistic individuals and poorer neural processing of sounds, which could impact language comprehension.

A third explanation for the spoken language difficulties in this subgroup is that many minimally speaking autistic individuals are believed to have motor speech difficulties, which hinder their ability to express themselves verbally. Developmental motor speech disorders are difficulties planning, executing, controlling and/or coordinating motor movement used to produce speech that occurs in childhood (American Speech-Language-Hearing Association, 2024a, 2024b). Several studies have demonstrated that Childhood Apraxia of Speech (a specific type of developmental motor speech disorder) presents itself more often in children on the autism spectrum (Chenausky et al., 2023; Tierney et al., 2015; Vashdi et al., 2021). Furthermore, Chenausky et al. (2019) reported that approximately a quarter of minimally speaking and low verbal autistic children and youth in their sample demonstrated five or more speech characteristics consistent with Childhood Apraxia of Speech (as defined by Iuzzini-Seigel et al., 2015). The speech production abilities of this subgroup significantly predicted the group's ability to produce spoken language (i.e., the number of different words they were able to produce).

Maffei et al. (2023) further characterized the Chenausky et al. (2019) sample's speech production abilities by assigning a rating (zero = no impairment to four = profound impairment) to 11 speech characteristics (e.g., consistency, intelligibility, pitch, vowel precision, coordination) of each participant. Virtually all participants were rated as having some level of impairment (i.e., a rating of one or higher) in consonant and vowel precision, and intelligibility with many showing signs of difficulties in speech consistency and

coordination [see Figure 1 in Maffei et al. (2023) for further details], concluding that many minimally speaking and low verbal autistic participants in the Chenausky et al. (2019) sample had motor speech difficulties. Finally, using the Directions Into Velocities of Articulators (DIVA) computational model (Guenther, 1994, 2016), Chenausky et al., (2021) identified two distinct profiles among minimally speaking autistic children with motor speech difficulties: those with motor speech issues alone and those with both motor speech and auditory processing difficulties.

Additionally, Butler and Tager-Flusberg (2023) provide preliminary evidence that motor skills from other domains, such as fine motor skills, may be linked to speech intelligibility. They found that poorer fine motor skills were associated with lower speech intelligibility in minimally speaking autistic children, but not in verbally fluent autistic children. Overall, these findings suggest that both speech and fine motor difficulties may be more pronounced in this autistic subgroup and play a significant role in the challenges that some minimally speaking autistic children face in producing intelligible speech.

Fourth, as is the case for all children on the autism spectrum, minimally speaking autistic children experience difficulties in social interaction, one of the core characteristics of autism, which can manifest in several ways [e.g., reduced joint attention and engagement] (American Psychiatric Association, 2013). Autistic individuals who exhibit diminished attention to social cues may miss crucial opportunities to engage in reciprocal communication, observe language use, and participate in interactive learning environments. This reduced engagement can limit their exposure to the social feedback that is critical for developing and practicing speech, ultimately hindering both spoken expression

and broader language acquisition. Over time, this can contribute to delays or difficulties in communication, as the essential building blocks of language learning such as turn-taking, imitation, and conversational interaction are less frequently experienced. Therefore, when these social difficulties are compounded with any or all the challenges mentioned in the paragraphs above (e.g., sound processing difficulties, motor speech impairments), they can lead to an amplification of spoken language difficulties.

Given the host of issues that converge to create barriers to understanding and producing spoken language, it is crucial that minimally speaking autistic individuals are introduced to methods of communication that do not rely on speech. Augmentative and Alternative Communication emerges as a viable option to bridge the communicative gap and meet the unique needs of this autistic subgroup.

The Minimally Speaking Autistic Experience - Communication Difficulties Acting as a Source of Caregiver Stress and a Barrier to Social Connection

Caregivers of autistic children (not just those who are minimally speaking) experience higher levels of stress compared to caregivers of children who are typically developing (Hayes & Watson, 2013). According to the literature, stress experienced by caregivers of autistic children is multifaceted, arising from challenges such as their child's behavioural and communication difficulties, financial costs associated with services and supports, limited access to respite and social networks, and worries regarding their child's future, particularly in terms of independent living and employment prospects (Curley et al., 2023; Lai & Oei, 2014).

For caregivers of minimally speaking autistic children, stress is also likely multifactorial, influenced by the various factors listed above. However, communication difficulties may play a particularly significant role in this autistic subgroup due to the profound communication barriers experienced by these children. For instance, Suswaram et al (2024) found a significant correlation between their child's communication difficulties, as reported by caregivers, and the caregivers' stress levels, suggesting that greater communication challenges are associated with higher caregiver-reported stress. These concerns are not unfounded, as language ability predicts later outcomes in autistic children whereby stronger spoken language abilities have been associated with better outcomes related to social and academic performance, employment, and independent living in adolescence and early adulthood (Howlin et al., 2004; Mayo et al., 2013; Venter et al., 1992).

Although first-hand accounts from minimally speaking autistic individuals are scarce in the literature, a study by Tesfaye et al. (2022) captured the lived experience and needs of autistic youth with a range of cognitive and spoken language abilities (including those who were identified as minimally speaking) using an adapted interview protocol. Thematic analysis revealed the autistic interviewees desire to seek social connections. However, as Tesfaye et al. (2022) pointed out, only one of their minimally speaking autistic youth participant had access to an Augmentative and Alternative Communication system. Given the desire to connect, early access to non-spoken communication methods, such as Augmentative and Alternative Communication, is crucial.

Augmentative and Alternative Communication (AAC)

Augmentative and Alternative Communication (AAC) uses non-spoken methods to enhance or replace spoken communication (Beukelman & Light, 2020). Most often used by people with complex communication needs[4] which includes minimally speaking autistic individuals, numerous studies have documented the positive effects of AAC on communication, language production and comprehension, literacy, and social inclusion (Dada et al., 2021; Drager & McNaughton, 2010; Leonet et al., 2022; O'Neill et al., 2018; Syriopoulou-Delli & Eleni, 2022).

AAC can take various forms, such as using adapted signs, pointing to symbols on a communication board, exchanging picture cards with a communication partner, or pushing buttons on a speech-generating device. Aided AAC systems make use of physical materials to support non-spoken communication whereas unaided AAC does not (Beukelman & Light, 2020). Aided AAC ranges from low-tech options such as a communication board to speech-generating devices that use specialized communication applications or software. See **Figure 1**.

An aided AAC system can be accessed (i.e., used) through various methods, ranging from simple motor movements like pressing a button with an index finger to more advanced techniques like using eye gaze to select an AAC symbol (Beukelman & Light, 2020). These diverse access methods bypass the complex vocal motor skills required for speech production, which often present challenges for individuals with complex communication

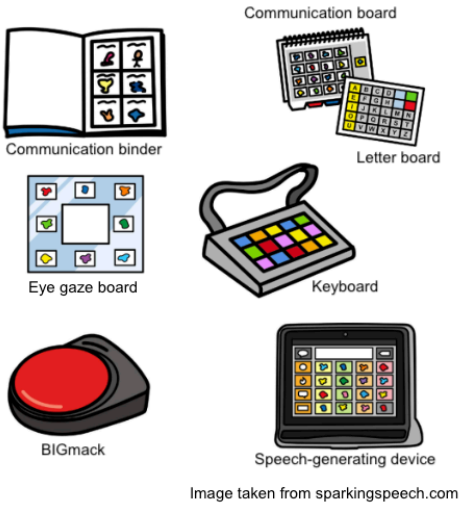
[4] The term "complex communication needs," as used in the AAC literature, refers to people who have cognitive, language, motor, and/or sensory difficulties which result in very limited speech and language abilities (Light & Drager, 2007).

needs. Additionally, being visually based, an aided AAC system can enhance the understanding of spoken language when used by the AAC user's communication partner (Beukelman & Light, 2020).

The method by which an aided AAC system is organized can vary widely. For children in the early stages of their communicative development (which includes most minimally speaking autistic children) aided AAC systems that use either a visual scene or a grid display are recommended (Light et al., 2019).

AAC symbols in a grid display are organized into rows and columns composed of isolated cells that contain an AAC symbol (Light et al., 2019; Thistle & Wilkinson, 2015). For emerging communicators, each language concept is represented by a symbol which varies in level of iconicity (e.g., photo versus colour line drawing of a book). The symbol is displayed in an isolated cell on a clear background in the grid. The grids vary in size (e.g., a 2 X 2 grid with a total of four symbols to a 7 X 10 grid with a total of 70 symbols) where larger grids allow children to select a wide array of symbols.

Figure 1. *Examples of Aided AAC Systems*



Aided AAC systems using a grid display design are available in low-tech (e.g., communication boards or binders) and high-tech options (e.g., communication apps on an iPad). Many emerging communicators may start with one grid (i.e., one page) that can expand to multiple grids over time. Once this happens, grids are often grouped symbols by activity, category, or theme (e.g., food or outdoor activities) with a main page that contains all high-frequency symbols. When the child selects a symbol, it is spoken either by the voice output of a high-tech device or by the child's communication partner (e.g., caregiver or peer). For example, a *story time* specific aided AAC grid might include color line-drawing symbols that represent the language concepts: *story time, book, stop, read, listen, look, what, who, surprised, sad, laugh, and bored*. See **Figure 2**. Grid-based AAC interventions (i.e., interventions that promotes the use of grid-based AAC systems) have been successful in increasing communication, language, and social interaction in people with complex communication needs (Biggs et al., 2018; O'Neill et al., 2018) including individuals on the autism spectrum (Ganz et al., 2012).

Figure 2. *Example of Aided AAC Grid-Based System*

Consistent-Symbol Location – An Aided AAC Grid Display Design Strategy

There are design strategies to enhance the efficiency with which an emerging communicator uses a grid-based aided AAC system. These include using specific background or border colours to categorize symbols (e.g., symbols representing verbs may have a green border) or organizing symbols from left to right in a subject-verb-object order. Consistent-symbol location (CSL) is a design strategy whereby symbols are kept in the exact same location (i.e., individual cell) as an aided AAC system expands and more symbols are added (Thistle et al., 2018).

Building upon the traditional Motor Learning Theory proposed by Fitts and Posner (1967), Dukhovny and Thistle (2019) hypothesize that using a CSL design strategy would encourage the development of a motor program. In the first of three stages, also known as the cognitive stage, cognitive systems are highly involved (Fitts & Posner, 1967). As the motor movement is practiced and becomes more fluent and automatic, a motor program is generated (i.e., the third autonomous stage). It is at this point where the cognitive system initially involved in performing the motor movement is no longer required and instead relies on the associated motor program, freeing up processing capacity.

In contrast, Dynamical Systems Theory (Kelso, 1995; Turvey, 1990), provides a more updated account of motor learning, suggesting that motor patterns are learned in a non-linear dynamic fashion through interactions of the motor system and other systems (e.g., sensory, cognition). Once all systems "self-organize", a motor pattern is established and performed with automaticity. Unlike Motor Learning Theory, Dynamical Systems Theory

suggests that all relevant systems (e.g., motor, sensory, cognitive) remain connected and involved even after the establishment of a stable motor pattern.

Though both theories differ on certain aspects, both theories acknowledge that a greater involvement from each system (e.g., sensory, cognition) is required early on to establish a fluent automatic movement. A CSL design allows for the establishment of a movement pattern by maintaining AAC symbols in the same consistent location on the grid. Once a motor pattern or program is fluent, the engagement of systems that support visual scanning and tactile feedback are needed to a lesser degree. This is important because as a child AAC user's language becomes more developed and the use of an aided AAC system becomes more complex (i.e., producing multi-symbol messages), a CSL design allows the child to focus on the communicative rather than the motor aspects of their AAC system. This is somewhat analogous to when we touch type on a keyboard and no longer need to search for the location of each letter - though these children are simultaneously learning language, adding another layer of complexity (Dukhovny & Thistle, 2019).

Studies involving neurotypical adults and children have demonstrated that grid-based aided AAC systems that use a CSL design strategy result in more accurate and faster access to learned symbols when compared with the grids that use variable symbol location designs, that is, move symbols to different cells (Dukhovny & Gahl, 2014; Dukhovny & Zhou, 2016; Thistle et al., 2018).

The rationale for using a CSL design is intuitive and therefore, many speech-language pathologists practicing in AAC recommend it but, to date, there is no empirical support documenting the benefits of a CSL design with AAC users (Thistle & Wilkinson, 2015).

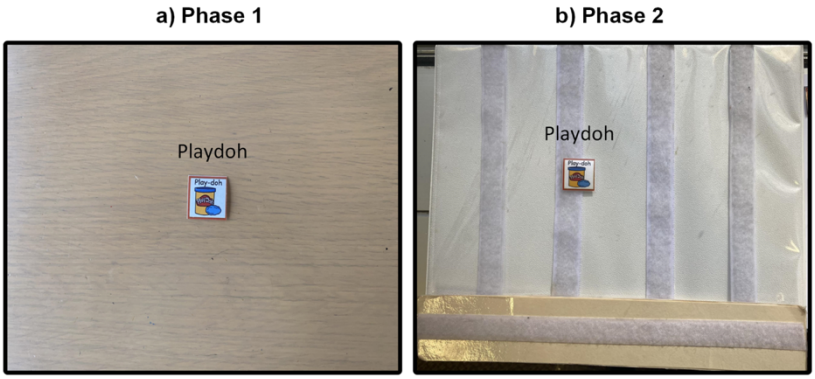
Furthermore, Picture Exchange Communication System (PECS; Frost & Bondy, 2002), an established aided AAC intervention that was developed for minimally speaking autistic children does not use a CSL design but rather a variable-symbol design.

Picture Exchange Communication System (PECS) – An Aided AAC Intervention that Uses Variable-Symbol Location Design

Established as an evidence-based intervention for autistic children, PECS is a manualized aided AAC intervention composed of six teaching phases where children are taught to communicate by exchanging pictures that symbolize a desired item, action, or activity (Hume et al., 2021; Wong et al., 2015). Phases are taught in an ordered sequence where the child must master one phase before the next phase can be initiated. The protocol is designed to teach AAC communication skills in an isolated and gradual fashion where the skill(s) learned in the previous phase(s) are carried forward and used in the current phase. **See introduction and methods sections of Chapter 1 for further details.**

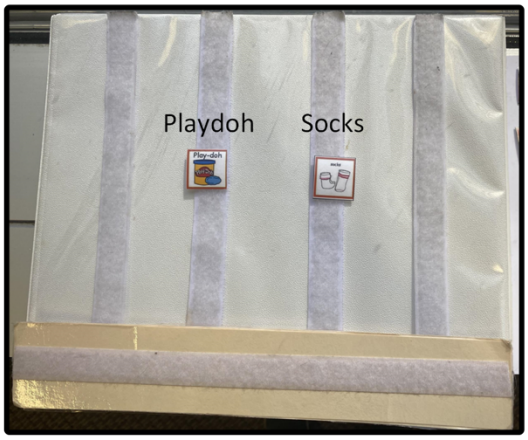
Unlike most other AAC systems, PECS is unique in using a variable-symbol location design in which picture-symbols are moved and not kept in a static location. Initially, a single picture-symbol is displayed on its own during Phase 1 (**Figure 3a**) and then on a binder using Velcro during Phase 2 (**Figure 3b).**

Figure 3. *PECS Phases 1 and 2 – Single Preferred Picture-Symbol Array*



In Phases 3a and 3b, the child is taught to visually discriminate among an array of the Velcro picture-symbols. In Phase 3a, the picture array consists of a preferred picture-symbol and distractor picture-symbol (i.e., picture array of two). See **Figure 4**. During Phase 3b, an array consists of preferred picture-symbols which begins with two and slowly increases in size. See **Figure 5a**.

Figure 4. *PECS Phase 3b – Preferred and Distractor Picture-Symbol Array of 2*

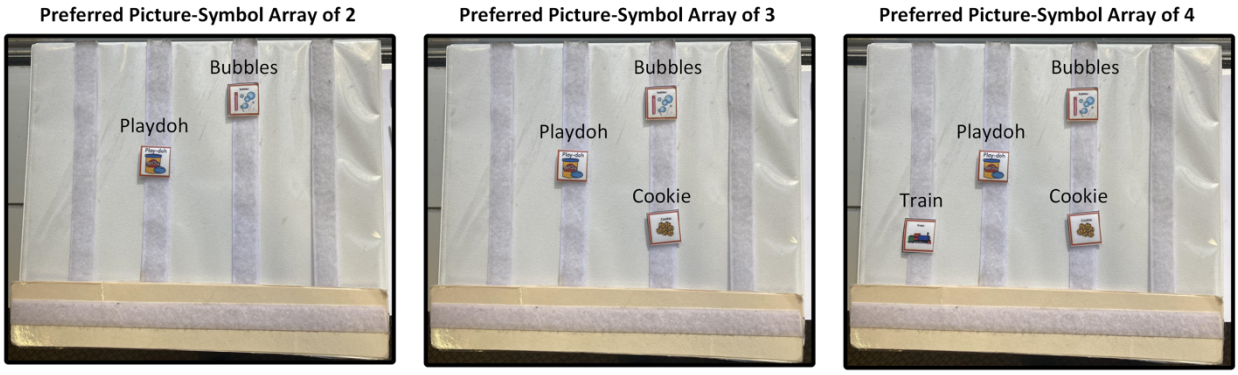


Importantly, in Phases 3a and 3b, picture-symbols are repositioned on the binder cover between teaching trials to ensure the child identifies the correct symbol without

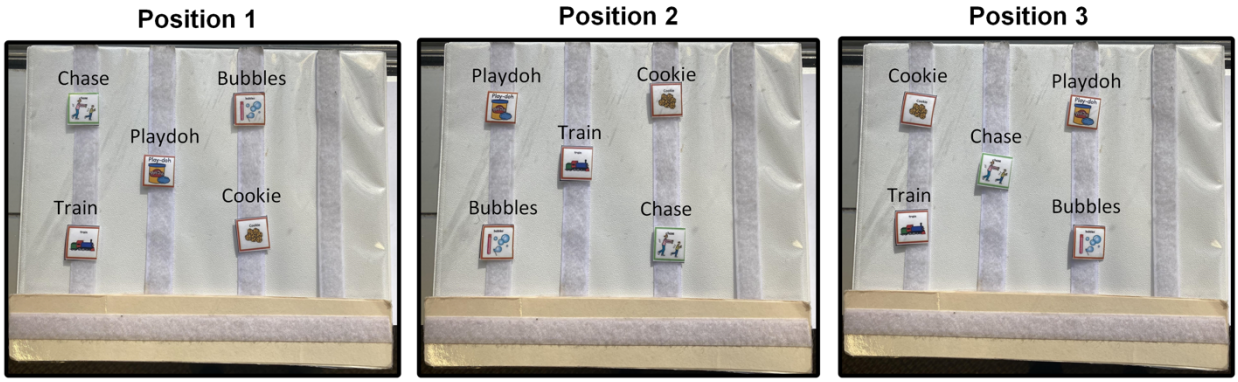
relying on cues such as location. See **Figure 5b** for an example. Therefore, it is assumed that in situations when a consistent-symbol location design is not feasible (e.g., transitioning a child from a communication board to a communication app where symbol locations change), the child is less likely to struggle with using the newly re-organized aided AAC system.

Figure 5. *PECS Phase 3b*

a) *Preferred Picture-Symbol Arrays Increasing in Size Over the Course of Phase*



b) *Preferred Picture-Symbol Array of Five Being Repositioned After Each Trial*



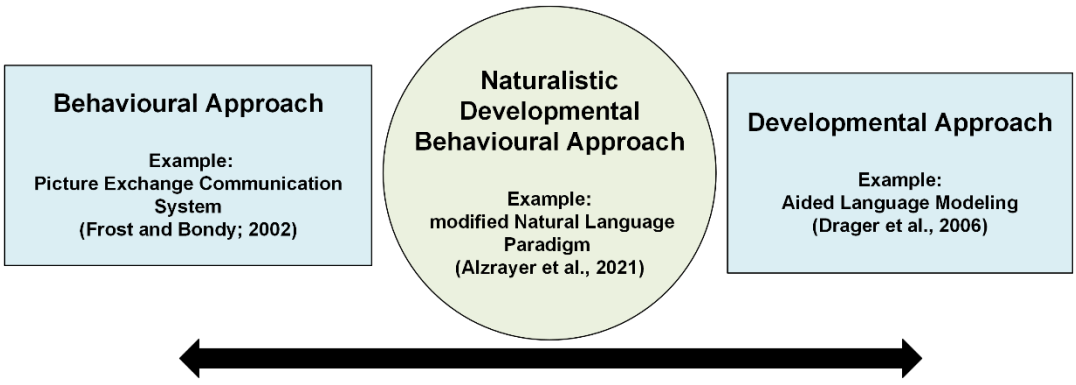
Once a child can consistently discriminate between at least five symbols, Phase 3 concludes. At this point, it is recommended that the picture-symbols the child has learned to visually discriminate be organized and kept in a consistent section in the binder whereby

picture-symbols belonging to the same category (e.g., food) are grouped on the same page (pg. 142-143, Frost & Bondy, 2002). Though similar, this organizational recommendation does not use a CSL design as outlined by Thistle et al. (2018) which emphasizes within-page consistency whereby picture-symbols are kept in the exact same location on the page.

Aided AAC Intervention for Minimally Speaking Autistic Children – Theoretical Approaches and State of the Empirical Evidence

Equally important to design are the teaching strategies used to support minimally speaking autistic children in using their aided AAC system. Interventions used to support children on the autism spectrum are divided into three broad theoretical approaches (Sandbank et al., 2023): behavioural, developmental, or an approach that combines both approaches, referred to as naturalistic developmental behavioural interventions (NDBI; Schreibman et al., 2015; Tiede & Walton, 2019). See **Figure 6.**

Figure 6. *Three Main Theoretical Approaches Used in Intervention to Support Autistic Children (With Specific Aided AAC Intervention Examples)*



PECS, an aided AAC intervention described in the previous section, follows a behavioural approach (Sandbank et al., 2023). Based on the science of Applied Behaviour Analysis (ABA; Baer et al., 1968), the PECS protocol is broken down into discrete steps whereby one AAC-related skill is taught at a time using detailed teaching instructions (Frost & Bondy, 2002). When implementing PECS, therapists use operant learning principles. The protocol emphasizes providing clear cues to initiate practice opportunities within a structured, low-distraction environment. Therapists implementing PECS are taught to follow the child's motivation or interest in the moment to determine the timing and nature of the communication opportunity. Therefore, contextually relevant reinforcement is used, such as offering a child a glass of water immediately after they pass a picture-symbol for *water*. Prompting, which involves explicit cues or hints to support AAC use, is also used. The PECS protocol is recognized as an evidence-based intervention (Hume et al., 2021; Wong et al., 2015). **See the introduction and methods sections of Chapter 1 for further details.**

In contrast, interventions that follow a developmental approach are child-led and guided by developmental and cognitive theories (Wagner et al., 2014). Developmental approaches do not use behaviour strategies such as prompting and reinforcement but instead, focus on the interpersonal relationship between the child and the adult and are implemented in natural play-based contexts. The sequence of typical development is often used to support goal selection. Specific to aided AAC interventions, Aided Language Modeling (ALM), as described by Drager et al. (2006), uses a developmental approach. ALM involves the delivery of aided language models which involve a person selecting, touching, or pointing to a symbol on an AAC system while simultaneously speaking it aloud to a child

AAC user. These models typically focus on child interest (e.g., what they are oriented to and/or engaging with at the moment) and are presented multiple times to emulate how children are exposed to and eventually develop spoken language (Romski & Sevcik, 1996).

There is empirical support for interventions that use ALM demonstrating positive gains in social communication and language with individuals with complex communication needs including minimally speaking autistic children (O'Neill et al., 2018; Sennott et al., 2016). However, two recent reviews of ALM interventions by Chazin et al. (2021) and Wandin et al. (2023) highlighted that ALM interventions often also include behavioural strategies (e.g., prompting, reinforcement) making it difficult to appraise the unique contribution of aided language modelling as an active ingredient. In addition, of the nine ALM only intervention studies reviewed by Chazin et al (2021), only four (44.4 percent) demonstrated positive gains in AAC use with individuals with complex communication needs in contrast to 23 out of 30 studies (76.7 percent) when the ALM intervention included behavioural strategies.

The third type of theoretical approach for autistic children, naturalistic developmental behavioural interventions (NDBIs), considered to be a "middle ground", offers a blend of both developmental and behavioural approaches. NDBIs are implemented in natural contexts, use typical development to guide target selection, encourage a strong relationship between child and caregiver to enhance learning, and use a behavioural framework (i.e., antecedent-behaviour-consequence) and therefore include strategies such as prompting and contextually appropriate reinforcement to increase the efficiency of learning (Schreibman et al., 2015). NBDIs such as the Early Start Denver Model (ESDM;

Dawson et al., 2010) and Joint Attention Symbolic Play Engagement and Regulation (JASPER; Kasari et al., 2006) have many high-quality studies demonstrating their efficacy (Fuller et al., 2020; Waddington et al., 2021). Pivotal Response Training (PRT; R. L. Koegel & Koegel, 2006), another type NBDI, is considered to be evidence-based (Hume et al., 2021; Wong et al., 2015).

NDBIs target several domains such as expressive and receptive language, play, social communication and engagement, joint attention, and cognition (Tiede & Walton, 2019). Specific to language and communication, meta-analyses confirm that NDBIs lead to significant positive increases in expressive language (g = 0.32 small-medium effect), social communication (*g* = 0.36, small-medium effect), and social engagement (*g* = 0.65, large effect) of young autistic children (Sandbank et al., 2023; Tiede & Walton, 2019). Furthermore, in a meta-analysis, Pope et al. (2024) found that NDBIs that targeted aided AAC system use (AAC-NDBIs) had very large positive effects (Tau-U = 0.85) on social communication and language outcomes of autistic children aged three to 12 years old who were minimally speaking. These results indicate that AAC-NDBIs enhance communication and language outcomes when implemented with this autistic subgroup. However, of the AAC-NDBI studies reviewed in Pope et al. (2024), none included a head-to-head comparison with another aided AAC intervention that uses a different approach (i.e., developmental or behavioural only).

Aided AAC Intervention for Minimally Speaking Autistic Children – Testing the Promising Combination of a Naturalistic Developmental Behavioural Approach and Consistent-Symbol Location Design

Since the publication of Tager-Flusberg and Kasari's 2013 article titled "Minimally Verbal School-Aged Children with Autism Spectrum Disorder: The Neglected End of the Spectrum", we have begun to learn more about the language and communication skills of minimally speaking autistic individuals. However, to support social inclusion and maximize the quality of life of these children, more research is needed in the area of AAC (Tager-Flusberg et al., 2023). To optimize the efficiency at which minimally speaking autistic children can learn to use an aided AAC system, we must carefully consider a design and theoretical approach that offers the most potential.

To date, the promising aided AAC design strategy, consistent-symbol location, has not been explicitly tested in the context of an AAC intervention with minimally speaking autistic children (Thistle et al., 2018). Furthermore, AAC-NDBIs have shown promise when implemented with minimally speaking children on the autism spectrum (Pope et al., 2024). However, this combination of consistent-symbol location design and naturalistic developmental behavioural approach has yet to be directly tested against another AAC intervention that uses a different theoretical approach such as PECS.

The interplay between AAC display designs and different theoretical approaches makes it essential to examine both simultaneously to understand how these components work together to support AAC use. In interventions like PECS, the teaching method

(behavioural approach) directly shapes the display design (variable-symbol location), showing that these dimensions are mutually reinforcing rather than independent. Furthermore, although NDBIs have been well-researched, earning a recommendation from the Canadian Academy of Health Sciences (2022) there remains a relative lack of research specifically on AAC-NDBIs. By evaluating both variables together - display design (consistent vs. variable symbol location) and approach (naturalistic developmental behavioural vs. behavioural), we can offer a more comprehensive understanding of the most effective combinations.

Therefore, in Chapter 1, we compared the efficacy of an aided AAC intervention that uses a naturalistic developmental behavioural approach and a consistent-symbol location design against an empirically-supported aided AAC intervention that uses a behavioural approach and a variable-symbol location design: Picture Exchange Communication System (Frost & Bondy, 2002). **The procedures and results of this comparison are provided in Chapter 1**.

Chapter 1: Testing The Effectiveness of a Naturalistic Developmental Behavioural AAC Intervention That Uses Consistent-Symbol Location

Abstract

Purpose: Approximately a quarter of children on the autism spectrum develop very little spoken language or are minimally speaking. Teaching these children to use Augmentative and Alternative Communication (AAC) is essential to enhancing communication, and promoting independence, social inclusion, and quality of life. Despite the prevalence of AAC platforms such as communication boards where symbols are placed and remain in the exact same location (i.e., use a consistent symbol location design; Thistle et al., 2018), we do not know if this design feature has advantages compared to other AAC displays. Moreover, there exists empirical support for AAC interventions that use naturalistic developmental behaviour approaches or behavioural only approaches, but no study has ever directly compared them in the context of an AAC intervention (Hume et al., 2021; Pope et al., 2024; Wong et al., 2015). Therefore, we tested a naturalistic developmental behavioural AAC intervention that uses a consistent-symbol location design (CSL-NDBI) against an established aided AAC intervention that uses a behavioural approach and a variable-symbol location design: Picture Exchange Communication System (PECS; Frost & Bondy, 2002).

***Methods*:** All aspects of the study were completed remotely. Eighteen caregivers and their minimally speaking autistic children were recruited: 11 dyads in the CSL-NDBI group and seven in the modified-PECS group. Each dyad received twelve weekly one-hour individual remote coaching sessions with the first author. Using videos of caregiver-child interactions collected at pre-, mid-, and post-intervention, naïve coders calculated: caregiver

implementation mastery, prompted/supported and independent AAC acts, mean length of AAC utterance, and number of different AAC symbols used. A caregiver report measure on child AAC use was also collected.

***Results*:** Caregivers in both groups increased their percent mastery of intervention strategies over the course of intervention (CSL-NDBI: $p = 0.0002$, modified-PECS: $p = 0.07$) but the CSL-NDBI group's percent mastery at mid-intervention was significantly higher ($U = 62.0$, $p = 0.03$, $\delta = 0.61$, large effect) than the mod-PECS group. However, at post-intervention, the vast majority of caregivers in both groups achieved a percent mastery that was greater than 80 percent. Children in both the CSL-NDBI and modified-PECS interventions significantly increased their prompted/supported AAC acts (CSL-NDBI: $p = 0.0003$, modified-PECS: $p = 0.009$). There was a trend for independent AAC acts to increase marginally over time ($p = 0.09$) in the modified-PECS condition. However, no significant differences were found when comparing the modified-PECS group's independent AAC acts with those of the CSL-NDBI group at mid- and post-intervention. Mean length of AAC utterance (CSL-NDBI: $p = 0.0004$, modified-PECS: $p = 0.007$) and total number of different AAC symbols used (CSL-NDBI: $p = 0.0003$, modified-PECS: $p = 0.02$) increased significantly in both groups over the course of intervention. No significant differences between groups were detected. The caregiver report measure was in line with the results from video analyses.

Conclusions: Our findings suggest the CSL-NDBI intervention was mastered in a shorter period, suggesting a naturalistic developmental behavioural AAC intervention may be easier for caregivers to learn and implement than an AAC intervention that uses a behavioural

approach. These results also demonstrate that both the CSL-NDBI and modified-PECS interventions increase AAC use in minimally speaking autistic children to a similar degree. Though gains in AAC were made, most of the AAC use was supported/prompted by caregivers over this 12-week intervention. This highlights the need for continued AAC services to increase independent AAC usage and complexity.

Introduction

Approximately a quarter of children on the autism spectrum will develop none or very little spoken language, that is, will be minimally speaking (Rose et al., 2016; Tager-Flusberg & Kasari, 2013). For these children, teaching them to use Augmentative and Alternative Communication (AAC) is essential to enhancing communication, and promoting independence, social inclusion, and quality of life. AAC enables someone with complex communication needs[5] to communicate using non-spoken methods such as adapted signs, communication boards, pictogram cards or speech-generating devices (Beukelman & Light, 2020). However, AAC intervention options for minimally speaking autistic children are critically lacking (Tager-Flusberg et al., 2023).

Similar to learning to fluently type on a keyboard, it is hypothesized that keeping AAC symbols in the exact same location (i.e., using a consistent symbol location design; Thistle et al., 2018) on AAC platforms such as communication boards and speech-generating devices (also referred to as aided AAC), encourages the development of a motor pattern, making AAC use more efficient and fluent (Dukhovny & Thistle, 2019). Despite the frequent implementation of this design strategy by speech-language pathologists (Thistle & Wilkinson, 2015), aside from a few single case studies, there is no empirical evidence of the benefits of a consistent-symbol location design in comparison to an AAC intervention that uses a variable location design (Thistle et al., 2018).

[5] The term "complex communication needs," as used in the AAC literature, refers to children who have cognitive, language, motor, and/or sensory difficulties which result in very limited speech and language abilities (Light & Drager, 2007).

Equally important to design are the teaching strategies used to help minimally speaking autistic children learn to use their aided AAC system. Naturalistic developmental behavioural interventions (NDBIs) that focus on aided AAC (AAC-NDBIs) have demonstrated large positive improvements in language and communication when implemented with minimally speaking autistic children (Pope et al., 2024). However, to date, AAC-NDBI group studies with autistic children remain rare (i.e., Kasari et al., 2014) and no research team has directly compared an AAC-NDBI to other aided AAC intervention that use different theoretical approach, such as one based on behavioural theory. Furthermore, there exists little empirical evidence documenting the efficacy of an AAC-NDBI when implemented by caregivers of minimally speaking autistic children (Elmquist et al., 2023).

Given these critical gaps in the literature and the importance of AAC use for minimally speaking autistic children, we tested the efficacy of a caregiver-mediated AAC-NDBI that uses a consistent-symbol location design against a caregiver-mediated, behaviorally based, AAC intervention that does not use a consistent-symbol location design.

Aided AAC Display Designs and Their Rationales - Consistent- and Variable-Symbol Location

Used in the context of an aided AAC system that uses a grid-based display (i.e., where each page within the AAC system is organized into rows and columns composed of isolated cells that contain an AAC symbol), a consistent symbol location design has potential benefits. Keeping an AAC symbol in the exact same location (i.e., individual cell) is likely to support the development of a motor pattern (Kelso, 1995; Turvey, 1990). Greater

involvement from each system (e.g., sensory, cognition) is required early on to establish a fluent automatic movement. However, once a motor pattern is fluent, the engagement of the systems that support visual scanning and tactile feedback is needed to a lesser degree.

Although many autistic children experience motor-related difficulties and delays in motor development (Bhat, 2020; McCleery et al., 2013), evidence demonstrates that they are capable of developing motor patterns (Izadi-Najafabadi et al., 2015). Therefore, it is hypothesized that keeping the AAC symbol in a static position on their communication board or speech-generating device will enable them to learn the motor pattern of a new symbol. Once this motor pattern is established and the symbol is accessed by the child with ease, they can focus on learning new symbols/language concepts and, therefore establishing new motor patterns. This is important because as a child AAC user's language becomes more developed and the use of an aided AAC system becomes more complex (i.e., producing multi-symbol messages), a CSL design allows the child to focus on the communicative rather than the motor aspects of their AAC system. This is somewhat analogous to when we touch type on a keyboard and no longer need to search for the location of each letter - though these children are simultaneously learning language, adding another layer of complexity (Dukhovny & Thistle, 2019).

Studies involving neurotypical adults and children have demonstrated that AAC platforms that use a consistent symbol location result in more accurate and faster access to learned words or icons when compared with the arrays that use a variable symbol location design (Dukhovny & Gahl, 2014; Dukhovny & Zhou, 2016; Thistle et al., 2018).

The rationale for using a consistent-symbol location design is intuitive and therefore, many speech-language pathologists practicing in the domain of AAC recommend it (Thistle & Wilkinson, 2015). However, to date, there are only three single-subject design studies documenting the positive outcomes of an aided AAC intervention that uses a consistent-symbol location design as a part of their intervention package (Karnes, 2019; Mason, 2016; Naguib Bedwani et al., 2015). Since none of the studies compared their consistent-symbol location AAC intervention packages against an active control that used a different type of design strategy, it is difficult to attribute the success of their interventions specifically to the consistent-symbol location design.

In contrast, the Picture Exchange Communication System (PECS; Frost & Bondy, 2002), an aided AAC intervention protocol composed of six teaching phases, uses a variable-symbol location design to promote visual discrimination. A single isolated picture (hereafter referred to as a picture-symbol) is presented on its own during the first phase (i.e., Phase 1) and then displayed (using Velcro) on the front cover of a binder (with Velcro strips on it) during the second phase (i.e., Phase 2). During the third teaching phase (i.e., Phases 3a/3b), the child is taught to visually discriminate between an array of different picture-symbols. Beginning with an array of two picture-symbols and slowly building up to an array of five (or more), the picture-symbols are moved to different locations on the binder cover between each practice opportunity, to provide a stringent test that the child can select the picture-symbol that represents the desired item or activity without relying on cues such as consistent location (Frost & Bondy, 2002). Therefore, it is assumed that in situations when a consistent-symbol location design is not feasible (e.g., transitioning a child from a

communication board to a communication app where symbol locations change), the child is less likely to struggle with using the newly re-organized aided AAC system.

Once a child has acquired the ability to visually discriminate among an array of at least five picture-symbols, Phase 3b concludes. At this time, it is recommended that the picture-symbols the child has learned to visually discriminate be organized and kept in a consistent section in the binder. The picture-symbols belonging to the same category (e.g., food) are grouped on the same page (pg. 142-143, Frost & Bondy, 2002). Though similar, this organizational recommendation does not use a consistent-location design as outlined by Thistle et al. (2018) which emphasizes within-page consistency whereby the picture-symbol is kept in the exact same location on the page. Furthermore, as the picture-symbols are placed on Velcro strips, even if desired, applying a consistent-symbol design would likely be difficult without altering the PECS binder display as outlined in the PECS manual.

Aided AAC Intervention Approaches - Naturalistic Developmental Behavioural Interventions and Picture Exchange Communication System

Naturalistic developmental behavioural interventions (NDBIs) are well-established evidence-based interventions for children on the autism spectrum that combine developmental and behavioural theoretical approaches. (Sandbank et al., 2020, 2023; Schreibman et al., 2015; Tiede & Walton, 2019). Examples of NBDIs include Pivotal Response Treatment (PRT; R. L. Koegel & Koegel, 2006), Early Start Denver Model (ESDM; Dawson et al., 2010), Joint Attention Symbolic Play Engagement and Regulation (JASPER; Kasari et al., 2006), and Reciprocal Imitation Training (RIT; Ingersoll & Schreibman, 2006).

Though differing in target areas and specific strategies used, NDBIs provide intervention in natural contexts, use typical development to guide target selection, and encourage a strong relationship between child and adult to enhance learning. In addition, NDBIs use a behavioural framework (i.e., antecedent-behaviour-consequence) and therefore include strategies such as prompting and contextually appropriate reinforcement to increase the efficiency of learning (Schreibman et al., 2015).

Importantly, in a meta-analysis, Pope et al. (2024) found that AAC-NDBIs had very large positive effects (Tau-U = 0.85) on the social communication and language of minimally speaking autistic children. With that said, of the AAC-NDBI studies reviewed in Pope et al. (2024), none included a direct comparison with another aided AAC intervention that used a different theoretical approach such as PECS.

Developed by Lori Frost and Andy Bondy in 1985, PECS is a manualized aided AAC teaching method where children are taught to communicate using picture-symbols that symbolize desired items, actions, or activities. The PECS protocol which uses a behavioural approach, is taught through a sequential progression of six phases. The child must master the current phase before instruction of the next phase can begin (Frost & Bondy, 2002). PECS is derived from the science of Applied Behaviour Analysis, or behavioural approaches (i.e., the "B" in NDBI). Therefore, there is overlap between PECS and AAC-NDBIs. While they differ slightly in their application (e.g., PECS is more structured), both PECS and AAC-NDBIs use child choice, reinforcement, prompting, and the antecedent-behavior-consequence sequence to structure practice opportunities.

In the context of requesting, the objective of each PECS phase is different. Phase 1 (i.e., *"How" to Communicate*) focuses on teaching a child to initiate a request by exchanging a single picture-symbol with their communication partner (e.g., a familiar adult). If the child's interest switches to another item or activity, the physical prompter (i.e., a second adult who supports the picture-symbol exchange) removes the previous picture-symbol and places another picture-symbol (symbolizing the new interest) in front of the child. In Phase 2 (i.e., *Distance and Persistence*), the child begins removing the picture-symbol from the front cover. The focus is on getting them to exchange a picture-symbol but at a distance and with no artificial cues (e.g., the communication partner is no longer oriented to the child with an expectant look and an open hand waiting to receive the picture-symbol). In Phase 3a (i.e., *Picture Discrimination – Preferred vs Non-Preferred*), the child is taught to make a request by selecting between the picture-symbol corresponding to their preferred item or activity and a distractor picture-symbol (i.e., a picture-symbol of a neutral item such as socks). The objective of Phase 3b (i.e., *Picture Discrimination – Preferred vs Preferred*) is teaching the child to discriminate between an increasing number of preferred picture-symbols to make a request, starting with two and building up to five. In between trials, the picture-symbols are moved around on the cover to different locations. By the end of this phase, practice is set up to teach the child to access their binder and select a picture-symbol to make a request. Finally, the objectives of Phases 4-6 include learning to request using the sentence starter "*I want"* paired with the picture-symbol of a desired item or activity (Phase 4), learning to respond to the question, "What do you want?" (Phase 5) and learning to comment (Phase 6).

PECS has many empirical research studies demonstrating its effectiveness (Flippin et al., 2010; Hart & Banda, 2010; Preston & Carter, 2009; Tien, 2008; Tincani & Devis, 2011). Given this evidence-based support, the PECS protocol remains a common "go-to" intervention protocol to teach beginner AAC skills to autistic children. However, in a systematic review of the PECS intervention literature (n = 58 across 17 studies), Forbes et al. (2024) found that across PECS studies, while most participants (n = 56) successfully mastered Phases 1 and 2, only 48 percent were able to master Phase 3b by the end of their respective interventions. Importantly, they found that those introduced to Phase 3b only learned to select, on average, from an array of three picture-symbols. Given most did not complete Phase 3b where participants have free access to multiple picture-symbols inside their binders, this may greatly limit the functionality of the PECS binder as an AAC system. Therefore, it is essential to compare other potential aided AAC interventions with PECS to explore the efficacy of new approaches and to expand the empirical evidence on AAC intervention for minimally speaking autistic children.

Caregiver-Implemented Aided AAC Interventions

In a systematic review, Elmquist et al. (2023) concluded that caregiver-implemented AAC interventions were effective at increasing communication in children with intellectual or developmental disabilities including children on the autism spectrum with complex communication needs. Of the 25 studies reviewed, 24 were conducted in home settings, where caregivers demonstrated a high level of intervention implementation (M = 95.3 percent, range = 83-100 percent). Three PECS caregiver-implemented studies showed

positive gains in communication (Chaabane et al., 2009; Park et al., 2011; Stiebel, 1999) with other five studies published after this review's search (i.e., 2018), showing similarly positive results (Alsayedhassan et al., 2020; Moore, 2023; Scott, 2023; Stamp, 2023; Treszl et al., 2022).

Though promising, Elmquist et al. (2023) point out that a majority (23 out of 25 studies) of the caregiver-implemented interventions reviewed used a behavioural approach. Given that NDBIs promote strong interpersonal bonds to enhance learning and are well-suited for implementation in real-life daily contexts, this theoretical approach may be particularly effective when applied by caregivers. Therefore, we must explore the potential to improve communication outcomes through the use of caregiver-implemented aided AAC interventions that use an NDBI approach.

Furthermore, only four studies included in the Elmquist et al. (2023) review were conducted using telehealth whereby the caregivers were coached on AAC intervention implementation via video conferencing. In Canada, autistic children and their families are spread out over a large geographical area with many living in rural and remote areas and many do not have access to in-person services (D. Parsons et al., 2017). Therefore, to ensure minimally speaking autistic Canadians have access to high-quality AAC coaching services regardless of where they reside, further investigation is warranted.

Rationale, Objectives, Questions, and Hypotheses

Currently, minimally speaking autistic children remain an understudied group who critically lack evidence-based AAC intervention protocols (Brignell et al., 2018; Tager-

Flusberg et al., 2023). To maximize the efficiency at which an aided AAC system is learned, we should explore the aided AAC display design strategy, consistent-symbol location (Thistle et al., 2018). Moreover, when considering theoretical approaches, AAC-NDBIs have shown promise when implemented with minimally speaking autistic children (Pope et al., 2024). However, such an intervention has not been directly compared with an active control. The PECS protocol, an empirically supported, behaviorally-based aided AAC intervention using a variable-symbol location design, presents a strong comparison option (Hume et al., 2021; Wong et al., 2015). Furthermore, to our knowledge, a naturalistic developmental behavioural AAC intervention coached remotely and implemented by caregivers, has yet to be tested for effectiveness in the literature (Elmquist et al., 2023).

Therefore, we tested the effectiveness of a remotely coached caregiver-implemented naturalistic developmental behavioural AAC intervention that uses a consistent-location design (CSL-NDBI) against a modified version of Picture Exchange Communication System (mod-PECS) that is also caregiver-implemented and coached remotely.

Primary Research Questions

Caregiver Implementation Mastery: When coached remotely, did caregivers in the CSL-NDBI and the mod-PECS groups demonstrate similar trajectories of intervention mastery? It was hypothesized that most caregivers would learn to implement their assigned intervention with competency by post-intervention with no significant difference between the CSL-NDBI and mod-PECS groups at mid- and post-intervention.

Child AAC Use: Did the minimally speaking autistic children in the CSL-NDBI intervention group increase their AAC use to a similar degree as children in the mod-PECS condition (a modified version of an established AAC intervention)?

We hypothesized that children in both the CSL-NDBI and mod-PECS groups would significantly increase their AAC use to comparable levels with no significant differences between groups at mid- and post-intervention. As we recruited children who did not use AAC consistently or independently and the intervention period was only 12 weeks with one, 1-hour individual coaching session per week, we suspected a majority of the AAC use would be supported (i.e., prompted) by their caregivers.

Child AAC Complexity: Did the AAC use of children in the CSL-NDBI group become more complex (i.e., longer AAC utterances and higher number of different picture-symbols) in comparison to children in the mod-PECS group over the course of intervention? Given the hypothesized benefits of a consistent-symbol location design, we predicted that, compared to the mod-PECS group, children in the CSL-NDBI group using an aided AAC system with a CSL design would produce significantly longer AAC utterances and use a significantly greater variety of picture-symbols.

Secondary Research Questions

Potential Negative Emotional Impact of Intervention on the Child: There has been a call for intervention researchers in the field of autism to better track potential adverse events (Bottema-Beutel, Crowley, et al., 2021; Bottema-Beutel et al., 2023). Given this and the particular vulnerability of our child participants (i.e., autistic children with very limited

means of communication), we investigated change and potential group differences in caregiver-by-proxy reported child anxiety, stress, and anger by asking, did caregivers report any significant negative changes in children's emotional state in either group from pre- to post-intervention? We hypothesized no significant changes (i.e., increase or decrease) in any of the caregiver-reported dimensions of child anxiety, stress or anger from pre- to post-intervention in either intervention group.

Intervention Acceptability: From the caregiver's perspective, did they report their assigned AAC intervention (CSL-NDBI or mod-PECS) to be acceptable? It was hypothesized that caregivers would report both interventions as acceptable with no significant difference between groups.

Caregiver Self-Efficacy, Stress, and Perception of their Child and Child Quality of Life: The potential impact on intervention on caregiver self-efficacy, stress, and positive perception of their child as well as child quality of life were also investigated. More information on the measures used to track these outcomes can be found in the methods section.

Methods

Participants

Thirty-seven potential families were recruited through a combination of responses from social media posts and direct referrals. The McGill Faculty of Medicine and Health Sciences Institutional Review Board approved the study. A screening questionnaire completed by the caregiver was used to assess eligibility for all criteria (see below) except the *minimally speaking* criterion. Confirmation of our definition of *minimally speaking* was

done by the first author[6] through a review of caregiver-child interaction videos as described in detail below.

To be included as *minimally speaking,* children's spontaneous spoken language abilities had to be less developed than consistent phrase speech (e.g., they did not speak, used single words only, or used at most simple two-word utterances) during 10 minutes of caregiver-child interaction video obtained at the start of the study. This criterion is used in the Autism Diagnostic Observation Schedule, 2nd edition manual (ADOS-2 manual; Lord et al., 2012, pg. 9-13) to assign children to the lowest language level (i.e., module 1 of the ADOS-2)[7]. However, this criterion is typically used with children who are five years and older (Bal et al., 2016; Chen et al., 2023), as children younger than age five may present with language delays that they will not retain at age five. To address this concern, children who were between the ages of 3;1 and 4;11 years old (n = 5) had to meet a more stringent criterion to be included as *minimally speaking*. In addition to being identified as an ADOS-2 module 1 candidate, they needed to speak 20 or fewer different words across the 10 minutes of video available. Pizzano et al. (2024) used the criterion just described to characterize children as young as three years old as minimally speaking.

In addition to being *minimally speaking*, to be eligible for the study, children needed to (1) have a confirmed diagnosis of Autism Spectrum Disorder from a qualified licenced

[6] A speech-language pathologist with over a decade of expertise in working with autistic children and trained to administer the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012).
[7] This is the most commonly used criterion in the autism research literature to identify *minimally speaking* children (Bal et al., 2016).

professional [i.e., physician or psychologist],[8] (2) be between three and nine years old, (3) be English-language dominant (i.e., their communication is mainly in English), (4) not use AAC (or not use it proficiently)[9] (5) not currently be receiving any AAC intervention in the home setting, and (6) have no fine motor, visual or hearing impairments significant enough to impact their ability to use a communication board.[10]

Caregivers needed to (1) be able to speak, read, and comprehend English well enough to participate in intervention sessions and complete questionnaires, (2) not have received any prior formal instruction or coaching on how to support AAC use, and (3) have access to a laptop, computer or smartphone with high-speed internet capable of hosting video conferencing calls. Please see the flowchart provided in **Figure 1** for details on recruitment, enrollment, assignment, and attrition.

Eighteen dyads of children and their caregivers (n = 36) were screened in and agreed to participate. Please see **Table 1** for child and caregiver demographic and pre-intervention characteristics. Given the focus of the intervention, the child's standard score of the *Peabody Picture Vocabulary Test – 5th Edition* (PPVT-5; Dunn, Douglas, 2019) was used to assign a dyad to either the AAC-CSL or the mod-PECS group, to have a similar range of

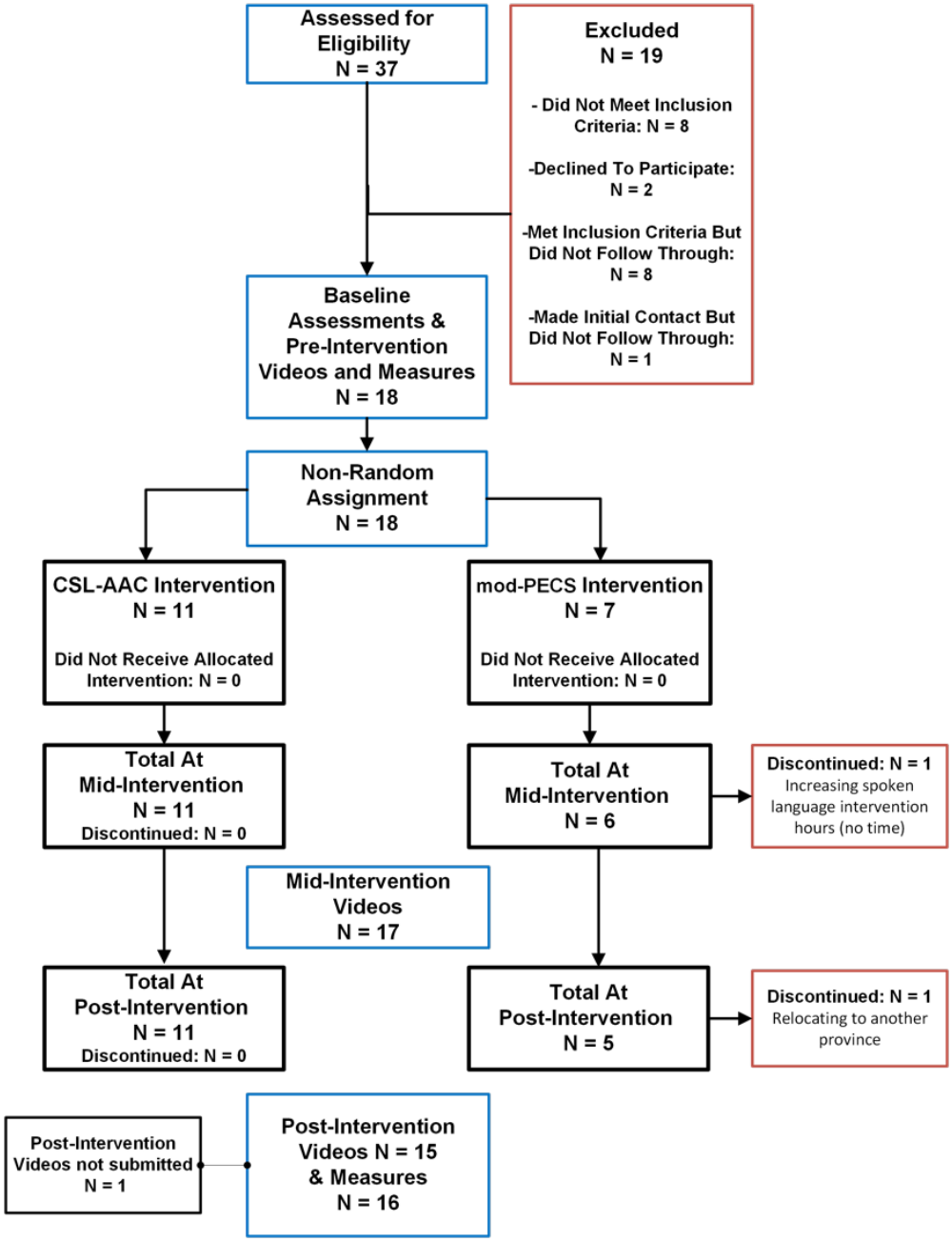
[8] Caregivers submitted a letter or diagnostic report confirming their diagnosis. One participant was on the waitlist for an autism assessment and upon completion of the study received a formal diagnosis of Autism. Following participation in the study, the participant received an official diagnosis of autism (as shared by the family through personal communication). This first author confirmed behaviours consistent with an autism diagnosis through the caregiver-child interaction videos.

[9] Non-proficient AAC use, adapted from Simacek et al. (2017) was defined as the child communicating using a total of five or fewer different communicative acts with their AAC system. For example, using a picture-symbol to request "juice" would be counted as one bid.

[10] Confirmed via the screening questionnaire submitted by caregivers and confirmed by first author during the characterization session.

receptive language ability in each group. Child age and sex were also kept balanced between the two groups.

Figure 1. *Flow Chart of Enrollment, Assignment, and Attrition*



Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Table 1. *Child and Caregiver Characteristics at Pre-Intervention*

	Intervention Group				
	CSL-NDBI[a] (N = 11)	**mod-PECS[b] (N =7)**			
Child Characteristics	***M* (range)**	***M* (range)**	***p*-value[c]**	**Cohen's *d***	**Variance Ratio**
Age (year;month)	6;4 (3;1-9;10)	5;10 (3;1-8;0)	0.57	0.28	1.20
Receptive Vocabulary[d]	49 (40-63)	55 (40-78)	0.14	0.46	0.35
Non-Verbal Cognition[e]	<0.5[i] (<0.5-50)	<0.5[i] (<0.5-10)	0.13	0.36[j]	3.20[j]
Social Abilities[f]	58 (50-74)	59 (51-68)	0.60	0.25	1.35
Motor Skills[g]	69 (56-97)	70 (59-75)	0.90	0.05	5.02
# of Direct Additional Service Hours During Intervention[h]	40.9 (0-192)	41.1 (0-144)	0.99	0.004	1.98
Child Characteristics	**%**	**%**	***p*-value[k]**	**Cramér's *V***	
Sex					
Male	81.8	85.7	1.00	<0.001	
Female	18.2	14.3			
Visible Minority[L]					
Yes	45.5	57.1	1.00	<0.001	
No	54.5	42.9			
Previous AAC Services					
Yes	45.5	42.9	1.00	<0.001	
No	54.5	57.1			
Current AAC Services (outside the home)					
Yes	9.1	14.3	1.00	<0.001	
No	90.1	85.7			

	Intervention Group			
	CSL-NDBI[a] (N = 11)	**mod-PECS[b] (N =7)**		
Caregiver Characteristics	**%**	**%**	***p*-value[k]**	**Cramér's *V***
Sex				
Male	9.1	14.3	1.00	<0.001
Female	90.9	85.7		
Visible Minority[L]				
Yes	54.6	42.9	1.00	<0.001
No	45.4	57.1		
Residency				
Canada < 5 years ago	27.2	14.2	0.81	0.15
Canada > 5 years ago	36.4	42.9		
Always in Canada	36.4	42.9		
Languages Spoken				
1 Language	9.0	28.6	0.31	0.36
2 Languages	45.5	57.1		
3 Languages	45.5	14.3		
Education				
High School	18.2	14.3	0.28	0.46
Bachelor's Degree	27.3	71.4		
Professional Degree	9.1	0		
Master's Degree	45.5	14.3		
Employment				
Employed	100	100	1.00	0
Not employed	0	0		
Household Income				
< $25k	18.2	0	0.18	0.65
$25k - $50k	9.1	14.3		
$50k - $100k	9.1	57.1		
$100k - $150k	9.1	14.3		
$150k - $200k	36.3	0		
> $200k	18.2	14.3		

Note. Standardized tests were administered remotely. a) CSL-NDBI = consistent-symbol location-augmentative and alternative communication, b) mod-PECS = modified version of Picture Exchange Communication System, c) *p*-value from t-test, d) Peabody Picture Vocabulary Test, Fifth Edition Standard Score, e) Raven's 2 Coloured Progressive Matrices Percentile, f) Vineland Adaptive Behaviour Scales, Second Edition, Survey Interview Form (Vineland-II) Socialization Domain Standard Score, g) Vineland-II Motor Domain Standard Score, h) total number of non-home-based direct intervention services provided over the course of this 12-week AAC intervention study. Services included in the total were speech-language pathology intervention services, naturalistic developmental behavioural intervention, and applied behaviour analysis intervention, i) median calculated, j) Raven's raw scores used for calculation, k) *p*-value from Chi-square test, l) term used by the Canadian government to describe a person who is non-white in colour or non-Caucasian in race (Statistics Canada, 2021), *p*-value significance levels: **p* < .05, ***p* < .01, ****p* < .001, Cohen's *d*: a value of 0.2, 0.5, and 0.8 indicates a small, medium, and large effect size, respectively, showing the standardized difference between two means. Cramér's *V*: a value of 0.1, 0.3, and 0.5 indicates a small, medium, and large effect size, respectively, showing the strength of association between two categorical variables.

Design, Procedure and Materials

Data for this study was collected between May 2022 and February 2023. All steps including the consent, child characterization, and AAC coaching sessions were administered remotely by the first author[11] on the secure video conferencing platform Webex®, which caregiver-child dyads joined from their homes. The study was approved by the McGill Faculty of Medicine and Health Sciences Institutional Review Board.

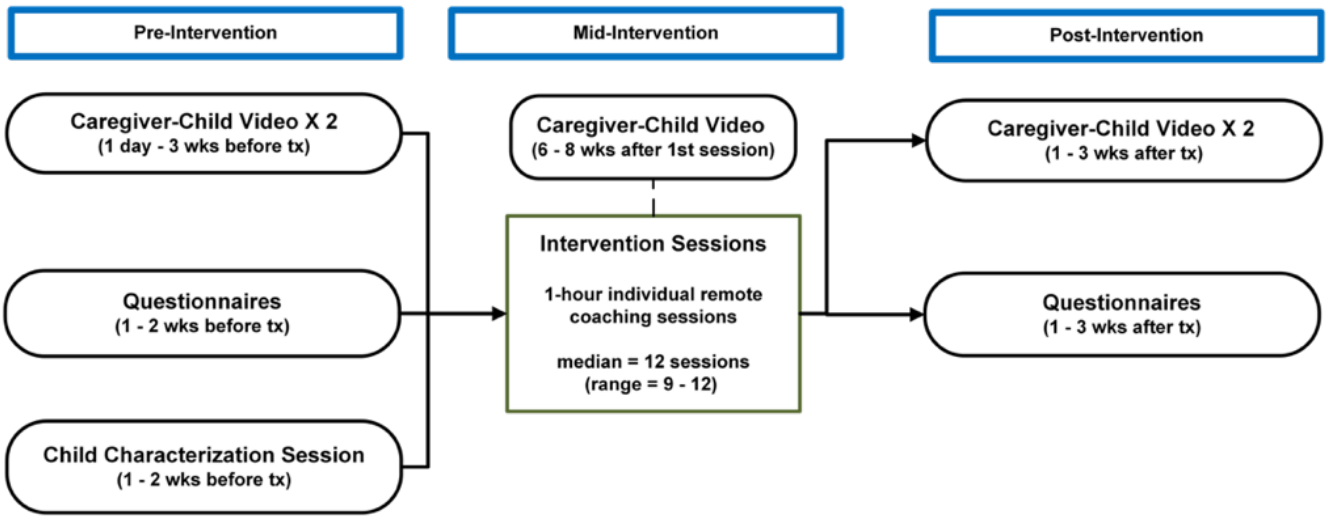
Before beginning the intervention, the child and their caregiver participated in a 1.5-hour characterization session where the *Raven's Coloured Progressive Matrices* (Raven's; Raven, 1998), the social and motor sections of the *Vineland Adaptive Behavior Scales – Survey Interview Form - 2nd edition* (VABS-II; Sparrow et al., 2005), and the PPVT-5 were administered by the first author. Following this session, a research assistant sent caregivers a secure link to complete all pre-intervention questionnaires on the digital survey platform Limesurvey (*Limesurvey*, 2017) which were completed again at post-intervention. See **Figure 2** for a timeline for all pre-, mid-, and post-data collection.

Caregivers submitted five 5-minute videos (two at pre-intervention, one at mid-intervention, and two at post-intervention) over the course of the study. For each video, caregivers were given standardized instructions to record themselves with their child at home, doing an activity or routine that the child finds enjoyable which involves some form of communication or interaction. If the child had an AAC system, caregivers were encouraged to have it present during the recording. The two five-minute videos recorded at pre- and post-

[11] The first author is a speech-language pathologist and board-certified behaviour analyst who has over a decade of experience working with minimally speaking autistic children and has experience implementing AAC interventions including PECS for which she has completed the PECS Basics Workshop.

intervention were recorded on the same day using two different activities.[12] See **Figure 2** for a timeline of data collection.

Figure 2. *Study Data Collection Timeline*



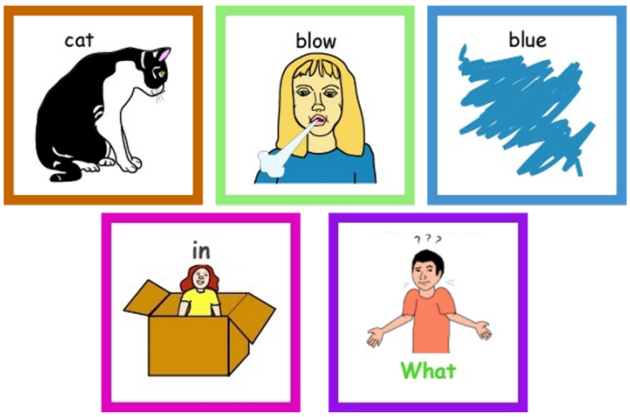
Note. tx = intervention, wks = weeks

Vocabulary Package. Following recommendations put forth by Laubscher and Light (2020), a majority of vocabulary items (n = 408) included in the standard set came from a developmentally-informed source, the vocabulary checklists of the MacArthur-Bates Communicative Inventories: Words & Gestures and Words & Sentences (Fenson et al., 2007). In addition, caregivers completed the *Vocabulary Selection Questionnaire for Preschoolers Who Use Augmentative and Alternative Communication* (Fallon et al., 2001). Responses were used to create up to 40 additional personalized picture-symbols that were added to their child's individualized package.

[12] At post-intervention, one participant from the CSL-NDBI group, submitted one 10-minute video of one activity.

For both intervention groups, the package included an 11.75 X 9.75-inch,1-inch-wide white binder and a standard set[13] of 423 (1 X 1 inch) AAC symbols, hereafter referred to as picture-symbols. Most of the picture-symbols were created using the PICS for PECS© image collection (e.g., coloured line drawing of a cat with the word "cat" written above). Coloured borders using the modified Fitzgerald Key (e.g., a green border was added to picture-symbols representing a verb) were added to each picture-symbol (Fitzgerald, 1929; Thistle & Wilkinson, 2009). See **Figure 3** for examples of picture-symbols. Packages also included additional Velcro, glue tape, and a smartphone tripod.

Figure 3. *Picture-Symbol Examples*



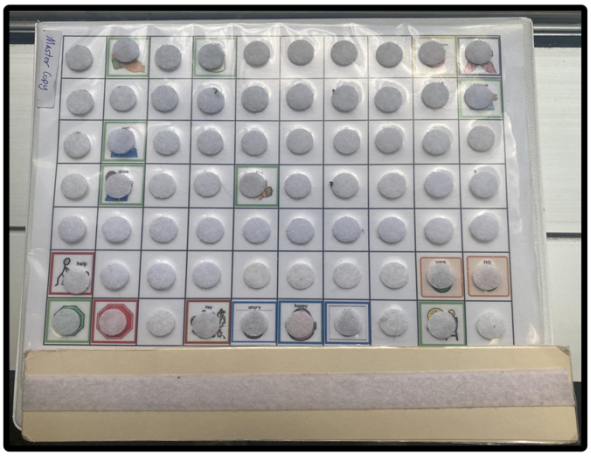
AAC Board versus mod-PECS Binder. The front cover of the CSL-NDBI participants' AAC board had a 70-box grid (a 10 X 7 grid with 1 X 1-inch boxes) under the binder's plastic cover. On top of the plastic cover, a piece of Velcro was placed in the centre of each box. The 70-box grid was pre-filled with 18 picture-symbols. Below the grid was a laminated beige carton strip with Velcro on it (hereafter referred to as the sentence strip). Four additional pages

[13] Each caregiver-child dyad in the CSL-NDBI intervention group was sent two copies of the standard set (i.e., one was the *Velcro* set and the other was the *Shadow* set). See AAC Board versus mod-PECS binder for further details.

were provided inside with 7 X 7 grids (with 49 boxes per page, making 266 boxes in total). These pages were left blank. To ensure the picture-symbols were kept in the same location, all picture-symbols had two copies: *Velcro* and *Shadow*. The *Velcro* picture-symbol had a piece of Velcro on the back, whereas the *Shadow* picture-symbol did not. For a given location, the *Shadow* picture-symbol was placed under the plastic cover, whereas the *Velcro* picture symbol was placed directly on top of it, attached to the Velcro on the plastic cover. See the figures for images of the CSL-NDBI front cover for **Figure 4a** – without *Velcro* picture-symbol where the *Shadow* image underneath can be seen and **Figure 4b** – with *Velcro* tiles affixed. In most cases, children exchanged the *Velcro* picture-symbols to communicate with their caregiver.

Figure 4. *Front Cover of AAC Board*

a) Shadow picture-symbols



b) Velcro picture-symbols

The front cover of the mod-PECS binder was modelled off the binder shown in the Picture Exchange Communication System Training Manual – Second Edition on page 63

(Frost & Bondy, 2002). The front cover had four strips of Velcro running from the top to the bottom of the binder with a sentence strip at the bottom. Four additional inside pages three strips of Velcro per page were also included. The cover and inside pages were left blank. See **Figure 5** for an image of the front cover of the mod-PECS binder.

Figure 5. *Front Cover of mod-PECS Binder*

Naturalistic Developmental Behavioural AAC Intervention that Uses a Consistent-Symbol Location Design (CSL-NDBI)

Children were taught to use their AAC boards using a consistent-symbol location design (Dukhovny & Thistle, 2019) whereby picture-symbols remained in the exact same location (i.e., same box in the grid) throughout the intervention. As previously mentioned, the AAC board was pre-filled with 18 picture-symbols (see **Figure 4b**), but as intervention progressed, additional picture-symbols were added to the board. See **Figure 6**. The first author who acted as the caregiver coach for all dyads, encouraged the addition of picture-symbols that were specific to the child's interests (e.g., *Peppa Pig*) but, when possible, also developmentally informed (e.g., *go*). See **Table 2** for front cover picture array size of each

CSL-NDBI participants' AAC boards at pre-, mid-, and post-intervention (contrasted with those of the mod-PECS participants).[14]

Table 2. *Front Cover Picture-Symbol Array Per Participant During Each Five-Minute Caregiver-Child Interaction Video*

CSL-NDBI[a] (n = 11)				**Mod-PECS**[b] (n = 7)			
ID[c]	**Pre**[d]	**Mid**[e]	**Post**[f]	**ID**	**Pre**	**Mid**	**Post**
1	0	39	55	***6***	0	1	20[i]
2	0	42	70	***7***	13[g]	1	2
3	0	38	31	***8***	0	n/a[j]	n/a[j]
4	3[g]	43	35	***9***	0	1	1
5	0	67	n/a[h]	***11***	0	1	1
10	0	31	70	***12***	0	1	n/a[j]
14	0	24	51	***13***	0	1	1
15	0	21	46				
16	0	18	58				
17	0	31	49				
18	66[g]	33	47				

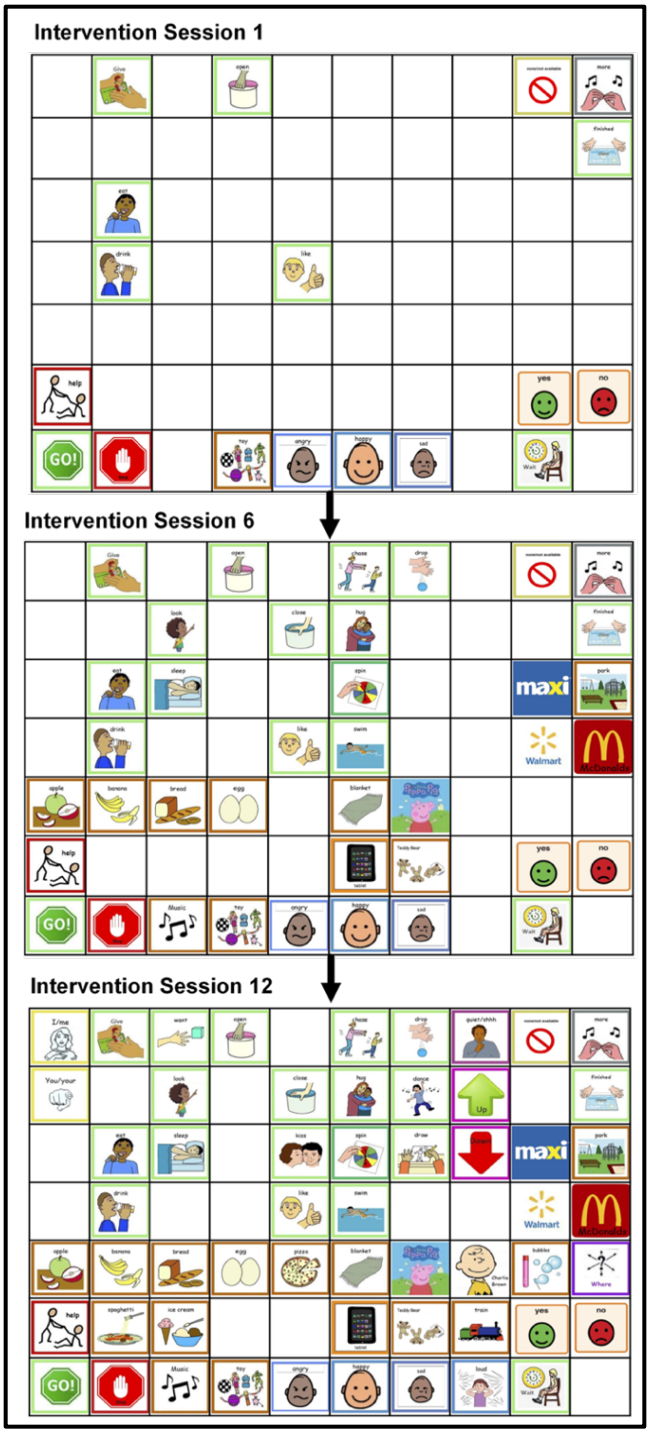
Note. picture array = number of picture-symbols displayed on child's AAC board or mod-PECS binder during five-minute caregiver-child interaction. Reminder: picture-symbols are always kept in a consistent-location in the CSL-NDBI condition (not in the mod-PECS condition. This table was created using a combination of study data: snapshots from videos, photos of the AAC board or mod-PECS binders provided by caregivers at post-intervention, and intervention session logs. a) CSL-NDBI = consistent-symbol location augmentative and alternative communication intervention, b) mod-PECS = modified version of Picture Exchange Communication System, c) ID = participant identification number, d) pre = pre-intervention, e) mid = mid-intervention, f) post = post-intervention, g) child's current AAC system not was not used independently or consistently, h) not applicable as video not submitted, i) child reached the end of phase 3b, therefore picture-symbols began to be placed in consistent location in their binder, j) not applicable as participant dyad dropped out.

[14] Please see **supplemental section 3, Table S3** for final total picture count for all participants in both conditions at post-intervention.

On the front cover, picture-symbols were grouped according to their border colour (e.g., all green-bordered picture-symbols, and verbs, were placed together) and organized from left to right in subject-verb-object order. The front cover was where most picture-symbols were added for quick access but the additional inside pages were sometimes used to group picture-symbols according to activity or category (e.g., outdoor activities, animals, colours, body parts).

When two similar picture-symbols (e.g., *on* and *off*) were added to the communication board,[15] they were placed diagonal to each other (or in a top-bottom arrangement) to support visual discrimination. During the intervention, suspected selection errors (i.e., when a child is suspected to have chosen the wrong picture-symbol) were tracked whereby the caregiver coach documented in her session

Figure 6. *Example of Picture-Symbol Additions Over the Course of Intervention in the CSL-NDBI Condition*



[15] Most picture-symbols were visually distinct from each other, so this type of placement was rarely needed.

log each instance where a child's observed behavior conflicted with the selected picture-symbol. For example, hypothesizing it was a request for a hug, the child selected the picture-symbol for *Hug* but then pushed the caregiver away when one was offered). If a suspected selection error occurred multiple times with a specific picture-symbol, the coach would encourage the caregiver to increase the number of practice opportunities devoted to this picture-symbol where the caregiver would be instructed to provide a supportive cue (i.e., prompt) to help the child select the accurate picture-symbol. In the very rare event that a suspected selection error persisted, the coach would recommend moving the picture-symbol to another location or switching it out for another more visually distinct picture-symbol. Over the course of intervention, the coach only recommended moving two picture-symbols for one participant (who had a final total of 47 picture-symbols on the front cover of his communication board).

During the first intervention session, the coach supported the caregiver in choosing an AAC communication goal to target with their child. The coach supported goal selection by guiding the caregiver to choose a goal that was related to the child's interests/motivation, and current developmental level, and would address a gap in their communicative repertoire (e.g., protesting a non-desired item or activity, requesting using verbs, initiating where questions). Information from the Vocabulary Selection Questionnaire (Fallon et al., 2001), the child participant's baseline assessment measure results (collected during the child characterization session), and the pre-intervention videos and questionnaires were reviewed in advance by the caregiver coach to help guide the discussion.

In addition to using a consistent-symbol location design, the CSL-NDBI intervention used strategies consistent with Naturalistic Developmental Behavioural Interventions (NDBI; Schreibman et al., 2015). Specifically, the following strategies which are common components of NDBIs, were used in the CSL-NDBI intervention: arranging the environment to promote communication, following the child's lead/motivation to create opportunities to use their AAC board, using prompts to support learning and fading them as independence emerges, providing reinforcement that directly relates to the context (i.e., natural reinforcement), and structuring AAC practice opportunities within antecedent-behaviour-consequence sequence. The main objective was to create opportunities for the child to practice the use of their AAC board. Also, to encourage the maintenance of communication abilities already in the children's repertoires (e.g., saying the word *Help* to request assistance or shaking/nodding their head in response to a yes/no question), caregivers were encouraged to reinforce/follow through on any clear communicative bids. **See supplemental materials section 1 for the caregiver mastery checklist for the CSL-NDBI intervention condition.**

To respect the child's bodily autonomy as much as possible, physical prompting was avoided as much as possible. Caregivers were instructed to point using their index finger (paired with an open hand) to prompt a picture-symbol exchange (i.e., AAC act). If this cue was unsuccessful, a hand-over-hand physical prompt was used sparely and only if the child assented (i.e., did not show any signs of discomfort when the adult contacted and moved their hand). In the rare event when a physical prompt was used and the child showed obvious signs of discomfort, the physical prompt was immediately discontinued, and the

child practice opportunity was terminated (e.g., if the child was making a request, the request item or activity was given to them with no need to exchange the corresponding picture-symbol). The practice opportunity was re-attempted using a less invasive, positional prompt (i.e., moving the AAC board closer to the child) while also providing the index finger point/open hand prompt. This prompt strategy was also used in the mod-PECS intervention condition (i.e., modified to replace the immediate and sole use of hand-over-hand physical prompting).

Finally, if a child demonstrates an interest in communicating something that was not currently on their AAC board, caregivers in the NDBI condition added the new picture-symbol(s). If this situation occurred in the mod-PECS condition, caregivers would switch out the current picture-symbol request for another picture-symbol that corresponded to their child's new request.

Modified Picture Exchange Communication System Intervention

All children in the mod-PECS condition were taught to use their PECS binders as described (with a few small modifications), in the PECS training manual working in sequence through six possible phases (Frost & Bondy, 2002). In addition to the modified prompting strategy described in the previous section, during Phase 1, the picture-symbol was displayed on the front cover of the binder, as was done in Phase 2, rather than being displayed on its own. This modification was introduced to give children more practice in removing the Velcro-attached picture-symbol from the cover.

A child needed to demonstrate the skill(s) required of each phase (as described in the PECS Training Manual) at a level of 80 percent or more during two sessions with at least three different picture-symbols before the next phase was initiated. Regardless of the phase the child had attained when a new picture-symbol was introduced, the caregiver was instructed to complete a few practice opportunities of each phase (starting with Phase 1) with the new picture-symbol. Of the five children in the mod-PECS condition who completed the study, two mastered Phase 2, one mastered Phase 3a, one mastered Phase 3b, and one participant did not master any phases. Please see **supplemental materials section 4, Table S4** for full details.

In contrast to the CSL-NDBI condition (see previous section for further details), visual discrimination was explicitly taught in Phases 3a and 3b. As mentioned in the introduction, in Phase 3a, the children were taught to discriminate between picture-symbols corresponding to their preferred item or activity and a distractor picture-symbol (e.g., sock) within the context of a request. If a child selected the corresponding picture-symbol, they were given the preferred item whereas if they selected the distractor picture-symbol, a four-step error correction sequence was completed which culminated in the child receiving the desired item (as described on pg 128; Frost & Bondy, 2002). Similarly, in Phase 3b, children were taught to discriminate between multiple preferred picture-symbols when making a request. Another distinct four-step error correction sequence was used (as described on pg 139; Frost & Bondy, 2002).

Given the remote nature of the study and the availability of only one caregiver to participate for several reasons (e.g., single-parent household), the procedures in the first

two phases were modified to have the caregiver take on both the communication partner and secondary prompter roles, as opposed to having two different people take on each role. **See supplemental materials section 2 for the caregiver mastery checklists for the mod-PECS intervention condition.**

Caregiver Coaching Dosage, Session Structure, and Approach

Apart from the two dyads that dropped out after the fourth and fifth sessions respectively, each dyad received between nine and twelve one-hour individual coaching sessions (median = 12 sessions) from the first author who acted as the caregiver coach for both intervention conditions. Coaching sessions took place on Webex®, with the caregiver and their child logging on from their home.

At the start of each intervention session, the caregiver and the coach checked in. The caregiver provided feedback on how their AAC intervention implementation went over the past week and took the opportunity to ask the coach any questions or to problem-solve any challenges related to implementation. Based on the previous session and check-in, the coach and the caregiver decided on a "focus" strategy for the session (i.e., a strategy that the caregiver needed more practice) and set up for the session. Once the environment was set up, the caregiver began engaging with their child to promote AAC use. Once practice concluded, the caregiver and coach did a final check-in where they debriefed on how the session went and discussed how the caregiver should apply the "focus" strategy at home during the coming week. The coach monitored the caregiver's skill acquisition using an in-

session monitoring checklist that was updated at the end of each session. See **supplemental materials Section 5** for the monitoring checklists.

To coach the caregiver on the "focus" strategy, the caregiver coach used a Behaviour Skills Training informed approach (M. Parsons et al., 2012) whereby she first verbally described the focus strategy, modelled it using her own AAC board or mod-PECS binder, and allowed the caregiver to practice the strategy while providing live feedback (e.g., both positive and constructive). In addition, the caregiver coach incorporated components of Rush and Shelden's Early Childhood Coaching approach (Rush & Shelden, 2020) which was used by Vismara et al. (2018) who carried out a remote caregiver-implemented NDBI intervention with young autistic learners. Coaching skills such as acknowledging the caregiver's existing knowledge, interacting in a non-judgemental manner, and providing balanced positive and constructive feedback were included.

Caregiver Coaching Procedural Integrity Checks

Before commencing coaching the CSL-NDBI and mod-PECS interventions, the coach (i.e., the first author) developed a caregiver implementation mastery checklist for each condition. In addition, she took the PECS Knowledge Test to verify her knowledge base (obtained a score of 100 percent) and reviewed and practiced the first four phases as outlined in the PECS training manual (with modifications).

Following each intervention session, the coach completed a brief self-assessment checklist to evaluate her coaching skills. Given the overlap between the Behaviour Skills Training and the Rush and Sheldon coaching approaches, the Coaching Practices Rating

Scale from the Early Childhood Coaching Handbook (p.290, appendix 9A; Rush & Shelden, 2020) was used. This checklist was comprised of 10 items. See **supplemental materials Section 6,** for the coaching checklist. Self-assessment of coaching skills was 91 percent across all intervention sessions.

Primary Outcome Measures

Caregiver Implementation Mastery

Intervention mastery was assessed by a speech-language pathologist with expertise working with autistic children who use AAC, including PECS, and who has completed the PECS Basics Workshop. She was naïve to timepoint and research questions/hypotheses.[16] Implementation mastery was assessed using a checklist. The CSL-NDBI implementation mastery checklist was developed by the first author. See **supplemental materials section 1.** For PECS, using the Picture Exchange Communication System Second Edition Training Manual – 2nd Edition (Frost & Bondy, 2002), the first author and the speech-language pathologist developed implementation mastery checklists for PECS Phases 1, 3a, and 3b (i.e., the phases that the caregiver opted to implement in the recorded videos. Phase 2 was not implemented during any recording). See **supplemental materials section 2**.

Using the appropriate mastery checklist, the naïve speech-language pathologist rater reviewed a video and assessed the correct application of a set of pre-determined strategies by assigning each strategy as observed (+), not observed (-) or not applicable

[16] As she has prior knowledge of PECS and AAC in general and was tasked with assessing implementation mastery, she could be not naïve to what AAC intervention she was assessing.

(N/A). The number of observed strategies was summed and divided by the total number of strategies to generate the percent mastery for the video. For each session, the caregiver was assigned an implementation mastery category of *Not Competent* (0-49 percent), *Emerging Competence* (50-79 percent), *Competent* (80-99 percent), and *Highly Competent* (100 percent). The naïve speech-language pathologist rater assessed a total of 50 videos. The first author acted as a second rater to assess the reliability of 32 percent of these (i.e.,16 videos). For both main and reliability coding, the first author ensured an equal distribution of timepoint and intervention group. Inter-rater reliability indicated substantial agreement with a Cohen's Kappa of 0.79 (percent agreement = 97.5 percent).

Two five-minute caregiver-child videos were recorded at pre- and post-intervention. At the mid-intervention, only one 5-minute video was recorded. To ensure an equivalent sampling across each timepoint, the video with the highest percentage of implementation mastery[17] was chosen to represent the pre- and post-intervention timepoints.

Child AAC Variables Observed

The same set of videos used to assess caregiver implementation mastery was also used to calculate the following: **(1)** total number of prompted/supported AAC acts (i.e., number of times the child used their AAC system with support from their caregiver), **(2)** total number of independent AAC acts (i.e., number of times the child used their AAC system

[17] When the percent mastery was the same across both videos, the first video was chosen. In addition, two participants had only pre-intervention one video each that was recorded with the "target" caregiver (i.e., the caregiver who completed the coaching). Therefore, for these two participants, the "target" caregiver videos were used for analysis.

without support from their caregiver), **(3)** mean length of an AAC "utterance" (i.e., average number of symbols used in an AAC act), and **(4)** total number of different AAC picture-symbols. The total number of prompted/supported AAC acts was included as an outcome variable, considering both the child and their caregiver had minimal to no exposure to AAC and the intervention was only 12 one-hour caregiver coaching sessions.

All AAC variables were coded by three coders (two psychology undergraduates and one doctoral student) naïve to timepoint, condition, and research questions/hypotheses. The AAC coders reviewed a training manual developed by the first author and then practiced coding training videos as a group and then individually until they achieved at least 80 percent agreement with the first author for a minimum of two training videos. The coders used ELAN – Linguistic Annotator software (Hellwig & Sloetjes, 2022) to code 16 to 17 videos each. (i.e. two coders coded 17 videos each, one coder coded 16 videos). Fourteen videos (28 percent) were double-coded to check for reliability. Each of the three coders acted as a reliability coder for four to five videos each (i.e. two coders coded five videos each for reliability, one coder coded four videos for reliability). For both main and reliability coding, the first author ensured an equal distribution of timepoint and intervention group.

The intra-class coefficient for the quantity of AAC acts was 0.99 (percent agreement = 93.8 percent) which indicates almost perfect agreement. The Krippendorf's alpha value for evaluating each AAC act as independent or prompted was 0.78 (percent agreement = 93.0 percent). Finally, the Krippendorf's alpha value for labelling the picture-symbol(s) used in each AAC act was 0.62 (percent agreement = 86.7 percent).

For each video, the coder identified all occurrences of the child AAC use (i.e., when a child removed the Velcro picture-symbol from their AAC board or PECS binder and placed it in their caregiver's hand). In addition, for each occurrence, the coder wrote the corresponding label of the picture-symbol (e.g., wrote "water" for the picture-symbol *water*) and the number of picture-symbol(s) used in the AAC "utterance". Finally, for each identified AAC act, the coder specified if the act was completed independently or with the support of the caregiver (i.e., was prompted). A support/prompt was defined as a hint or cue provided by the caregiver to encourage, facilitate or support the child in using their AAC board or PECS binder. Prompts ranged from an explicit cue such as a *verbal instruction* (e.g., "Use your AAC board or PECS binder.") to a more subtle hint such as a *positional prompt* (e.g., The caregiver looks expectantly and nudges the AAC board or PECS binder in the direction of the child to encourage AAC use).

Finally, the same naïve speech-language pathologist who rated the caregiver's intervention implementation mastery (see caregiver implementation mastery section in methods for details) also evaluated the AAC acts for suspected selection errors across the entire video set for both the CSL-NDBI and mod-PECS conditions. A suspected selection error was defined as an instance where a child's behaviour did not correspond with the picture-symbol they had just selected (e.g., the child selects the picture-symbol *water*, the caregiver hands the child a glass of water, the child pushes the glass of water away). If a suspected selection error was observed, the speech-language pathologist coded the AAC act as a suspected selection error in the corresponding ELAN file. When the AAC data were extracted from ELAN, all AAC acts coded as being suspected selection errors were

subtracted and not included. **See Table S7 in the supplemental section 7** for the number of suspected selection errors coded across each video.

Child AAC Variable Reported

To complement our video-based observational measures, caregivers completed a modified version of the Checklist of Communicative Functions and Means (CCFM; Wetherby, 1995): the Ways and Reasons Checklist (Hearing and Speech Nova Scotia, 2010) at pre- and post-intervention. This was done to capture changes in child AAC use as reported by their caregiver.

Both the CCFM and the Ways and Reasons Checklist were designed to profile the early developing communicative functions a child engages in (e.g., requesting actions) and the means they use to communicate it (e.g., requesting actions by saying single words). The CCFM contains 12 functions and 17 means whereas the Ways and Reasons has 16 functions and 10 means. The Ways and Reasons Checklist was chosen as it included picture-symbol as an option for a communicative *way* and allowed caregivers to report on a larger number of communicative *reasons* compared to the CCFM.

The Ways and Reasons Checklist is presented in a grid format where the caregiver is instructed to review each *reason* (e.g., protests) and when applicable, check off the primary *way* their child uses to communicate it (e.g., protests by engaging in pre-symbolic behaviours). If their child did not use any *way* to communicate a *reason*, they selected the *not yet/does not do* option. See **supplemental materials section 8**.

The results of this checklist are typically used to profile the communicative repertoire of a child and support the selection of intervention targets. For our study, the Ways and Reasons Checklist was plotted and descriptively analyzed. Picture-symbol use from pre- to post-intervention across each condition were discussed. All communicative *ways* primarily communicated through gestures, picture-symbols, or spoken word(s) were added together to make a *Social Function Total* that was compared from pre- to post-intervention and across groups at each timepoint.

Secondary Outcome Measures

Potential Negative Emotional Impact of Intervention on the Child

Given the absence of a direct measure of intervention acceptability from the child, three sub-scales from the emotional distress domain (i.e., anxiety, psychological stress, and anger) of the *Patient-Reported Outcomes Measurement Information System - Autism Battery - Youth* (PAB-Y; Graham Holmes et al., 2020) taken at pre- and post-intervention were plotted and analyzed. The sub-scales were filled out by the child's caregiver and allowed for monitoring of any significant negative change in the emotional state of the child from pre- to post-intervention, which could potentially be attributed to participation in intervention.

The PAB-Y is a part of the PROMIS Autism Battery-Lifespan (PAB-L) and was assembled by Graham-Holmes et al. (2020) using the National-Institutes of Health's Patient-Reported Outcomes Measurement Information System (PROMIS) measures. The PAB-Y covers various domains of functioning, can be used with people on the autism

spectrum from five to 17 years old (via caregiver proxy or self-report), and allows for comparison with the general population norms.

Despite five participants being under five years old (3;1 to 4;11), we chose the PAB-Y measure due to its broad applicability and unique strengths. The PAB-Y provides comprehensive insights into quality of life (QoL) aspects that other tools often lack, covering areas such as social relationships and emotional well-being. While not specifically validated for children under 5, the robustness and relevance of this measure to our population justified its use across the broad age range of our sample (3;1 to 9;11). We will interpret our results with this limitation in mind and exercise caution in drawing conclusions for the younger participants.

The PAB-Y (n = 106 items) is comprised of four domains one of which is emotional distress. Most items are rated on a five-point Likert-type scale. Many scales range from (1) "*never*" to (5) "*always* ". Emotional Distress (n = 27 items) is made up of the constructs of anger (n = five items), anxiety (n = eight items), psychological stress (n = eight items), and depression (n = six items). Each construct is scored individually to generate a T-score (*M* = 50, SD = 10). A higher T-score indicates a stronger presence of that specific quality-of-life indicator (e.g., higher T score for anxiety = lower quality of life).

Intervention Acceptability

At post-intervention, caregivers filled out the *Treatment Acceptability Form - Revised* (TAF-R; Reimers & Wacker, 1992). Sixteen of the 21 items use a seven-point Likert-type scale ranging from (1) "*not at all acceptable*" to (7) "*very acceptable*". The other five items are reverse-scored. Higher scores indicate higher levels of satisfaction. As was done in Simacek

et al. (2017) and Suess et al. (2014), the TAF-R instructions and items were revised to focus on the theme of AAC intervention and communication. In addition, six additional Likert-scale questions were added to allow the caregivers to rate specific aspects of the intervention (e.g., duration, format, setting). Finally, an optional open-ended question was added at the end to allow caregivers to give their overall impressions of the intervention.

Caregiver Self-Efficacy

Given that this AAC intervention study was implemented by caregivers, we investigated their perception of self-efficacy in supporting their child's communication difficulties. At pre- and post-intervention, caregivers completed the *Parental Sense of Competence Scale* (PSOC; Gibaud-Wallston, 1978), which consists of 17 items examining caregiver role satisfaction, efficacy, and interest on a six-point Likert scale (i.e., (1) "*strongly agree*" to (6) "*strongly disagree*"). Higher scores (maximum possible total score = 102) indicate higher ratings of caregiver self-efficacy. Following the methods used by Ingersoll et al. (2016), the total score of the PSOC was used to assess caregivers' perceived ability to support their child's communication skills.

Caregiver Stress and Positive Perception of their Child

The *Family Impact Questionnaire - Revised* (FIQ-R; Donenberg & Baker, 1993) was completed by caregivers to report any change in stress and the positive perception they have of their minimally speaking autistic child from pre- to post-intervention. The questionnaire has 50 items. Most items are rated on a four-point Likert-type scale ranging from (1) "*not at*

all" to (4) "*very much*".[18] The FIQ-R's items are grouped into six sub-scales: the impact their child has on their social life, stress levels, finances, relationship with their partner and siblings (if applicable), and general feelings and attitudes towards the child. All items from the social life and feeling/attitudes subscales (n = 8 items) were averaged to generate a mean *Positive Perception of Child* rating. All stress related items (n = 10 items) were averaged to create a mean *Caregiver Stress* rating (procedure taken from Ingersoll et al., 2016). Higher scores for caregiver stress indicate a greater negative child impact, whereas higher scores for positive perception reflect a greater positive child impact.

Child Quality of Life

Improvement of quality of life (as opposed to improvement in autism diagnostic symptomology) has been identified as a valued outcome by autistic people and their families (Ne'eman, 2010; Pellicano et al., 2014; Robertson, 2009). Therefore, we explored the potential impact of intervention on child quality of life using the PAB-Y (Graham Holmes et al., 2020) that was filled out by the child's caregiver at pre- and post-intervention.

The PAB-Y is comprised of four domains: social functioning, subjective well-being, health, and emotional distress. Each domain is further divided into separate constructs. Social functioning (n =15 items) is made up of two constructs: peer (n = seven items) and family (n = eight items) relationships. The Subjective Well-Being domain (n = 24 items) contains three constructs containing eight items each: life satisfaction, positive affect, and meaning & purpose. The health domain (n = 40 items) has five constructs: sleep disturbance

[18] The two remaining items are rated using two different seven-points scales: one ranging from (1) "much easier" to (7) "much more difficult" and the other ranging from (1) "much less positive" to (7) "much more positive".

(n = eight items), sleep impairment (n = eight items), physical activity (n = eight items), cognitive function (n = seven items), and global health (n = nine items). Finally, the emotional distress domain (n = 27 items) is made up of the constructs of anger (n = five items), anxiety (n = eight items), psychological stress (n = eight items), and depression (n = six items). **See the above section *Potential Negative Emotional Impact of Intervention on the Child* for further details on the PAB-Y.**

Given the purpose of this study (i.e., testing the effectiveness of a 12-week AAC intervention), the subjective well-being, social functioning, and emotional distress domains will be reported. All T-scores from each construct within a domain were averaged to obtain the mean T-score per domain.

Results

Imputation of Missing Data for Intervention Efficacy Analyses

Two caregiver-child dyads in the mod-PECS group withdrew from the study and one dyad from the CSL-NDBI group did not submit their post-intervention video recordings. Given the small sample size, rather than removing their data, an intention-to-treat analysis (Armijo-Olivo et al., 2009) was carried out. The missing data points were imputed using data from the prior available timepoint (i.e., pre- or mid-intervention, when post-intervention data was missing), referred to as the Last Observation Carried Forward method (Shao & Zhong, 2003).

Given the descriptive nature of the analysis, data from the Ways and Reasons Checklist was plotted and descriptively analyzed using only participants that completed the

measure at both pre- and post-intervention (CSL-NDBI n = 10, mod-PECS n = 5). As the intervention acceptability questionnaire was only collected at post-intervention, no imputation was completed. This analysis included a total of 16 responses (CSL-NDBI n = 11, mod-PECS n = 5). All other analyses included the full sample (CSL-NDBI n = 11, mod-PECS n = 7).

Analysis Plan

Before analysis, all outcome variables were assessed for normality within each group. Plots were visually inspected and Shapiro-Wilk tests, commonly used to assess normality for small to moderately-sized samples, were carried out (Ghasemi & Zahediasl, 2012; Rani Das, 2016). The assumption of equal variance between groups was also tested. Primary caregiver and child variables and intervention acceptability outcome variables were not normally distributed, therefore non-parametric tests were employed except as indicated below.

We went beyond basing our results on a *p*-value alone by also calculating and reporting the appropriate measure of effect size (Kraft, 2020). Interpretation of each type of effect size used in this study can be found in **Table S9** in **supplemental materials, section 9.** Large or greater effect sizes were discussed and interpreted regardless of the *p*-value's significance level (Bakker et al., 2019).

For variables sampled at pre-, mid-, and post-intervention, taken from the caregiver-child interaction videos, a Friedman test was used to examine within-group change over the three timepoints. Kendall's coefficient of concordance (i.e., Kendall's W*)* was used as a measure of effect size. Variables sampled at pre- and post-intervention were analyzed using

Wilcoxon signed-rank tests, with a rank bi-serial correlation (i.e., *r*) reported as an effect size.

Statistical comparisons between the two intervention groups at pre-, mid-, and post-intervention were analyzed using a Mann-Whitney U test with continuity correction, with effect size reported using Cliff's Delta (i.e., δ). Interpretation will focus on the mid- and post-intervention timepoint.

The secondary outcome variables of caregiver self-efficacy, stress, positive perception of their child, and most child quality of life domains[19] were normally distributed and had equal variance between groups. For these variables, repeated measures ANOVAs were employed. Generalized Eta squared (i.e., $\eta 2_g$) is reported as an effect size.

Primary Outcome Variables

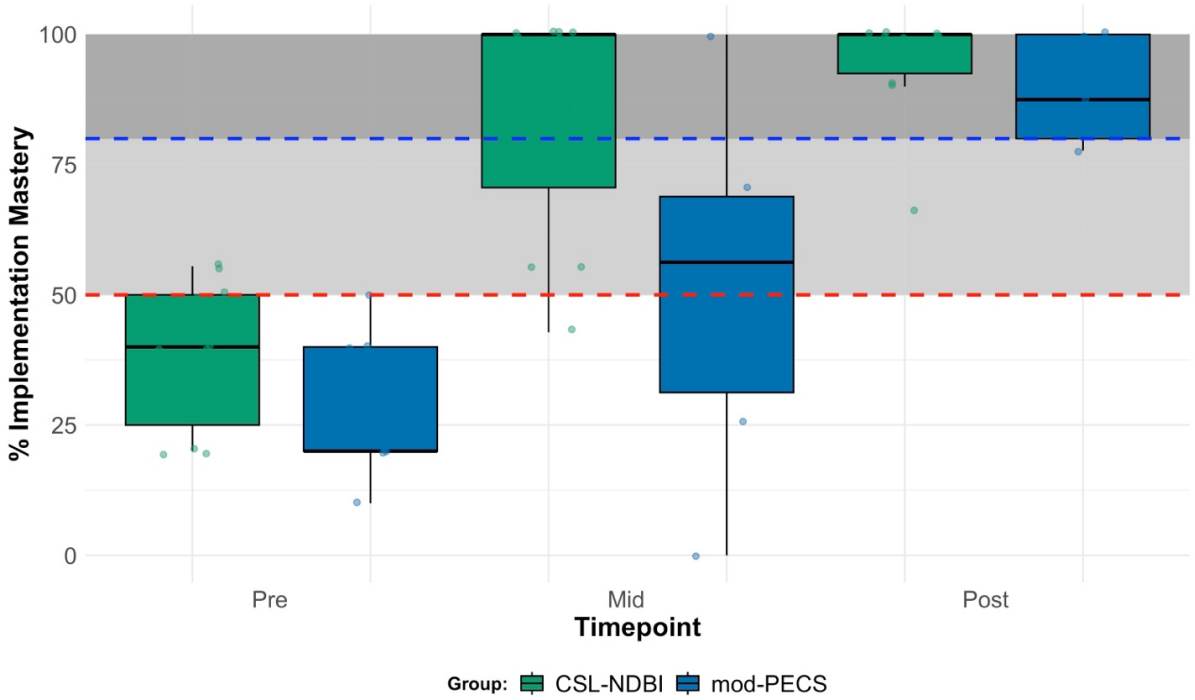
Caregiver Implementation Mastery

In looking at **Figure 7** at pre-intervention, most (i.e., 13 out of the 18) caregivers in both intervention groups had a percent mastery under 50 percent, categorizing them as *Not Competent*. The other five caregivers were categorized as *Emerging Competence* (i.e., 50 to 79 percent) with a percent of mastery that fell between 50 to 55.5 percent. At mid-intervention, the percent mastery was variable with a range of 42.8 to 100 percent for the CSL-NDBI group and 0 to 100 percent for the mod-PECS group. Finally, at post-intervention, a majority of all caregivers across both groups (i.e., 13 out of 15) were categorized as either

[19] The child quality of life domain of Emotional Distress was normally distributed but did not have equal variance between the two intervention groups. Therefore, a linear mixed effect model was used to analyze this variable instead of a repeated measures ANOVA.

Competent (80 to 99 percent) or *Highly Competent* (100 percent) with the two remaining participants categorized as *Emerging Competence* (i.e., 66.6 percent for one participant in CSL-NDBI group, 77.7 percent for one participant in mod-PECS group).

Figure 7. *Caregiver Percentage of Implementation Mastery Across Group and Timepoint*



Note. red dashed line = borderline between the mastery rating of *Not Competent* and *Emerging Competence*, blue dashed line = borderline between the mastery rating of *Emerging Competence* and *Competent*, pre = pre-intervention, mid = mid-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

Differences Over Time. From pre-, mid- and post-intervention, there was a significant increase in caregiver implementation mastery ($\chi^2(2, n=11) = 17.66$, $p = 0.0002$, Kendall's W = 0.80) in the CSL-NDBI intervention group. Kendall's W effect size was large. For the mod-PECS intervention group, the increase in implementation mastery was trending towards significance with a medium effect size ($\chi^2(2, n=7) = 5.33$, $p = 0.07$, Kendall's W = 0.38).

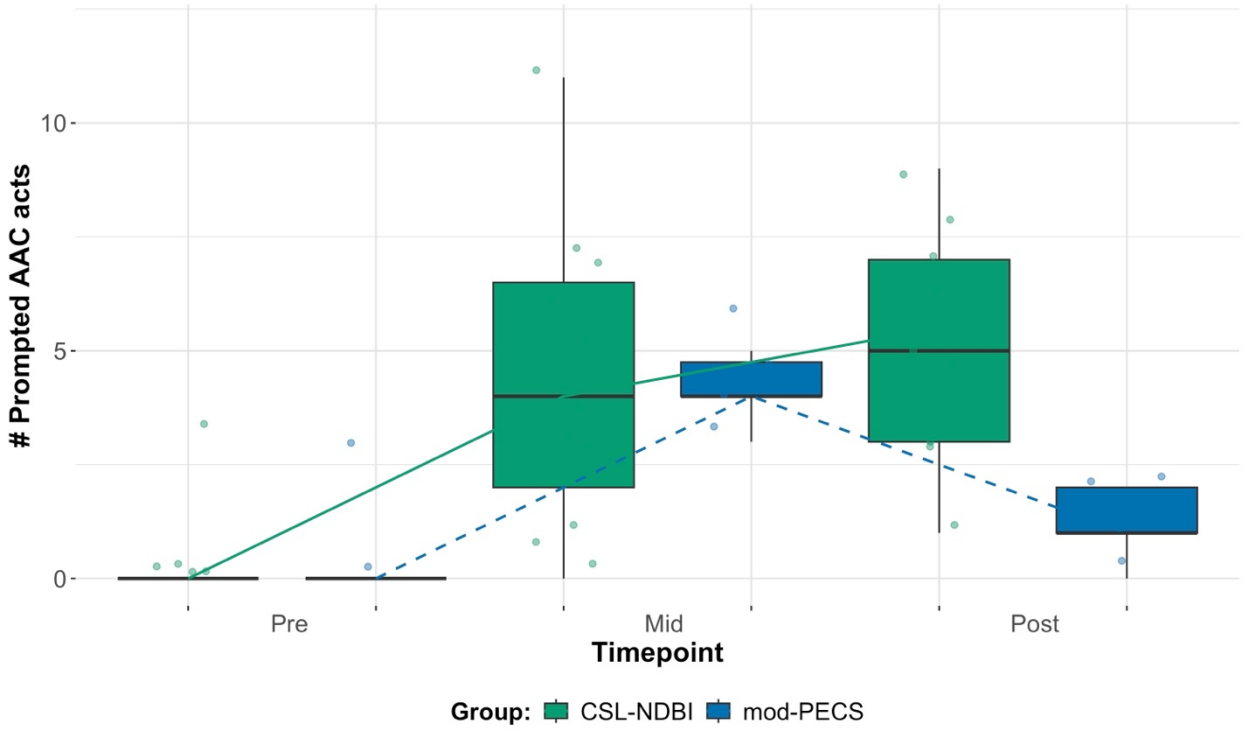
Differences Between Groups. There were no significant differences between the two intervention groups at pre-intervention ($U = 53.5$, $p = 0.18$, $\delta = 0.39$). Therefore, we see that in both groups caregivers had similarly low levels of mastery at the beginning of intervention. However, at mid-intervention, the CSL-NDBI group percent implementation mastery was significantly higher than the mod-PECS group's ($U = 62.0$, $p = 0.03$, $\delta = 0.61$, large effect) and marginally significant at post-intervention ($U = 56.0$, $p = 0.10$, $\delta = 0.46$, medium-large effect). Though the CSL-NDBI group showed significantly stronger mastery at mid-intervention, both groups increased implementation mastery throughout intervention where a majority of caregivers in both groups achieved a level of competence, allowing for the interpretation of changes in child AAC variables due to intervention effects.

Child AAC Variables Observed

1) Prompted/Supported AAC Acts

The medians and ranges for each intervention group showed a sizable increase in prompted/supported AAC acts from pre- to mid-intervention. From mid- to post-intervention, the CSL-NDBI group made a small increase in prompted/supported AAC acts whereas the number decreased in the mod-PECS group from mid- to post-intervention. See **Figure 8**.

Figure 8. *Box Plot of Total Prompted/Supported AAC Acts Across Group and Timepoint*



Note. pre = pre-intervention, mid = mid-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

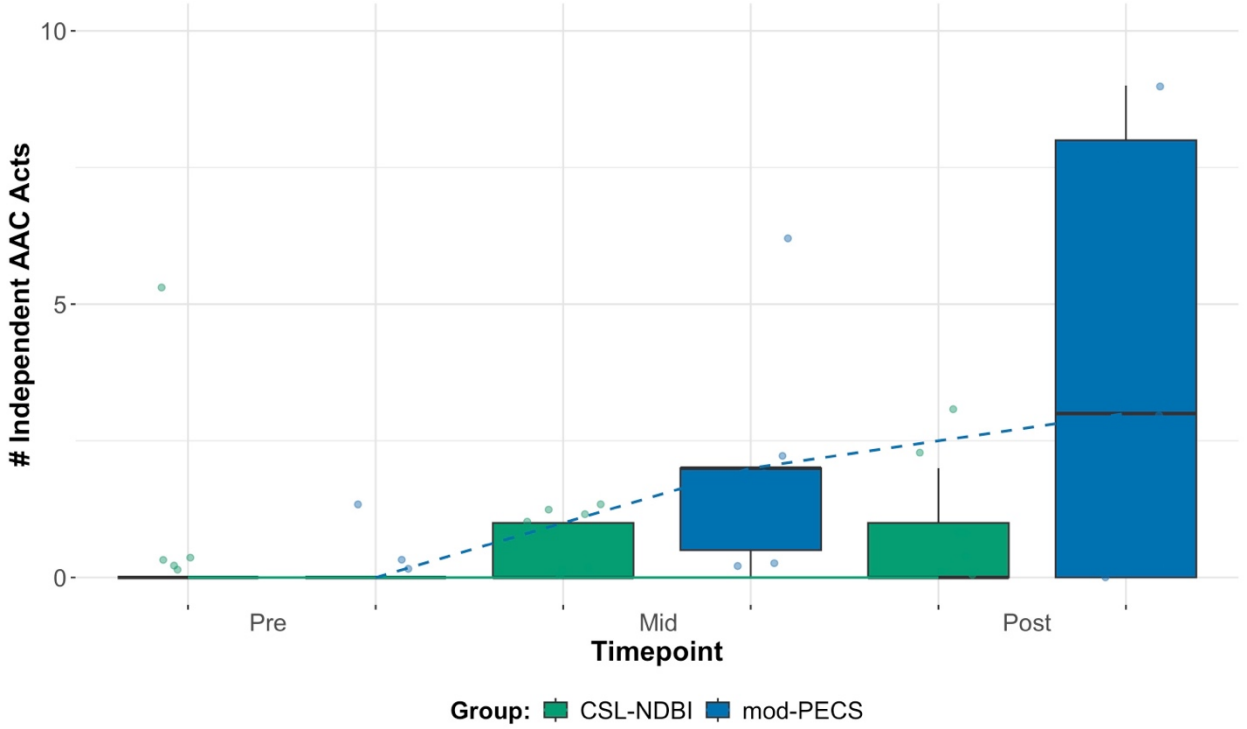
Differences Over Time. Across the three timepoints, both the CSL-NDBI [$\chi^2(2, n=11) = 16.55$, $p = 0.0003$, Kendall's W = 0.75] and mod-PECS [$\chi^2(2, n=7) = 9.36$, $p = 0.009$, Kendall's W = 0.69] had large and significant increases in prompted/supported AAC acts.

Differences Between Groups. There were no significant differences detected in prompted/supported AAC acts at pre- *(U* = 36.5, *p* = 0.80, δ = 0.05) and mid-intervention *(U* = 42.0, *p* = 0.78, δ = 0.09). However, at post-intervention, children in the CSL-NDBI group produced a significantly larger number of prompted/supported AAC acts compared to the mod-PECS group *(U* = 67.5, *p* = 0.009, δ = 0.75).

2) Independent AAC acts

Medians and ranges for each group at each timepoint can be visualized in **Figure 9**. The median independent AAC acts for the CSL-NDBI group was zero (range = 0-5) at pre-intervention, zero (range = 0-1) at mid-intervention, and zero (range = 0-3) at post-intervention. The medians and ranges for the mod-PECS group were zero (range = 0-1) at pre-intervention, two (range = 0-6) at mid-intervention, and three (range = 1-9) at post-intervention.

Figure 9. *Box Plot of Total Independent AAC Acts Across Group and Timepoint*



Note. pre = pre-intervention, mid = mid-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

Difference Over Time. There was no significant difference in the CSL-NDBI group [$\chi^2(2, n=11) = 2.24$, $p = 0.33$, Kendall's W = 0.10] across the three timepoints. However, it is worth

noting that the mod-PECS group's total number of independent AAC acts was trending towards significance [$\chi^2(2, n=7) = 4.78$, $p = 0.09$, Kendall's $W = 0.34$].

Difference Between Groups. Comparisons between groups at each timepoint did not reveal any significant differences (pre-intervention: $U = 37$, $p = 0.87$, $\delta = -0.04$, mid-intervention: $U = 24$, $p = 0.17$, $\delta = -0.38$, post-intervention: $U = 23$, $p = 0.14$, $\delta = -0.40$).

3) Mean Length of AAC Utterance

As AAC acts increased (see earlier sections in the results), the mean length of AAC utterance also increased. Children in both groups began producing AAC acts that were, for the most part, one picture-symbol in length. However, one child in the mod-PECS group at mid-intervention and two children in the CSL-NDBI group at post-intervention began producing AAC acts that were two picture-symbols in length. The medians and ranges for each group at each timepoint are reported in **Table 3.**

Table 3. *Medians and Ranges of Mean Length of AAC Utterance Across Group and Timepoint*

CSL-NDBI[a] median (range)			**Mod-PECS[b]** median (range)		
Pre[c]	**Mid[d]**	**Post[e]**	**Pre**	**Mid**	**Post**
0 (0-1)	1 (0-1)	1 (1-1.17)	0 (0-1)	1 (1-1.25)	1 (1-1)

Note. a) CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, b) mod-PECS = modification of Picture Exchange Communication System c) pre = pre-intervention, d) mid = mid-intervention, e) post = post-intervention

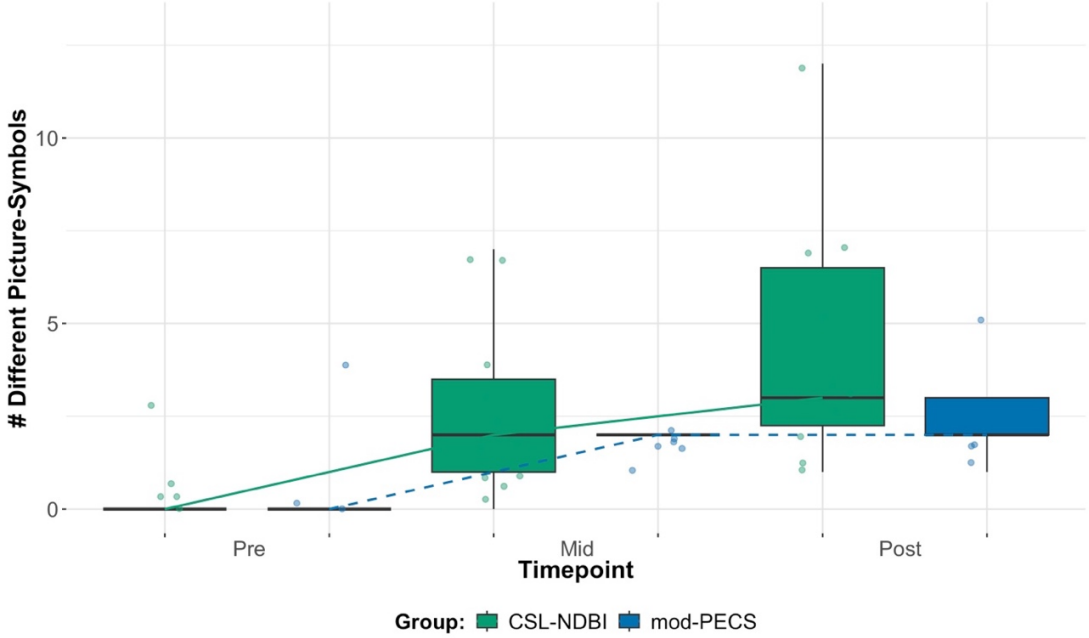
Differences Over Time. Both the CSL-NDBI and mod-PECS groups made significant increases in the mean length of AAC utterance [CSL-NDBI: $\chi^2(2, n=11) = 15.79$, $p = 0.0004$, Kendall's W = 0.72, mod-PECS: $\chi^2(2, n=7) = 10.0$, $p = 0.007$, Kendall's W = 0.71].

***Differences Between Groups*.** All between groups comparisons revealed no significant differences (pre-intervention: $U = 40.0$, $p = 0.89$, $\delta = 0.04$, mid-intervention: $U = 35.5$, $p = 0.73$, $\delta = -0.08$, post-intervention: $U = 41.0$, $p = 0.58$, $\delta = 0.13$).

4) Different AAC Picture-Symbols

The medians and ranges for each group at each timepoint can be visualized in **Figure 10.** A notable increase in the number of different picture-symbols from pre- to mid-intervention in both groups can be visualized.

Figure 10. *Box Plot of Different AAC Symbols Across Group and Timepoint*



Note. pre = pre-intervention, mid = mid-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

Differences Over Time. Both the CSL-NDBI and mod-PECS groups had significant increases in the number of different AAC symbols across all three timepoints [CSL-NDBI: $\chi^2(2, n=11) = 16.55$, $p = 0.0003$, Kendall's W = 0.75, mod-PECS: $\chi^2(2, n=7) = 7.52$, $p = 0.02$, Kendall's W = 0.54].

Differences Between Groups. When compared, there were no significant differences in the number of different symbols between groups at pre- ($U = 39$, $p = 1.0$, $\delta = 0.01$), mid- ($U = 46.5$, $p = 0.47$, $\delta = 0.21$), and post-intervention ($U = 52$, $p = 0.23$, $\delta = 0.35$).

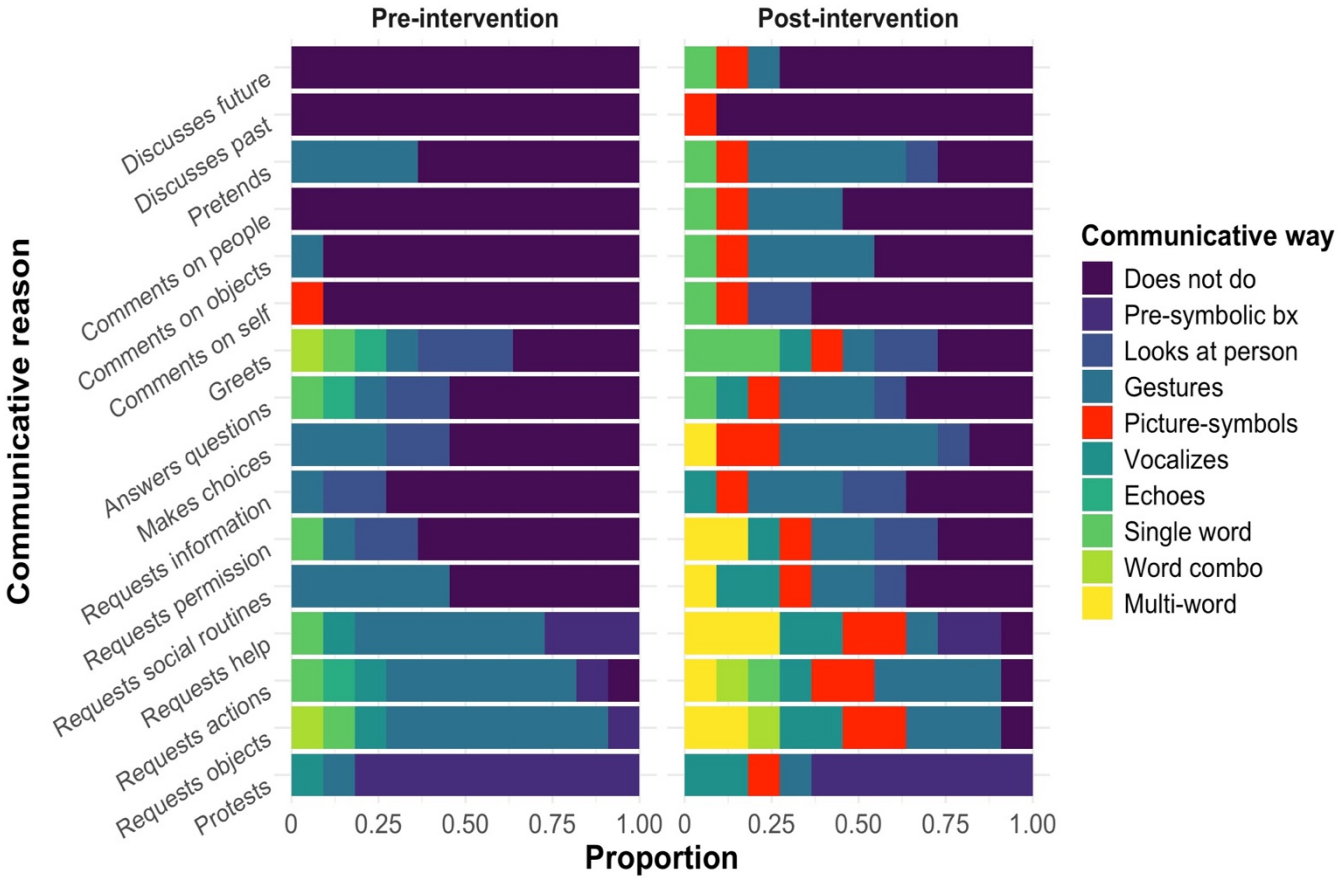
Child AAC Variables Reported

Upon review of the Ways and Reasons Checklist, a small increase in picture-symbol use (shown in red in **Figures 11 and 12**) from pre- to post-intervention in both intervention groups was noted. This indicates a small proportion of children are using picture-symbols as their primary method to communicate certain social functions as per caregiver report.

At pre-intervention, the *Social Function Total* [i.e., functions primarily communicated through gestures, picture-symbols, or spoken word(s)] for the CSL-NDBI group had a median of two (range = 2-10) which increased to five (range = 0-16) at post-intervention. The mod-PECS group had a median of five (range = 2-12) at pre-intervention which increased to six (range = 4-15) at post-intervention. Overall, the proportion of children communicating the 16 different social functions [using gestures, picture-symbols, or spoken word(s)] increased from pre- to post-intervention. This trend can be visualized in

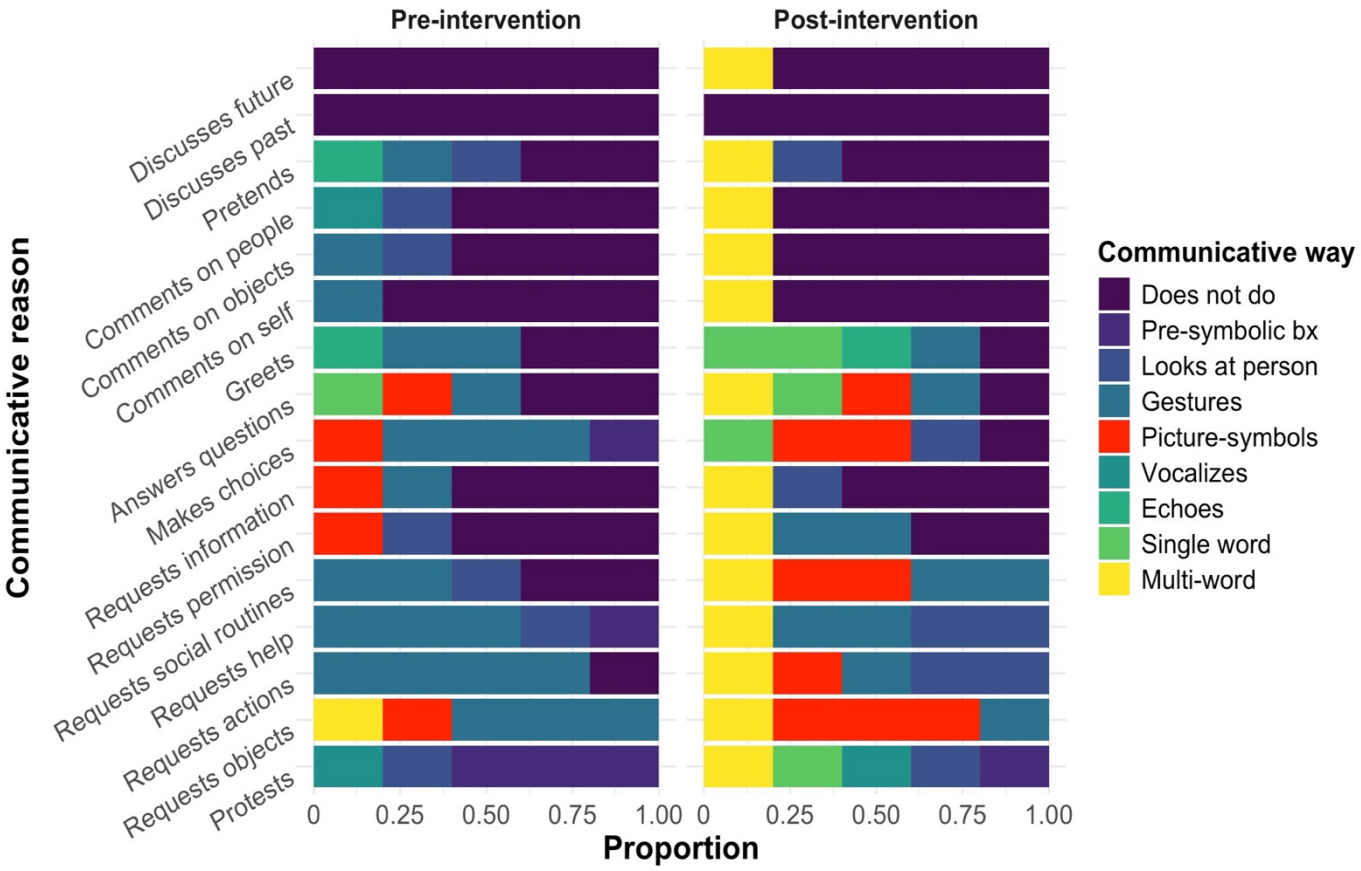
Figures 11 and 12 where more colours (depicting an increase in communicative *ways*) are present at post-intervention (right panel) in comparison to pre-intervention (left panel).

Figure 11. *Proportion of Participants Different "Ways" Used to Communicate Different "Reasons" From Pre- to Post-Intervention in CSL-NDBI Intervention Group (n = 11)*



Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group

Figure 12. *Proportion of Participants Different "Ways" Used to Communicate Different "Reasons" From Pre- to Post-Intervention in mod-PECS Intervention Group (n = 5)*



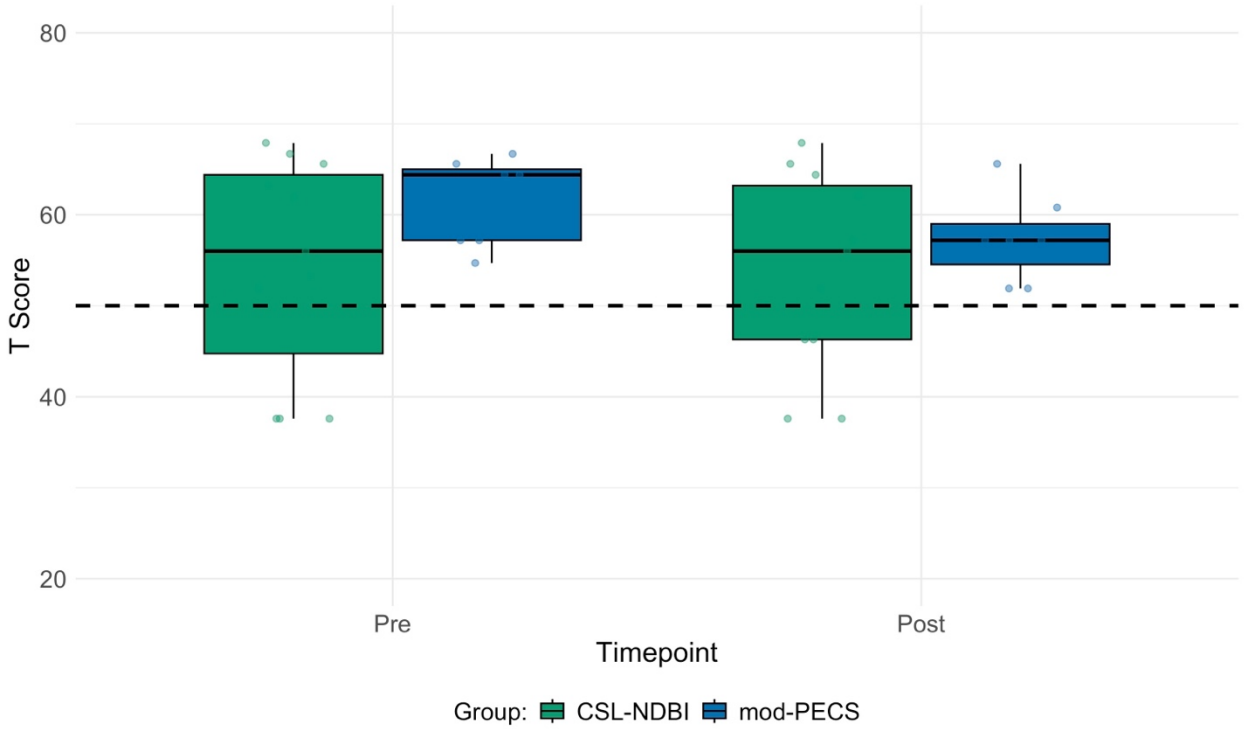
Note. mod-PECS = modification of Picture Exchange Communication System group

Secondary Outcome Variables

Potential Negative Emotional Impact of Intervention on the Child

There were no significant differences detected between the pre- and post-intervention T-scores of anxiety, psychological stress, and anger for each intervention group. Notably, however, the pre- to post-intervention decrease in the psychological stress T-scores *(W* = 1.0, *p* = 0.20, *r* = 0.47) in the mod-PECS group had a medium-large effect size. No significant differences between intervention groups for each variable were found at pre- and post-intervention. See **Figure 13**.

Figure 13. *Box Plot of Child Psychological Stress Across Group and Timepoint*



Note. dashed line = mean T score (i.e., 50), SD = 10, small difference compared to mean = 0.5-1.0 SD, moderate difference compared to mean = 1.0-2.0 SD, large difference compared to mean = >2.0 SD, pre = pre-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

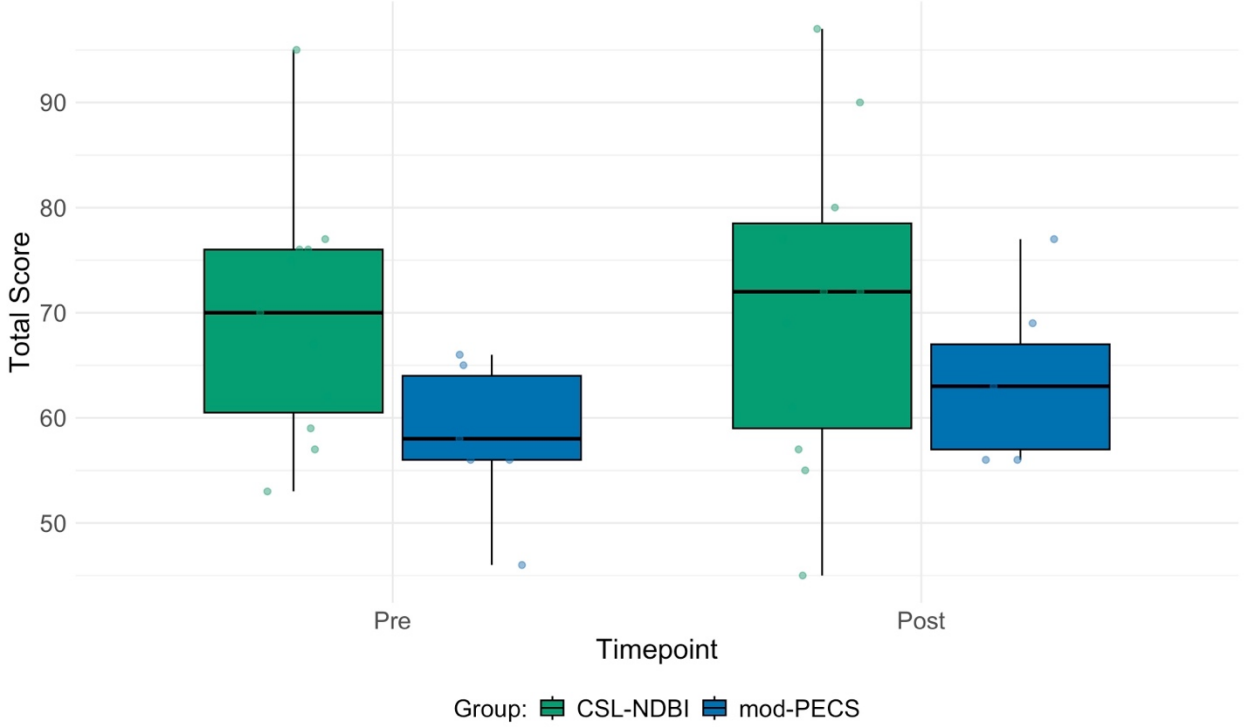
Intervention Acceptability

The median acceptability score for the CSL-NDBI group was 5.8 (range = 4.5-6.7) and 5.8 (range = 5.1-6.6) for the mod-PECS group. These median scores indicate that caregivers from both groups found their AAC interventions to be acceptable (e.g., scores of 4.0 = *neutral* and 7.0 = *very acceptable*). No significant difference between groups was found (U = 25.5, p = 0.86, δ = -0.07). See **supplemental materials section 10, Figures S10a-S10d** for box plots of caregiver's ratings of specific aspects of the intervention (e.g., frequency, virtual format, home location, coaching).

Caregiver Self-Efficacy

At pre-intervention, the mean self-efficacy score of the CSL-NDBI group was found to be significantly larger compared to the mod-PECS group [$t(16) = 2.23$, $p = 0.04$, $d = 1.0$]. There were no significant differences in caregiver self-efficacy across timepoint and group. However, the effect of intervention group was trending towards significance; there were higher scores in the CSL-NDBI group with a large effect size [$F(1,16) = 3.32$, $p = 0.09$, $\eta^2 g = 0.14$]. See **Figure 14**.

Figure 14. *Box Plot of Caregiver Self-Efficacy Across Group and Timepoint*



Note. pre = pre-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

Caregiver Stress and Positive Perception of their Child

See **supplemental materials section 11**, **Figure S11a** and **S11b** for box plots of caregiver stress and positive perception of their child**.** There were no significant differences in either caregiver stress or caregiver positive perception across intervention groups, timepoints, or the interaction between intervention group and timepoint.

Child Quality of Life

See **supplemental materials section 12**, **Figure S12a-S12c** for box plots of the PROMIS subjective well-being, social functioning, and emotional distress domains**.** Statistical analyses revealed no significant effects of group, timepoint or the interaction of group and timepoint.

Table 4. *Results Summary Table – Primary Outcome Variables*

	Difference Over Time (within a group)		**Difference Between Groups** (at different timepoints)	
	CSL-NDBI[a]	**mod-PECS[b]**	**Mid-Intervention**	**Post-Intervention**
Primary Outcome Variables				
Caregiver Implementation Mastery	Yes	Marginal	Yes	Marginal
Child AAC[c] Variables Observed				
1) Prompted/Supported AAC Acts	Yes	Yes	No	Yes
2) Independent AAC Acts	No	Marginal	No	No

3) Mean Length of AAC Utterance	Yes	Yes	No	No
4) Different AAC Picture-Symbols	Yes	Yes	No	No
Child AAC Variables Reported				
Picture-Symbol Use & Social Function Total	Small increase in descriptive stats	Small increase in descriptive stats	N/A	No

Note. a) Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, b) modified-Picture Exchange Communication System group, c) augmentative and alternative communication

Table 5. *Results Summary Table – Secondary Outcome Variables*

	Difference Over Time		**Difference Between Groups**
	CSL-NDBI[a]	**mod-PECS[b]**	**Post-Intervention**
Secondary Outcome Variables			
Potential Negative Emotional Impact of Intervention on Child	No	No	No
Intervention Acceptability	N/A	N/A	No
	Time Effect	**Group Effect**	**Interaction of Time and Group**
Caregiver Self-Efficacy	No	Marginal[C]	No
Caregiver Stress	No	No	No
Caregiver's Positive Perception of Their Child	No	No	No
Child Quality of Life	No	No	No

Note. a) Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, c) marginal difference is related to a significant difference between the CSL-NDBI and mod-PECS groups found at pre-intervention. See Caregiver Self-Efficacy results for further details.

Discussion

Minimally speaking autistic children critically lack evidence-based AAC intervention options (Tager-Flusberg et al., 2023). The main objective of this study was to test the effectiveness of a remotely coached caregiver-implemented naturalistic developmental behavioural AAC intervention that uses a consistent-location (CSL-NDBI) design. This was compared against a modified version of the Picture Exchange Communication System (mod-PECS), which was also caregiver-implemented and remotely coached. Specifically, we wanted to know if 1) caregivers in the CSL-NDBI group could learn to implement their AAC intervention as well as the caregivers in the mod-PECS group, 2) a CSL-NDBI intervention was just as effective as a mod-PECS intervention at increasing AAC use, and 3) children in the CSL AAC group's AAC use was more complex than their counterparts in the mod-PECS group.

Primary Research Questions

Did caregivers in the CSL-NDBI and the mod-PECS groups demonstrate similar trajectories of intervention mastery?

Caregivers in both the CSL-NDBI and mod-PECS groups successfully learned to implement their assigned AAC interventions over the course of the study. The improvements made by caregivers in the CSL-NDBI group were highly significant, with a large effect size. Meanwhile, caregivers in the modified-PECS group also demonstrated gains in implementation mastery, which were marginally significant, with a medium effect size.

As shown in **Figure 7**, when directly comparing each group at each timepoint, caregivers in the CSL-NDBI group demonstrated significantly stronger intervention implementation at mid-intervention ($U = 62.0$, $p = 0.03$, $\delta = 0.61$, large effect) compared to caregivers in the modified-PECS group. This points to the possibility that caregivers in the CSL-NDBI group mastered the implementation of their intervention in a shorter period than those in the mod-PECS group.

We hypothesize that the superior implementation mastery seen in the caregivers in the CSL-NDBI group at mid-intervention could be due to the different intervention approaches (i.e., naturalistic developmental behavioural versus behavioural).

First, the strategies taught in the mod-PECS intervention condition were highly operationalized in comparison to the intervention strategies in the CSL-NDBI condition. **See supplemental materials sections 1 and 2.** For example, at mid-intervention, only one caregiver in the mod-PECS group received credit for the *Immediate Reinforcement of AAC Use* strategy as most caregivers did not provide reinforcement as their first action following the child's AAC act as defined in the mod-PECS implementation mastery sheet created using the PECS manual. For example, the caregiver would not receive credit if they first put the picture-symbol back on the binder cover and then reinforced/followed through on their child's request. In comparison, a majority (i.e., 9 out of 11) of caregivers received credit rating on the equivalent CSL-NDBI strategy which is more openly defined (i.e., *Following a child AAC or spoken act, the caregiver immediately follows through and/or responds to it within a couple of seconds or as soon as it is reasonable to do so*."). Strategies were more openly defined and kept flexible to accommodate slight deviations with the idea of allowing

caregivers the ability to apply these strategies across a multitude of naturally occurring daily settings and activities (where naturalistic developmental behavioural interventions are implemented). With that said, a detailed definition of each strategy in the CSL-NDBI intervention was provided to ensure consistent application.

Second, given the naturalistic approach used in the CSL-NDBI intervention, strategies related to child engagement and child choice were included. Though caregivers in the mod-PECS group did assess child interest to select items or activities to use for AAC, explicit strategies related to engagement and following the child's lead were not a part of the skill breakdown in the PECS manual and consequently not included in the mod-PECS mastery checklist. Therefore, given the inclusion of these strategies in the CSL-NDBI mastery checklist and the fact that it was explicitly implemented by caregivers in this condition, it is plausible that many either came in knowing how to engage and follow their child's lead (or, if not, quickly picked it up), boosting their percent of mastery at each timepoint.

Finally, the group difference seen in implementation mastery could have been attributed to the mod-PECS group's significantly lower self-efficacy score at pre-intervention compared to the CSL-NDBI group. This compounded with the learning of a more technical intervention, may have led to lower implementation mastery in the mod-PECS group.

Regardless, at post-intervention, after having received between nine and twelve remote one-hour coaching sessions (median = 12 sessions), a majority of caregivers from both the CSL-NDBI (9 out of 10) and mod-PECS (4 out of 5) groups were competent

implementers of their assigned intervention, achieving an implementation mastery percent of 80 percent or higher. Therefore, this increases our confidence that any gains observed in AAC use are a consequence of receiving the intervention.

Did children in the CSL-NDBI intervention group increase their AAC use to a similar degree as children in the mod-PECS group?

Both the CSL-NDBI and mod-PECS interventions were effective at increasing AAC use as evidenced by the significant increases in prompted/supported AAC acts over the course of intervention as observed in caregiver-child interaction videos. From pre-, mid-, and post-intervention, the number of independent AAC acts did not significantly increase in the CSL-NDBI group and increased marginally in the mod-PECS group. Although the increase in the number of independent AAC uses over time was trending towards significance in the mod-PECS group, there were no statistically significant differences between the groups at any timepoint, including post-intervention.

At post-intervention, children in the CSL-NDBI group were producing a significantly greater number of prompted/supported AAC acts compared to children in the mod-PECS group. This may be partly attributed to the AAC boards in the CSL-NDBI group, which used a consistent-symbol location design. These boards allowed for a large number of directly accessible AAC symbols, which grew substantially over the course of the intervention compared to the limited number of symbols available on the front cover of the mod-PECS binders (see **Table 2**). Therefore, children in the CSL-NDBI group likely required more support from their caregivers to navigate the larger arrays, resulting in significantly more

prompted AAC acts in the CSL-NDBI condition. In contrast, in the mod-PECS condition, it is hypothesized that the simplicity of the much smaller picture arrays used (see **Table 2**) allowed children in that group to produce slightly more independent AAC acts from mid- to post-intervention which likely contributed to the significant decrease in prompted AAC acts seen in **Figure 8** at post-intervention.

The above findings are supported by caregiver report. From pre- to post-intervention, on the Ways and Reasons Checklist, more (but not most) children were reported to use picture-symbols as a primary method to communicate several different communicative functions in both groups (shown in red in **Figures 11 and 12**). This increase is very modest and indicates, for the most part, children are not yet using their AAC boards or mod-PECS binders as a functional system to communicate, which is not surprising given all children were only introduced to these AAC systems at the start of intervention which was nine to twelve weeks long.

Therefore, in sum, at mid- and post-intervention, though not independent, when in a supported context with their caregivers, children in both CSL-NDBI and mod-PECS intervention groups were using AAC to communicate.

Finally, of note, though not significant, when comparing the number of independent AAC acts between each group at each timepoint, children in the mod-PECS group appeared to trend towards a higher number of independent AAC acts compared to children in the CSL-NDBI group. This trend is supported by decreasing *p*-values and increasing effect sizes [pre- ($U = 37$, $p = 0.87$, $\delta = -0.04$, negligible effect), mid- ($U = 24$, $p = 0.17$, $\delta = -0.38$, medium effect), post- ($U = 23$, $p = 0.14$, $\delta = -0.40$, medium effect)]. It is hypothesized that with continued

practice using a small array of picture-symbols (as outlined in the PECS protocol), children in the mod-PECS group would have started to produce significantly more AAC acts independently compared to children in the NDBI-CSL who used much larger picture-arrays.

Did the AAC use of children in the CSL-NDBI group become more complex (i.e., longer AAC utterances and higher number of different picture-symbols) in comparison to children in the mod-PECS group over the course of intervention?

Now that we've established that the AAC use was similar between both groups, let's look at complexity. Over the course of intervention, mean length of AAC utterance and number of different picture-symbols, as observed via caregiver-child interaction videos, increased significantly in both the CSL-NDBI and mod-PECS groups. For mean length of AAC utterance, the significant increase is attributed to the fact that most children were not using AAC at pre-intervention and were using at mid- and post-intervention (i.e., going from a mean length of AAC utterance of zero to one). There was no significant difference in the mean length of AAC utterance between the CSL-NDBI and mod-PECS groups at post-intervention.

For the number of different picture-symbols, the level of significance as well as the effect size were more pronounced in the CSL-NDBI group ($p = 0.0003$, Kendall's W = 0.75) in comparison to mod-PECS group ($p = 0.02$, Kendall's W = 0.54) when looking at change over time. However, there was no statistical difference in the number of different picture-symbols used when directly comparing each group at mid- and post-intervention.

Therefore, by the end of intervention, children in the CSL-NDBI group using a consistent-symbol location design AAC board did not produce longer and more diverse AAC acts than the mod-PECS group which is counter to our initial hypothesis. In comparison children in the mod-PECS group who, for the most part, had access to one to two picture-symbols at a time, children in the CSL-NDBI group were better positioned to produce diverse multi-symbol AAC acts given the consistent-symbol location design of their AAC board provided direct access to many picture-symbols. However, all children began the 12-week intervention study not using AAC, attaining only a novice level of AAC use by the end. Given the large number of new picture-symbols introduced and subsequently displayed on the front cover of their new AAC boards (see **Table 2**), it is possible that children in the CSL-NDBI group did not have an opportunity to establish stable motor patterns through practicing and therefore reap the potential benefits of the consistent-symbol location design. Additionally, this highlights that for minimally speaking autistic children in the CSL-NDBI group, diverse AAC use was not solely about ensuring ready access to picture-symbols. In comparison, the mod-PECS group typically had direct access to only one or two picture-symbols at a time (as shown in **Table 2)**. It also underscores the critical importance of having someone actively support the learning process, particularly when teaching children to use complex multi-symbol, grid-based AAC systems.

With that said, though not statistically significant, when comparing the number of different picture-symbols between each group at each timepoint, children in the CSL-NDBI group appeared to trend towards using a higher number of different picture-symbols. This trend is supported by the following results: [pre- ($U = 39$, $p = 1.0$, $\delta = 0.01$, negligible effect),

mid- (U = 46.5, p = 0.47, δ = 0.21, small effect), post- (U = 52, p = 0.23, δ = 0.35, medium effect)]. Therefore, it is possible that given more time and practice with continued access to a large array of picture-symbols, children in the CSL-NDBI group would have begun to produce a significantly higher number of picture-symbols in comparison to the mod-PECS group.

Secondary Research Questions

Did caregivers report any significant negative changes in children's emotional state in either group from pre- to post-intervention?

No significant negative changes (i.e., increases) in child anxiety, psychological stress, and anger were reported from pre- to post-intervention. Also, though not a specific objective of the study, caregiver proxies in the mod-PECS group reported a decrease in their child's stress from pre- to post-intervention. This provides some evidence that these interventions, as implemented in this study, did not negatively impact the emotional states of the participating children.

Did caregivers report their assigned AAC intervention (CSL-NDBI or mod-PECS) to be acceptable?

Caregivers in both the CSL-NDBI and mod-PECS groups found their assigned intervention to be acceptable. In addition, in response to the additional questions related to specific aspects of the intervention (i.e., format, location, duration), caregivers also rated

each as acceptable. All caregivers found the coaching format to be very acceptable, assigning a rating of six or seven (maximum rating = seven). Apart from four caregivers, all caregivers found the virtual format to be very acceptable (i.e., rating it a six or seven out of seven). It is suspected that the neutral ratings (i.e., four out of seven) from the four caregivers could have been impacted by the COVID-19 pandemic (i.e., the period in which intervention sessions took place) when health restrictions and social distancing measures were in place, forcing many normally in-person events to take place online. In sum, these findings indicate that the two 12-week remote AAC interventions, carried out by caregivers from their homes, were satisfactory.

Did caregivers report an increase in self-efficacy from pre- to post-intervention?

From pre- to post-intervention, there was no statistically significant change in caregivers' self-efficacy scores in both groups. As the CSL-NDBI group's self-efficacy score at pre-intervention (*M* = 69.7) was significantly higher than that of the mod-PECS group (mod-PECS: *M* = 58.6), it is possible that there was less room to increase the perception of their abilities (maximum score = 102). Though there was no statistical difference found in the self-efficacy score of the mod-PECS from pre- to post-intervention, the mean score did increase by six points (see **Figure 14**). This six-point increase is similar to what was reported by the two caregiver groups in the Ingersoll et al. (2016) intervention study where each intervention group reported a statistically significant increase of 5.4 and 6.8 points. This demonstrates that caregivers in the mod-PECS group did see meaningful improvements in their perceptions of being able to support their child's communication difficulties.

Did caregivers report any change in stress and the positive perception they have of their minimally speaking autistic child from pre- to post-intervention?

Caregiver stress and positive perception remained stable from pre- to post-intervention in both the CSL-NDBI and mod-PECS groups. No difference between the groups at post-intervention was found. These findings indicate that over the course of intervention, there was no substantial decrease in stress and no substantial increase in positive perception. A study by Suswaram et al. (2024) found that greater communication difficulties were associated with higher caregiver-reported stress for caregivers of minimally speaking children. Therefore, it is possible that stress did not decrease because caregivers in both groups did not perceive any global changes in their child's ability to communicate which aligns with their responses on the Ways and Reasons Checklist.

When comparing the pre-intervention mean stress scores of the CSL-NDBI group (*M* = 2.3) and the mod-PECS group (*M* = 2.4) to the scores from the Ingersoll et al. (2016) study, where the self-directed caregiver group had a mean of 1.2 and the therapist-assisted caregiver group had a mean of 1.0 (out of a maximum score of 4.0), stress levels in the current study were higher. This difference may be attributed to two possible reasons. First, the autistic children (age range = 1.5 – six years old). in the Ingersoll et al. (2016) study were delayed in their spoken language development but not minimally speaking. Therefore, it is hypothesized that their communication levels were stronger than our child participants. Second, these higher levels of reported caregiver stress may be associated with the COVID-

19 pandemic which occurred during the period in which this study took place (Yılmaz et al., 2021).

To contrast, the mean positive perception scores at pre-intervention for the CSL-NDBI (*M* = 2.9) and mod-PECS groups (*M* = 2.5) (out of a maximum mean score of 4.0) were higher than those reported at pre-intervention in the Ingersoll et al. (2016) study (self-directed group *M* = 1.52, therapist-assisted group *M* = 1.40). This shows that despite the higher self-reports of stress in comparison to the caregivers in the Ingersoll et al. (2016) study, caregivers in both the CSL-NDBI and mod-PECS groups reported experiencing a higher positive impact from their minimally speaking autistic child, including feelings of joy, happiness, fun, and love.

Did children in either intervention group experience a positive change in social functioning, well-being or emotional distress from pre- to post-intervention?

Globally, children in both groups did not experience any significant changes in well-being, social functioning, and emotional distress from pre- to post-intervention as reported by their caregivers. This is not surprising given the intervention was only 12 one-hour sessions and targeted only one domain (i.e., improving communication). Finally, it is also possible that the measure was not sensitive enough to capture change, as a proportion of our sample (n = 5) were under the age of five, and the PAB-Y is validated for children aged five and older.

Summary and Contributions

Our findings demonstrate that caregivers can successfully learn to implement a naturalistic developmental behavioural AAC intervention using a consistent-symbol location (CSL-NDBI) when coached remotely through telehealth. This combination, which had not been empirically tested in a telehealth setting until now, shows promise in supporting caregivers (Elmquist et al., 2023). In addition, caregivers in the other intervention condition learned to competently implement a modified version of Picture Exchange Communication System intervention (mod-PECS), adding to the existing knowledge base showing that this type of behaviourally-based aided AAC intervention can be learned via telehealth by caregivers.

In addition, our findings indicate that the 12-week CSL-NDBI AAC intervention was mastered by caregivers in a shorter period pointing to the possibility that an NDBI approach may be better suited to caregivers in a telehealth AAC intervention context compared to a behaviourally-based one. To our knowledge, this is the first study to compare an aided AAC intervention that uses a naturalistic developmental behavioural approach with another one that uses a behavioural method such as mod-PECS. Therefore, further replication is needed to confirm this finding.

Both the CSL-NDBI and mod-PECS interventions significantly increased AAC use in minimally speaking autistic children who were not yet using AAC consistently or independently. Specifically, both remotely coached caregiver-implemented interventions led to similar increases in AAC use when directly supported (i.e., prompted) by their trained caregiver. These results showcase that the CSL-NDBI intervention with a growing but less

established evidence-base as Picture Exchange Communication System, can lead to similar positive outcomes. Although AAC use by children in both groups was largely prompted by caregivers, this outcome is clinically meaningful. The increase in AAC use occurred despite the relatively small number of coaching sessions (nine to twelve one-hour sessions) and the remote, caregiver-mediated delivery method. This progress represents a notable departure from the group's previously very limited communicative abilities. However, it also highlights the complexity of each AAC system's design and emphasizes the ongoing need for AAC services to support minimally speaking autistic children in becoming efficient and independent communicators. Additionally, it emphasizes the need to further explore potential design alternatives in AAC research to optimize the learning process and ensure it is tailored to minimally speaking autistic children who are emergent communicators.

Children in the CSL-NDBI and mod-PECS intervention groups both produced AAC utterances that were on average one picture-symbol in length. There were no significant differences in the number of different picture-symbols used at post-intervention between the two groups. These results indicate that the consistent-symbol design used in the CSL-NDBI condition, when used at an early stage of AAC development, does not lead to significantly more complex AAC use than those in the mod-PECS group. Therefore, it is hypothesized that a consistent-symbol location design may be more important as children advance in their AAC learning and the complexity of their communication becomes more sophisticated (e.g., multi picture-symbol messages). This suggests that the current clinical practice where consistent-symbol location design is often used in grid-based aided AAC

systems, may be less beneficial for minimally speaking autistic children during the early stages of language learning. However, further research is needed to assert this conclusion.

Limitations

First, since the two intervention conditions differed in both design and teaching approach, the interpretation of our findings is limited. We cannot attribute the outcomes to a single factor, such as design or approach alone.

Second, as shown in **Table 1**, a small percentage of child participants in each group were receiving AAC services outside of the home. Though there were no significant differences between both groups, it could have boosted child performance, inflating our results. Also, our sample was small, unequal, and underpowered and therefore likely not representative of this heterogenous autistic subgroup, limiting the generalizability of our findings.

Third, since the intervention was implemented by the children's caregivers, the significantly lower caregiver self-efficacy score in the modified Picture Exchange Communication System (mod-PECS) group, compared to the CSL-NDBI group, may have influenced their ability to effectively learn their assigned intervention.

Fourth, children were assigned to intervention condition by the first author using a non-randomized process to ensure both groups were matched according to receptive vocabulary ability. She also acted as the caregiver coach for both intervention groups as well as the reliability coder for the caregiver mastery implementation ratings. Therefore, her direct involvement in these study tasks could have unknowingly biased the results.

Fifth, this AAC intervention study did not have a post-intervention follow-up after the completion of the intervention sessions to check for maintenance of caregiver implementation mastery and further change in child AAC use across both conditions. In addition, given a majority of AAC use at post-intervention was directly supported by the caregiver in both groups, it is likely that the intervention dosage was not enough.

Finally, the emotional state of participating children was only monitored at two timepoints using a third party (i.e., a questionnaire filled out at pre- and post-intervention by their caregiver). Therefore, it is possible that these measures and procedures were not sensitive enough to detect increases in child anxiety, stress or anger.

Future Directions

First, we recommend replicating this study using a higher dosage (e.g., one-hour session per week over 16 weeks or two one-hour sessions over 9 to 12 weeks). It should also recruit a larger sample, use a randomized intervention assignment procedure, implement an unmodified version of Picture Exchange Communication System, and include a two-to-three-month post-intervention follow-up timepoint. This higher dosage design would allow participating children more time to develop their AAC skills and would allow the research team the opportunity to evaluate the difference in conditions as AAC use becomes more independent and increases in complexity.

Second, we recommend tracking and analyzing the types of caregiver supports/prompts used to support AAC in each condition as an increasing trend of subtle prompts (e.g., pushing the AAC board toward the child), as opposed to more explicit

prompts (e.g., pointing directly to the target picture-symbol), may be a pre-cursor to independent AAC use.

Third, to increase the rigour of the CSL-NDBI condition, we recommend incorporating dynamic assessment whereby the number of picture-symbols, types of prompts, types of symbols (e.g., icons or letters) as well as communication targets can be individualized using a more structured method (Gevarter et al., 2020; Holyfield, 2021).

Finally, given the importance of tracking adverse events when implementing intervention with autistic individuals (Bottema-Beutel, Crowley, et al., 2021), it is recommended that the monitoring of the child's emotional state be expanded beyond pre- and post-intervention tracking by a familiar third party to include multiple timepoints of direct observation (e.g., coding of specific negative valence behaviours by a naïve third party).

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Supplemental Materials

Testing The Effectiveness of a Naturalistic Developmental Behavioural AAC Intervention That Uses Consistent-Symbol Location

Supplemental Section 1

Caregiver Implementation Mastery Sheet Data Sheet - Consistent-Symbol Location and Naturalistic Developmental Behavioural Intervention Condition – Abbreviated Version

Intervention component rated per trial (CP = Communication Partner, AAC = Augmentative and Alternative Communication)	Examples	Codes per trial					Code Summary + or - or NA	Notes (or spoken codes)
1 - Getting engagement going when there is no lead to follow: If the child does not have an obvious lead to follow OR seems to be losing interest in the current activity, the CP presents, sets up, and engages with an activity or routine (tangibles not required) that is of potential interest to the child (i.e., the child should show signs of engagement otherwise CP should be pivoting to another potential activity/routine). + = CP tried to engage when no lead present - = CP did not try to engage when no lead present NA = lead already present *throughout duration of coding sequence* (5min) no attempts to engage required by CP	*Example* - The child sitting in front of a doll house and has not engaged with anything for a period of time. The CP pulls out a bucket of animal figurines, presents them to the child, and begins to drop them down the chimney (because the CP knows the child likes this action based on prior interactions). *Non-Example* - The child is sitting in front of a doll house and has not engaged with anything for a period of time. The CP sits beside the child. The child eventually gets up and goes to another room.	Before opp 1	Before opp 2	Before opp 3	Before opp 4	Before opp 5		
		Before opp 6	Before opp 7	Before opp 8	Before opp 9	Before opp 10		
		Before opp 11	Before opp 12	Before opp 13	Before opp 14	Before opp 15		
2 - Following the child's lead when engaged: If the child does have a lead to follow (i.e., is engaged in an activity of interest), the CP tries to incorporate themselves into the activity in a manner that pleases or at a minimum is accepted by the child (i.e., child doesn't avoid the CP and even sees the CP as "valuable" to the interaction/activity). + = lead followed by CP - = lead not followed by CP, no lead created by CP so none to follow by CP	*Example* - The child takes a dog figurine and drops it down the chimney of a doll house. The CP takes a cat figurine and drops it down the chimney while making a fun sound effect. *Non-Example* - The child takes a dog figurine and drops it down the chimney of a doll house. The CP takes the dog figurine, tells the child to stop dropping it, and insists that they use it in a more "appropriate" way by making the dog figurine "drink" from a pretend bowl.	Before opp 1	Before opp 2	Before opp 3	Before opp 4	Before opp 5		
		Before opp 6	Before opp 7	Before opp 8	Before opp 9	Before opp 10		
		Before opp 11	Before opp 12	Before opp 13	Before opp 14	Before opp 15		

3 - Contriving an opportunity to *expressively* communicate: Once child choice is established by following or "creating" a lead to follow and the child is engaged in an activity, the CP generates an opportunity for the child to communicate or interact using their AAC system **by gaining shared control, briefly pausing the activity, and expecting the child to respond.** When no AAC present, base coding on if the CP can create MO/opps to communicate using spoken or gesture. + = MO to communicate created appropriately by CP - = MO to communicate not created appropriately by CP NA = MO creation not needed as child spontaneously uses AAC (or if no AAC, spon uses spoken or gesture) *throughout duration of coding sequence* (5min)	*Example* - The child and the CP are taking turns putting figurines down the chimney of a doll house. When the CP goes to take their next turn, <u>they pause, hold the cat figurine at the top of the chimney waiting for the child to communicate</u>! *Non-Example* - The child and the CP are taking turns putting figurines down the chimney of a doll house. The CP continues the activity "as is" with no expectation that the child communicates or responds to any communicative bids from the CP.	AAC 1	AAC 2	AAC 3	AAC 4	AAC 5		
		AAC 6	AAC 7	AAC 8	AAC 9	AAC 10		
		AAC 11	AAC 12	AAC 13	AAC 14	AAC 15		
4 - Proactively prompting to support successful AAC use BEFORE: Once an opportunity to communicate has been set up, **as needed**, the CP provides a proactive hint/cue to encourage successful AAC use. **Though a range of prompts tailored to the needs of the child can be provided, the least invasive/non-physical prompts are highly encouraged.* + = prompted appropriately - = not prompted or inappropriate prompt or no AAC present NA = no proactive prompt support needed *throughout duration of coding sequence* (5min)	*Example* - The CP generates an opportunity to communicate by pausing and holding the cat figurine at the top of the chimney, the child begins to scan their communication board. The <u>CP points to the "go" picture-symbol on the board with the expectation that the child imitates their point</u>. *Non-Example* - The CP generates an opportunity by pausing and holding the cat figurine at the top of the chimney, the child begins to scan their communication board. The CP continues to pause. The child continues to scan the board then attempts to grab the cat figurine out of the CP's hand. The child begins to show signs of frustration and eventually loses interest and moves onto another activity.	AAC only 1	AAC only 2	AAC only 3	AAC only 4	AAC only 5		
		AAC only 6	AAC only 7	AAC only 8	AAC only 9	AAC only 10		
		AAC only 11	AAC only 12	AAC only 13	AAC only 14	AAC only 15		
5 - Reactively prompting to support successful AAC use AFTER: As needed, the CP provides a reactive hint/cue to correct an OBVIOUS selection error, refine/improve AAC use or to clarify an unclear spoken bid. If the definition of suspected selector error is met - prompting should occur. However, with that said, if a parent provides a reactive prompt <u>based on their own judgment</u> (e.g., feels the child could increase the specificity of their AAC use: use	*Example* - CP generates an opportunity to communicate by pausing and holding the cat figurine at the top of the chimney, the child begins to scan their communication board and independently <u>selects the picture-symbol "stop"</u> when it is VERY VERY clear that what they <u>intended to select was "go"</u> as the child is trying to move the CP hand's to make the cat go down the chimney. Therefore, the <u>CP points to the "go" picture-symbol on the board</u>. *Non-Example* - CP generates an opportunity to communicate by pausing and holding the cat figurine at the top of the chimney, child begins to scan their communication board and independently selects the picture-symbol "stop" when it is VERY VERY clear that what	AAC only 1	AAC only 2	AAC only 3	AAC only 4	AAC only 5		
		AAC only 6	AAC only 7	AAC only 8	AAC only 9	AAC only 10		

"go away" instead of "stop"), though it might not qualify as a selection error (e.g., "go away" or "stop" might both be okay in the context) based on your clinical judgment, rate the parent's performance based on the delivery and effectiveness of the reactive prompt. + = prompted appropriately - = not prompted or inappropriate prompt or no AAC present NA = no reactive prompt support needed *throughout duration of coding sequence* (5min)	they intended to select was "go" as the child is looking for the CP make the cat go down the chimney. However, the CP stops & the child looking confused, continues to scan the board then attempts to grab the cat figurine out of CP's hand. Child begins to show signs of frustration & eventually loses interest and moves onto another activity.	AAC only 11	AAC only 12	AAC only 13	AAC only 14	AAC only 15		
6 - Immediately following through and/or responding to *expressive* communication. After the child communicates (AAC or clear spoken), the CP reinforces the child by *immediately* following through (within a few seconds) and/or responding to their interaction (not for gesture as it is used as a "cue" to prompt for AAC use). When no formal AAC: assess spoken + gesture + = appropriate rx provided (tangible rx, social rx, etc) - = no rx or inappropriately rx NA = teaching "loop" incomplete	*Example* - The child points to the "go" picture-symbol and the CP immediately follows through by putting the cat figurine down the chimney. *Non-Example* - The child points to the "go" picture-symbol and the CP says, "Yes go! Great work." and puts their hands up in the air.	AAC 1	AAC 2	AAC 3	AAC 4	AAC 5		
		AAC 6	AAC 7	AAC 8	AAC 9	AAC 10		
		AAC 11	AAC 12	AAC 13	AAC 14	AAC 15		
7 - NOT insisting on additional communication: The CP does NOT *go back* and *insist* on the child using additional communication (e.g. saying the word or expanding on the AAC utterance) when AAC or clear SPOKEN communication has already been provided (not for gesture as it is used as a "cue" to prompt for AAC use). + = no insistence on additional - = insistence on additional NA = teaching "loop" incomplete	*Example (+)* - The child points to the "go" picture-symbol and the CP immediately follows through by putting the cat figurine down the chimney. *Non-Example (-)* - The child points to the "go" picture-symbol and the CP says, "Great now say the word "GO!"	AAC 1	AAC 2	AAC 3	AAC 4	AAC 5		
		AAC 6	AAC 7	AAC 8	AAC 9	AAC 10		
		AAC 11	AAC 12	AAC 13	AAC 14	AAC 15		
8 - Returning picture-symbol: Following the AAC use, the CP returns the picture symbol(s) to the/their designated spot(s) on the board (i.e., same place where the child removed it from initially). This should at a minimum occur at the LATEST before starting the next communication opportunity is set up. **If the child*	*Example* - After the AAC use is completed, the CP returns the "go" picture-symbl to the bottom right corner (i.e., the same spot where the child picked it up). *Non Example* - After the AAC use is completed, the CP puts the "go" picture-symbol on the sentence strip, not the bottom right corner.	AAC only 1	AAC only 2	AAC only 3	AAC only 4	AAC only 5		
		AAC only 6	AAC only 7	AAC only 8	AAC only 9	AAC only 10		

points to the AAC symbol(s) code this item as a "+" as long as the AAC symbol is NOT moved. + = returned to right spot (or not moved at all) - = not returned or returned to wrong spot or no AAC present NA = teaching "loop" incomplete		AAC only 11	AAC only 12	AAC only 13	AAC only 14	AAC only 15		

Intervention component rated per video sample (based on overall impression)	**Summary Code**	**Notes**
9 - Arranges environment to promote communication/pre-plans: A) CP positioned appropriately (in front of child and/or generally oriented to the child) B) CP seems to have done some pre-planning by having an item or activity, etc ready ahead of time. C) IF APPLICABLE, AAC system is available for use/generally within arm's reach of the child (if not the CP ensures it is) + = an overall effort is made to arrange the environment for communication (need A, B, and C to be "+" to receive a summary code of "+") - = effort is not made to arrange the environment for communication during a majority of the video sample		
10 - Adapts AAC prompts to the current skill level of the child: CP adjusts their level of support (i.e., number and type of prompts/cues) to the child's current needs by either (e.g., 1) fading support to promote independence, 2) maintaining the same level of support to get more practice in, or 3)increasing support to ensure the child is successful (as based on observation, the child needs it) + = an overall appropriate level of support using prompts is provided - = appropriate level of support using prompts is not provided during a majority of the video sample or no formal AAC present		

	TOTAL RATING SCORE: **____ / ____ = _____ %** **Final interpretation: circle one of the following…** **Not Competent (0-49%)** **Emerging Competence (50-79%)** **Competent (80-99%)** **Highly competent (100%)**

Supplemental Section 2

Phase 1 - Caregiver Implementation Mastery Sheet Data Sheet - modified version of Picture Exchange Communication System Intervention Condition

STEP **Legend:** **EC = error correction, bx/s = behaviour/s Rx = reinforcer , MO = motivating operation, VP = verbal prompt, NA = not applicable, NT = no time**	**Opportunities Count** **{→Go horizontally→}** **(ex. √ or X or NA or NT)**					**Interpretation** **(Binary + or -)**	**Notes & Observations**
NO Verbal Prompting for Communicative Bxs: Caregiver does not give any verbal instruction or question to prompt the child (but natural talking in the activity is ok). No vocal speech to *deliberately entice* the child to speak. Non-verbal prompts are ok. VPs for non-comm Bxs are ok.							
Entices Appropriately WHEN THE CHILD SHOWS MO FOR ITEM/ACTIVITY: Caregiver *SHOWS* the Rx (for tangibles) OR, briefly sets up/starts the activity (for non-tangibles). The caregiver is trying to develop MO by partially or fully withholding tangibles or non-tangibles that the child *may* be interested in.							
Prompts to Pick Up, Reach, Release <u>AFTER</u> child has initiated (i.e. timing of prompts are appropriate): Caregiver uses non-verbal prompt: Initiation means child goes first to *start* the communication (reach, look, grab, smile, point etc.)							

No insistence on speech: There is **NO** delay between item/picture exchange and Rx given to attempt to elicit speech. Caregiver can offer one recast but does NOT *go back* and *insists* on the child speaking (saying/repeating) a verbal model							
Reinforces Immediately for correct responses: The FIRST action that caregiver engages in after getting picture/item is engaging is GIVING the Rx. Caregiver must reinforce a COMMUNICATIVE Bx.							
Provides Praise/RECAST: Caregiver SAYS the Rx word with a happy intonation (ex: Cheese!) immediately after or while Rx is given. Caregiver must reinforce a COMMUNICATIVE Bx.							
Returns Picture (while child continues to play with R+): Caregiver returns picture (while child consumes/plays with Rx) <u>at the LATEST before starting the next trial.</u> Picture DOES NOT need to be returned to exact same spot.							

General Scores - based on observations from the whole video	**Interpretation (Binary + or -)**	**Notes & Observations**
Arranges effective training environment: A) pictures available one at a time (when applicable) B) caregiver positioned appropriately (in front of child and/or generally oriented to the child) C) caregiver has control of reinforcers (give access to one preferred activity at a time, withhold, item out of reach of the child)		

Fades prompts effectively: Caregiver fades prompt(s) to promote independence, (most-to-least prompting). If not seen, then NA. If you see it, is it done appropriately		
Interrupts/prevents child's interfering Bxs <u>related to the PECS Binder</u>: The caregiver prevents child from interacting with the AAC system (pecs binder, picture) in ANY way that is NOT communicative (ex: stimming, playing etc). This CODE is NOT about prob Bx related to Initiation or to the teaching loop.		

	TOTAL RATING SCORE: **____ / ____ = _____ %** **Final interpretation: circle one of the following...** **Not Competent (0-49%)** **Emerging Competence (50-79%)** **Competent (80-99%)** **Highly competent (100%)**

Supplemental Section 2

Phase 3a - Caregiver Implementation Mastery Sheet Data Sheet - modified version of Picture Exchange Communication System Intervention Condition

STEP **Legend:** **EC = error correction, bx/s = behaviour/s Rx = reinforcer , MO = motivating operation, VP = verbal prompt, NA = not applicable, NT = no time**	**Opportunities Count** **{→Go horizontally→}** **(ex. √ or X or NA or NT)**					**Interpretation** **(Binary + or -)**	**Notes & Observations**
NO Verbal Prompting for Communicative Bxs: Caregiver does not give any verbal instruction or question to prompt the child (but natural talking in the activity is ok). No vocal speech to *deliberately entice* the child to speak. Non-verbal prompts are ok. VPs for non-comm Bxs are ok.							
ENTICES WITH BOTH ITEMS and WAITS for child to SHOW MO for 1 ITEM: Caregiver *SHOWS* the Rx (for tangibles) OR, briefly sets up/starts the activity (for non-tangibles).							
Socially reinforces (within 1 sec.) as soon as child touches correct picture: Caregiver differentially reinforces when child touches correct picture (ex: "Oooh, gasp, that's right etc)							
No insistence on speech: There is **NO** delay between							

item/picture exchange and Rx given to attempt to elicit speech. Caregiver can offer one recast but does NOT *go back* and *insists* on the child speaking (saying/repeating) a verbal model							
Reinforces Immediately for correct responses: The FIRST action that caregiver engages in after getting picture/item is engaging is GIVING the Rx. Caregiver must reinforce a COMMUNICATIVE Bx.							
Provides Praise/RECAST: Caregiver SAYS the Rx word with a happy intonation (ex: Cheese!) immediately after or while Rx is given. Caregiver must reinforce a COMMUNICATIVE Bx.							
Conducts **FULL** EC procedure correctly with high vs. non-desired item: Caregiver completes **ALL** steps of the error correction procedure correctly and in order. ***Code as NA if NO EC necessary*** ● Gives distractor **AND** waits for negative response ● **Shows** - (TAPs or POINTs) target picture ● **Practice** - open hand, child gives, praise but *don't* give picture ● **Switch** - distractor-DEF-anything to visually distract child OR Time **Delay** (p.129) ● **Repeat** - represent - **SWITCH PICTOS' SPOTS**							
Conducts second error correction (when applicable) - and (if applicable - backsteps to phase 1 after 1 or 2 cycles of EC							

Moves pictures around on book (diagonal, vertical, horizontal) <u>FOR EACH TRIAL</u>							

General Scores - based on observations from the whole video	**Interpretation (Binary + or -)**	**Notes & Observations**
Arranges effective training environment: A) pictures available one at a time (when applicable), B) caregiver positioned appropriately (in front of child and/or generally oriented to the child) and, C) caregiver has control of reinforcers (access one activity at a time, withhold, item out of reach) ***ALWAYS CODE THIS ONE****		
Fades prompts effectively: Caregiver fades prompt(s) to promote independence, (most-to-least prompting). If not seen, then NA. If you see it, is it done appropriately? ***IF seen in video CODE IT, if NOT present throughout video, write NA****		
Interrupts/prevents child's interfering Bxs <u>related to the PECS Binder</u>: Caregiver prevents child from interacting with AAC system (pecs binder, pictos) in ANY way that is NOT communicative. This CODE is NOT about Prob Bx related to Initiation or to the Teaching Loop. ***IF seen in the video CODE, if NOT present in video, write NA***		

TOTAL RATING SCORE:

____ / ____ = _____ %

Final interpretation: circle one of the following...

Not Competent (0-49%)
Emerging Competence (50-79%)
Competent (80-99%)
Highly competent (100%)

Supplemental Section 2

Phase 3b* - Caregiver Implementation Mastery Sheet Data Sheet - modified version of Picture Exchange Communication System Intervention Condition

*End of Phase 3b when child is taught to go into binder and picture-symbols are organized via category.

STEP **Legend:** **EC = error correction, bx/s = behaviour/s** **Rx = reinforcer , MO = motivating operation, VP = verbal prompt, NA = not applicable, NT = no time**	**Opportunities Count** **{→Go horizontally→}** **(ex. √ or X or NA or NT)**					**Interpretation** **(Binary + or -)**	**Notes & Observations**
NO Verbal Prompting for Communicative Bxs: Caregiver does not give any verbal instruction or question to prompt the child (but natural talking in the activity is ok). No vocal speech to *deliberately entice* the child to speak. Non-verbal prompts are ok. VPs for non-comm Bxs are ok.							
ENTICES WITH BOTH ITEMS and/OR WAITS FOR CHILD TO INITIATE: Caregiver *SHOWS* the Rx (for tangibles) OR, briefly sets up/starts the activity (for non-tangibles).							
No insistence on speech: There is **NO** delay between item/picture exchange and Rx given to attempt to elicit speech. Caregiver can offer one recast but does NOT *go back* and *insists* on the child speaking (saying/repeating) a verbal model							

Reinforces Immediately for correct responses: The FIRST action that caregiver engages in after getting picture/item is engaging is GIVING the Rx. Caregiver must reinforce a COMMUNICATIVE Bx.							
Provides Praise/RECAST: Caregiver SAYS the Rx word with a happy intonation (ex: Cheese!) immediately after or while Rx is given. Caregiver must reinforce a COMMUNICATIVE Bx.							
Caregiver has binder open to appropriate activity page							
Caregiver returns picture to its place in the binder (same page, and *similar* location - <u>doesn't have to be *exact* same spot</u> - ***no detailed info in PECS manual about this*****)**							

General Scores - based on observations from the whole video	**Interpretation (Binary + or -)**	**Notes & Observations**
Arranges effective training environment: A) pictures available one at a time (when applicable), B) caregiver positioned appropriately (in front of child and/or generally oriented to the child) and, C) caregiver has control of reinforcers (give access to one preferred activity at a time, withhold, item out of reach of the child)		

Fades prompts effectively: Caregiver fades prompts to promote independence, (most-to-least prompting). If not seen, then NA. If you see it, is it done appropriately.		
Interrupts/prevents child's interfering Bxs <u>related to the PECS Binder</u>: The caregiver prevents child from interacting with the AAC system (pecs binder, pictos) in ANY way that is NOT communicative (ex: stimming, playing etc). This CODE is NOT about Prob Bx related to Initiation or to the teaching loop.		

	TOTAL RATING SCORE: **____ / ____ = _____ %** **Final interpretation: circle one of the following...** **Not Competent (0-49%)** **Emerging Competence (50-79%)** **Competent (80-99%)** **Highly competent (100%)**

Supplemental Section 3 - Final Total Picture Count

At post-intervention, caregivers were asked to provide photo image of the front cover as well as the inside pages of their Augmentative and Alternative Communication board or Picture Exchange Communication System binder. A research assistant used the images to create a digital version of the child's low-tech AAC system that was saved as a PDF. The total number of picture-symbols in PDF was counted to generate a *final picture-symbol count* for each child.

Table S3 – *Final Picture-Symbol Count per Group and per Participant at Post-Intervention*

CSL-NDBI[a] (n = 11)		**mod-PECS**[b] (n = 7)	
	M (range)		*M* (range)
	94.3 (35-209)		**73.8 (29-145)**
ID[c]	**Total**	**ID**	**Total**
1	86	***6***	82
2	209	***7***	65
3	109	***8***	n/a
4	35	***9***	29
5	67	***11***	48
10	186	***12***	n/a
14	96	***13***	145
15	59		
16	58		
17	84		
18	47		

Note. a) Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, b) modified-Picture Exchange Communication System group, c) ID = participant ID, n/a = not applicable as participant dropped out of study before final picture count data was provided.

Supplemental Section 4 – Progression of Picture Exchange Communication System Phases Taught During Coaching Sessions

Table S4. *Progression of Phases Taught Across Coaching Sessions For mod-PECS[a] Group (n = 7)*

Session #	AAC_06	AAC_07	AAC_08	AAC_09	AAC_11	AAC_12	AAC_13
1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1
2	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1
3	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phase 1	Phases 1, 2
4	Phase 1	Phases 1, 2	Phase 1	Phase 1	Phase 1	Phase 1	Phases 1, 2
5	Phases 1, 2	Phases 2, 3a	Phase 1	Phase 1	Phase 1	Phase 1	Phases 1, 2
6	Phases 1, 2	Phases 1, 2	Attrition	Phase 1	Phase 1	Phase 1	Phases 1, 2
7	Phases 1, 2, 3a	Phases 1, 2	Attrition	Phase 1	Phases 1, 2	Attrition	Phases 1, 2
8	Phases 1, 2	Phases 1, 2, 3a	Attrition	Phase 1	Phases 1, 2	Attrition	Phases 1, 2
9	Phases 2, 3a	Phases 1, 3a	Attrition	Phase 1	Phases 1, 2	Attrition	Phases 1, 3a
10	Phases 2, 3a, 3b	Phases 3a	Attrition	Phase 1	Phases 1, 2	Attrition	Phases 1, 3a
11	Phases 1, 3a, 3b	Phase 3a	Attrition	Phase 1	Phases 1, 2	Attrition	Phases 1, 3a
12	Phases 1, 3b	Phase 3a	Attrition	Phase 1	Phases 1, 3a	Attrition	Phase 1, 3b
Total # of Phases Introduced	**4**	**3**	**1**	**1**	**3**	**1**	**4**
Phases Mastered	Phase 1, Phase 2, Phase 3a, Phase 3b	Phase 1, Phase 2	None	None	Phase 1, Phase 2	None	Phase 1, Phase 2, Phase 3a

Note. a) modified version of Picture Exchange Communication System, a benchmark of at least 80 percent accuracy with a minimum of three different picture-symbols across 2 consecutive sessions was required before the coaching of the new phase could begin

Supplemental Section 5 – In-Session Monitoring Checklists

CSL-NDBI[a] Checklist

Over the course of this coaching session, did you, as the coach, see the implementer do the following:

	Implementation Item	Y or N	Comments
1	Increase child engagement (ad needed when there is no child lead to follow)?		
2	Follow the child's lead/interests/motivation?		
3	Contrive/create opportunities for the child to expressively communicate?		
4	Proactively prompt to support successful AAC use (as needed)?		
5	Reactively prompt to support successful AAC use (as needed)?		
6	Immediately follow through and/or respond to the child's expressive communication?		
7	Did NOT insist on additional communication (once the child successfully communicated their message)?		
8	Returned the picture-symbol following successful AAC use (as needed)?		
9	Arranged the environment to promote expressive communication?		
10	Adapted prompts and supports to the current skill level of the child?		

Note. a) CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group

mod-PECS[b] Checklists

Based on the mod-PECS phase being implemented, over the course of this coaching session, did you, as the coach, see the implementer do the following:

Phase 1	Y or N	Comments
Arranges training environment effectively – pictures available one at a time, trainers positioned appropriately, control of reinforcers		
No verbal prompting		
Entices appropriately		
Uses open hand effectively – appropriate timing		
Reinforces within ½ second and provides praise		
No insistence on speech		

Returns picture (while student consumes/plays with R+		
Waits for student to initiate (reach for R+)		
Physically guides to pick up, reach, release		
Fades prompts effectively		
Interrupts/prevents student's interfering behaviours		
No social interaction with the student		

*Note. T*aken from the Picture Exchange Communication System Training Manual – Second Edition (pg. 79; Frost & Bondy, 2002).

Phase 2	Y or N	Comments
Plans for each student to have own communication book		
Arranges training environment effectively – pictures available one at a time, trainers positioned appropriately, control of reinforcers		
Entices appropriately		
Gradually increases distance between student and communicative partner		
Teacher student to cross room to reach communicative partner		
Gradually increases distance between student and communication book		
Teaches student to cross room to reach communication book		
Turns away from student		
Reinforces appropriately – new behaviour within ½ second		
Eliminates subtle trainer prompts – body orientation, eye contact, expectant look, etc.		
Does not insist on speech		
Teaches student to travel from room to room		
Waits for initiation		
Prompts removal of picture from book if necessary		
Physically guides student to communication book if necessary		
Does not interact socially with the student		
Uses Backstepping if necessary		

*Note. T*aken from the Picture Exchange Communication System Training Manual – Second Edition (pg. 110-111; Frost & Bondy, 2002).

Phase 3a	Y or N	Comments
Arranges effective training environment		
Entices with both items		
Socially reinforces as soon as student touches correct picture		

Appropriate reinforcement with requested item		
Conducts error correction procedures correctly – high vs. non-desired • Gives non-desired item • Elicits negative response • Model • Practice • Switch • Repeat		
Conducts second error correction if necessary		
Moves pictures around on book (diagonal, vertical, horizontal)		
No insistence on speech		

*Note. T*aken from the Picture Exchange Communication System Training Manual – Second Edition (pg. 146; Frost & Bondy, 2002).

Phase 3b	**Y or N**	**Comments**
Arranges effective training environment		
Entices with both items		
Conducts Correspondence Check		
Appropriate reinforcement with requested item		
Conducts error correction procedures correctly – high vs. high with Correspondence Check • Prevents student from taking non-corresponding item • Models picture of item reached for • Model • Practice • Switch • Repeat • Ends with correspondence check		
Conducts second error correction if necessary		
Moves pictures around on book (diagonal, vertical, horizontal)		
Teaches 3-, 4-, 5-way discrimination with Correspondence Checks		
Uses a variety of target pictures in the 2-, 3-, 4-, or 5-way array		
Teaches looking inside the book		
No insistence on speech		

*Note. T*aken from the Picture Exchange Communication System Training Manual – Second Edition (pg. 147; Frost & Bondy, 2002).

Supplemental Section 6 – Coaching Checklist

Over the course of this coaching session, did you, as the coach, do the following:

	Coaching Practice Item	Y or N	Comments
1	Acknowledge the learner's existing knowledge and abilities as the foundation for improving knowledge and skills?		
2	Interact with the learner in a nonjudgmental and constructive manner during the coaching conversations?		
3	**Identify and describes with the learner the target skill or "focus" strategy for this session?**		
4	**Observe the learner's use of the targeted skill or practice?**		
5	**Create opportunities for the learner to observe the coach model the target skill or practice?**		
6	Promoting use of multiple opportunities for the learner to practice implementation of the targeted skill and practice using both planned and spontaneous opportunities to strengthen the learner's knowledge and skills?		
7	Ask probing questions to examine the learner's knowledge and abilities?		
8	Prompt learner reflection on his/her knowledge and use of the targeted skill(s) and practice(s) compared against research-based practice standards?		
9	**Provide feedback about the learner's knowledge and skills following the learner's reflection on their performance?**		
10	Provide or promote access to new information and resources after the learner reflects on their performance?		

Note. This checklist is an abbreviated version of the Coaching Practices Rating Scale from the Early Childhood Coaching Handbook (pg. 290, appendix 9A; Rush & Shelden, 2020). Strategies in bold overlap with Behaviour Skills Training approach used to coach. This checklist was used to evaluate the use of this approach as well.

Supplemental Section 7 – Suspected Selection Error Table

Table S7. *Number of Suspected Selection Errors Per Participant During Each Five-Minute Caregiver Child Interaction Video*

CSL-NDBI[a] (n = 11)					**Mod-PECS**[b] (n = 7)				
ID[c]	**Pre**	**Mid**	**Post**	**Total**	**ID**	**Pre**	**Mid**	**Post**	**Total**
1	no AAC	1	0	**1**	***6***	no AAC	0	0	**0**
2	no AAC	0	0	**0**	***7***	0	0	2	**2**
3	no AAC	2	0	**2**	***8***	no AAC	n/a	n/a	n/a
4	0	1	0	**1**	***9***	no AAC	0	1	**1**
5	no AAC	2	n/a	n/a	***11***	no AAC	1	0	**1**
10	no AAC	0	0	**0**	***12***	no AAC	0	n/a	n/a
14	no AAC	0	1	**1**	***13***	no AAC	0	0	**0**
15	no AAC	1	0	**1**					
16	no AAC	0	1	**1**					
17	no AAC	0	0	**0**					
18	5	1	3	**9**					

Note. a) Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, b) modified-Picture Exchange Communication System group, c) ID = participant ID, n/a = not applicable as participant dropped out of study before final picture count data was provided.

Supplemental Section 8

Hearing and Speech Nova Scotia's Ways and Reasons

Instructions: Please list the reasons and ways your child communicates by selecting a "way" (e.g., gestures) for each "reason" (e.g., requests). If your child uses multiple ways to accomplish 1 reason, select the way that your child uses the most frequently. If your child does not communicate for a particular "reason", simply choose the "not yet/does not do" option. Please note to check off the single words or multi-word combinations as a way, it must be spontaneous (e.g., not parroted or repeated). When a "reason" is repeated most of the time, check off the "echoes" column.

	Ways Your Child Communicates									
Reasons Your Child Communicates	Pre-symbolic behaviour (e.g., crying, hitting)	Looks at person	Gestures (e.g., pointing, leading) or signs	Pictures (or symbols)	Echoes (i.e., repeats)	Vocalizes or makes sounds	Spontaneous words	Spontaneous 2-word combos	Spontaneous multi-word phrases	Does not do/not yet
Protest										
Request Objects										
Request Actions										
Request Help										
Request Social Routine										
Request Permission										
Request Information										
Make Choices										
Answer Questions										
Greet										
Comment on self										
Comment on Objects										
Comment on People										
Discuss Past										
Discuss Future										
Pretend										

Note. This checklist is modified version of the Checklist of Communicative Functions and Means (Wetherby, 1995).

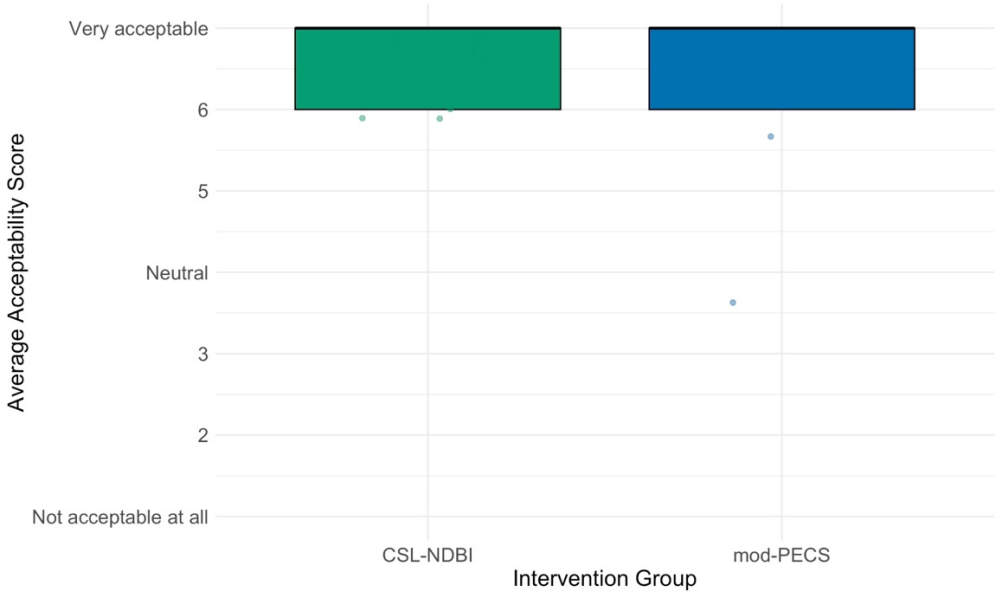
Supplemental Section 9 – Effect Size Interpretations

Table S9. *Effect Sizes and Corresponding Interpretations*

Kendall's W (W)	Cliff's Delta (δ)	Cohen's d (*d*)	Generalized eta squared (η^2)	Interpretation
<0.1	<0.147	<0.2	<0.01	Negligible
0.1	0.147	0.2	0.01	Small
0.3	0.330	0.5	0.06	Medium
0.5	0.474	0.8	0.14	Large

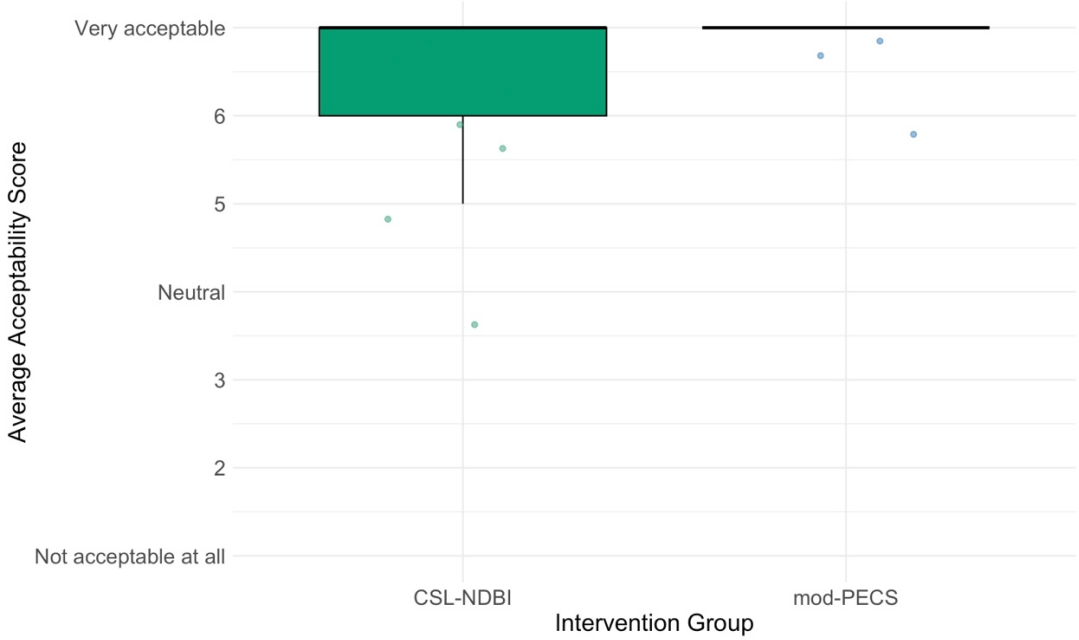
Supplemental Section 10 – Acceptability of the Intervention - Extra Question Box Plots

Figure S10a. *Box Plot of Acceptability Rating of Intervention Frequency of 1 hr/wk Across Group at Post-Intervention*



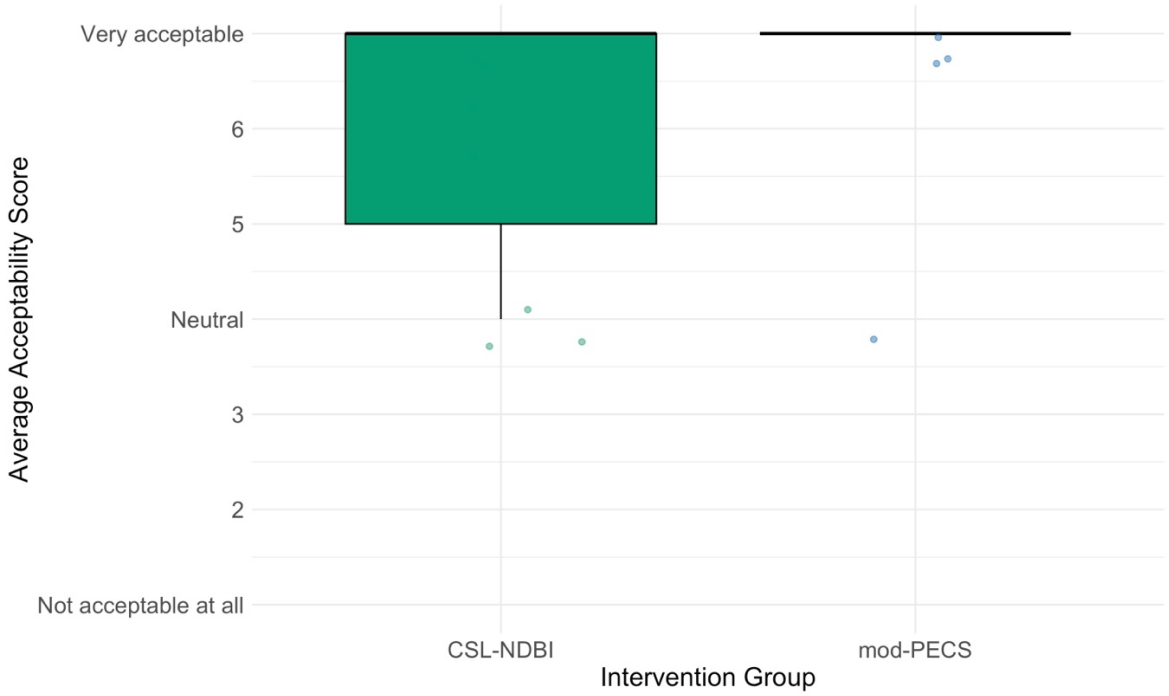
Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Figure S10b. *Box Plot of Acceptability Rating of Intervention Location (Home) Across Group at Post-Intervention*



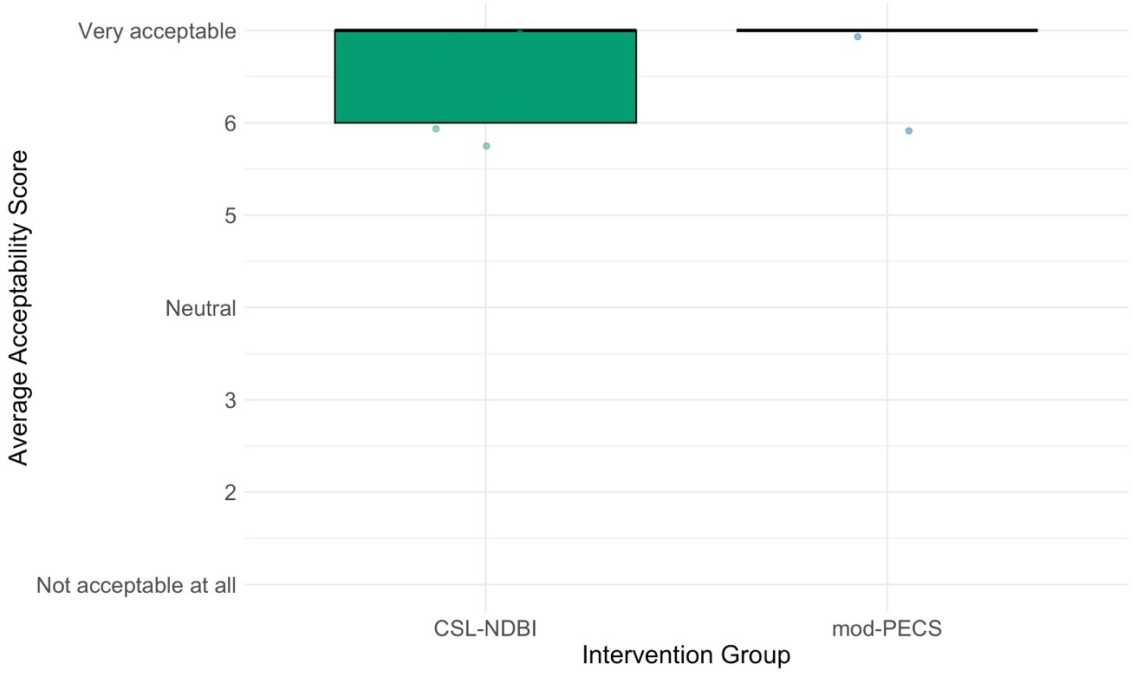
Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Figure S10c. *Box Plot of Acceptability Rating of Intervention Virtual Format Across Group at Post-Intervention*



Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

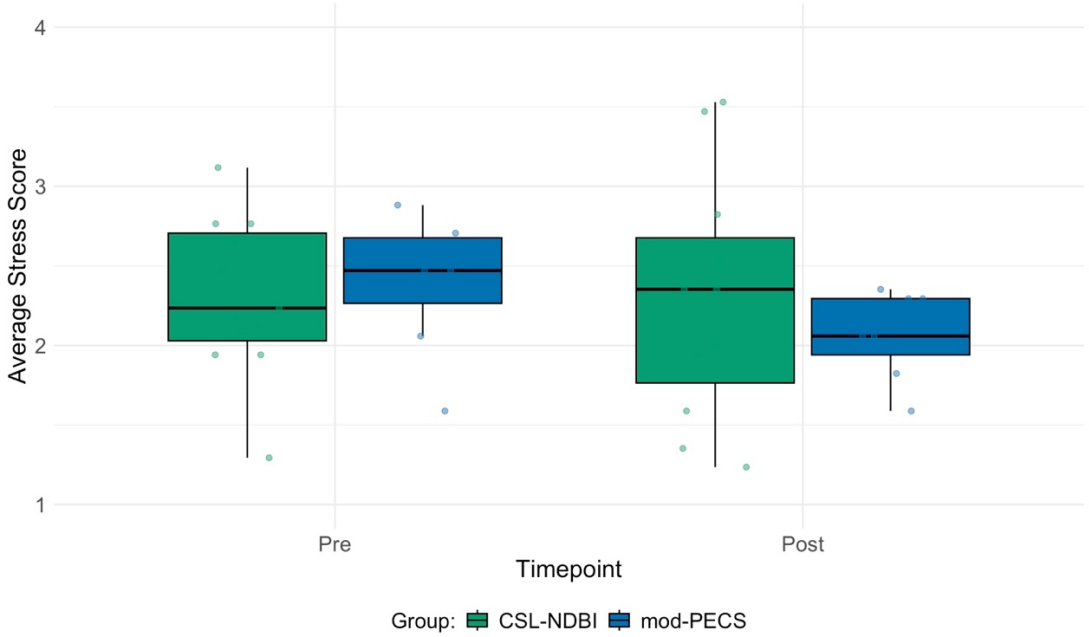
Figure S10d. *Box Plot of Acceptability Rating of Intervention of Coaching Format Across Group at Post-Intervention*



Note. CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

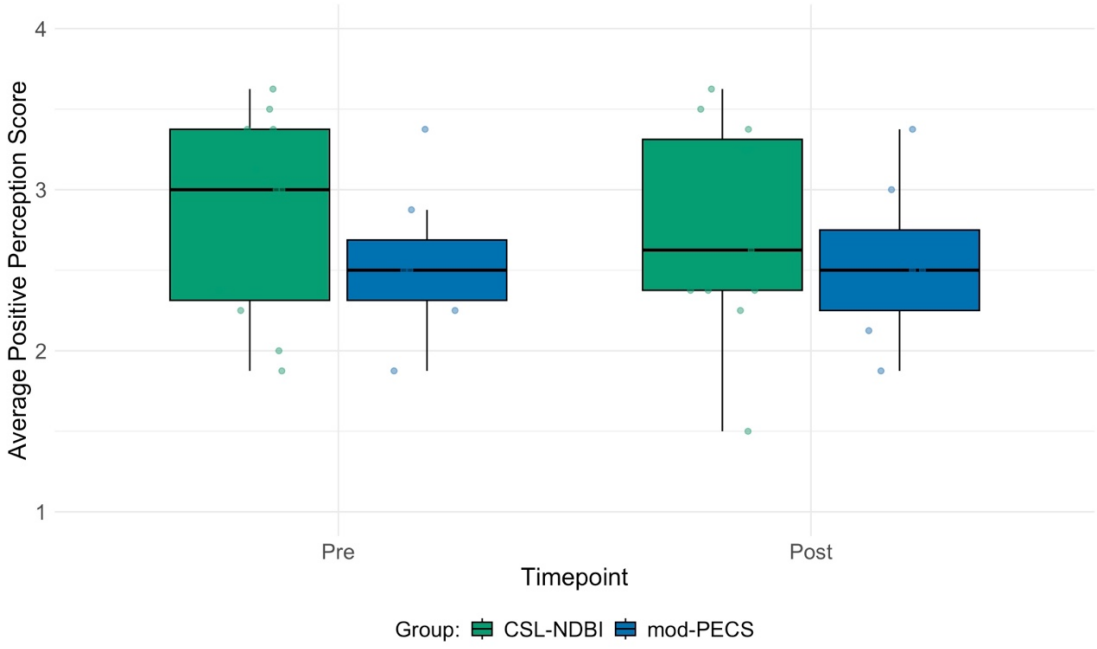
Supplemental Section 11 – Caregiver Stress and Positive Perception Box Plots

Figure S11a. *Box Plot of Caregiver Stress Score Across Group and Timepoint*



Note. pre = pre-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

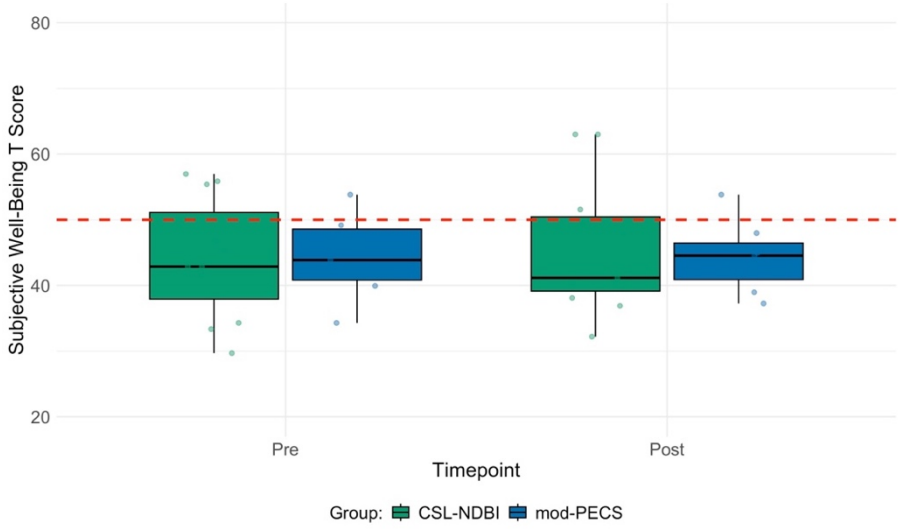
Figure S11b. *Box Plot of Caregiver Positive Perception of Their Child Score Across Group and Timepoint*



Note. pre = pre-intervention, post = post-intervention, CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System group

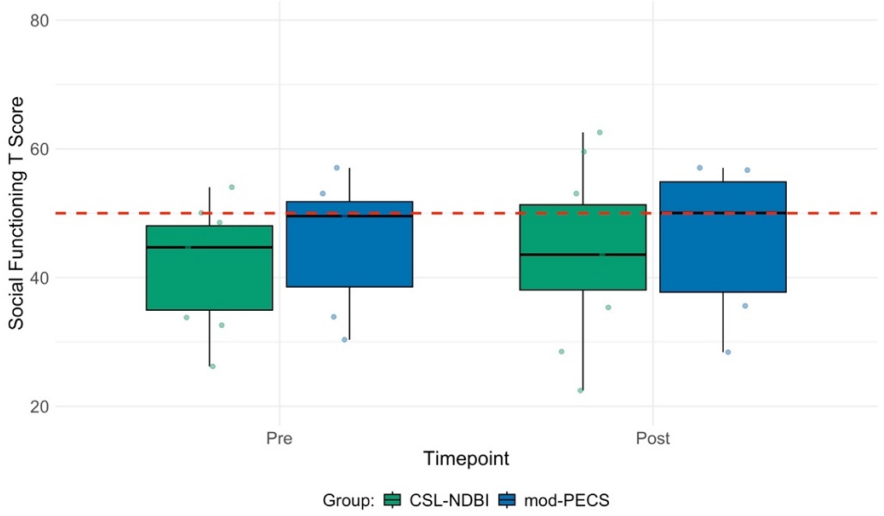
Supplemental Section 12 – Child Health, Subjective Well Being, Social Functioning, and Emotional Distress Domains Box Plots

Figure S12a. *Box Plot of Child Subjective-Well Being From The PAB-Y Across Group and Timepoint*



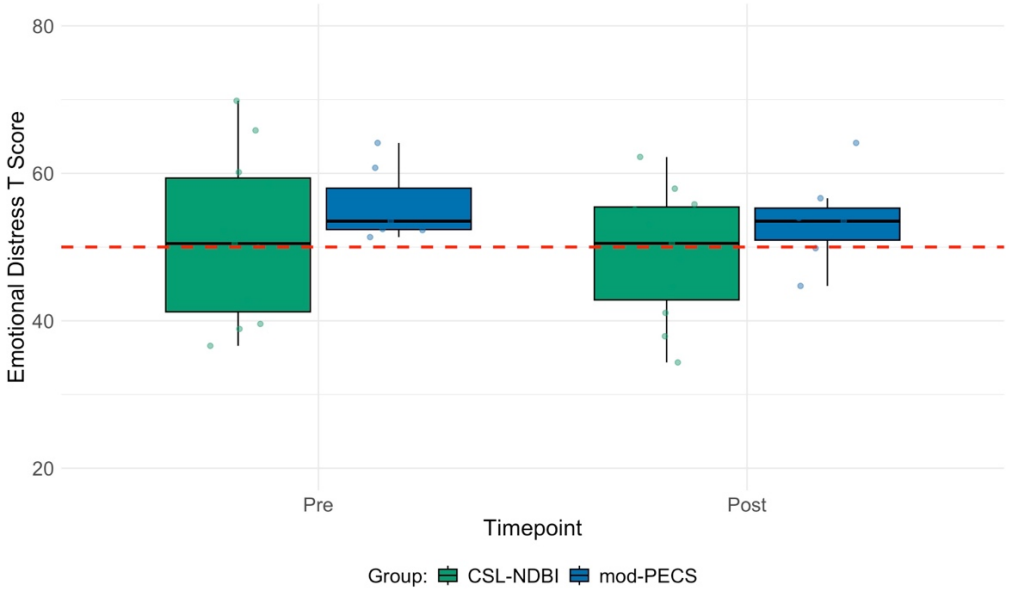
Note. red dashed line = mean T score (i.e., 50), SD = 10, small difference compared to mean = 0.5-1.0 SD, moderate difference compared to mean = 1.0-2.0 SD, large difference compared to mean = >2.0 SD, pre = pre-intervention, post = post-intervention, *PAB-Y = Patient-Reported Outcomes Measurement Information System - Autism Battery – Youth,* CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Figure S12b. *Box Plot of Child Social Functioning From The PAB-Y Across Group and Timepoint*



Note. red dashed line = mean T score (i.e., 50), SD = 10, small difference compared to mean = 0.5-1.0 SD, moderate difference compared to mean = 1.0-2.0 SD, large difference compared to mean = >2.0 SD, pre = pre-intervention, post = post-intervention, *PAB-Y = Patient-Reported Outcomes Measurement Information System - Autism Battery – Youth,* CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Figure S12c. *Box Plot of Child Emotional Distress From The PAB-Y Across Group and Timepoint*



Note. red dashed line = mean T score (i.e., 50), SD = 10, small difference compared to mean = 0.5-1.0 SD, moderate difference compared to mean = 1.0-2.0 SD, large difference compared to mean = >2.0 SD, pre = pre-intervention, post = post-intervention, *PAB-Y = Patient-Reported Outcomes Measurement Information System - Autism Battery – Youth,* CSL-NDBI = Naturalistic developmental behavioural augmentative and alternative communication intervention that uses a consistent-symbol location design group, mod-PECS = modification of Picture Exchange Communication System

Link Between Chapters 1 and 2

The study presented in Chapter 1 was the first to compare the effectiveness of two augmentative and alternative communication (AAC) approaches for minimally speaking autistic children. Specifically, an intervention that uses a naturalistic developmental behavioural approach and a consistent-symbol location design was evaluated against an established augmentative and alternative communication intervention that uses a behavioural approach and a variable-symbol location design (Picture Exchange Communication System; Frost & Bondy, 2002). The findings from this study add to the evidence base on Augmentative and Alternative Communication interventions for minimally speaking autistic children.

In addition to gaps in AAC intervention research for this population, properly adapted language assessment tools (Kasari et al., 2013a) are scarce. Many standardized language assessment tools are not adapted for individuals who use AAC. For example, standardized language assessments often require pre-requisite language skills (e.g., ability to follow basic spoken instructions) that may not be in the skill set of a minimally speaking individual (Barokova & Tager-Flusberg, 2018). Due to this and the language skills assessed being at a higher level, minimally speaking autistic individuals often score at floor. Therefore, the results are often not sensitive enough to properly characterize their language and communication profiles, nor to detect change over time, which is critical in both research and clinical settings. To address these limitations in language assessment tools, in Chapter 2 we modified the MacArthur-Bates Communicative Development Inventory - Words and Gestures, English Long Form (CDI: Words and Gestures; Marchman et al., 2023) to capture

non-spoken (in addition to spoken), expressive vocabulary to explore expressive vocabulary size and composition of minimally speaking autistic children.

Chapter 2: Value added by assessing non-spoken vocabulary in minimally speaking autistic children

Value added by assessing non-spoken vocabulary in minimally speaking autistic children

Angela MacDonald-Prégent[a,b], Lauren McGuinness[c], Aparna Nadig[a,B]

[a]School of Communication Sciences and Disorders, McGill University, Montréal, Québec, Canada

[b]Centre for Research on Brain, Language, and Music, Montréal, Québec, Canada

[c]School of Psychology, University of Kent, Canterbury, United Kingdom

Author Note

We have no conflicts of interest to declare.

Correspondence to Angela MacDonald-Prégent: angela.macdonald@mail.mcgill.ca

Abstract

Purpose: There is a scarcity of language assessment tools properly adapted for use with minimally speaking autistic children. As these children often use non-spoken methods of communication (i.e., Augmentative and Alternative Communication; AAC), modification of traditional assessment tools is needed to capture the full range of their communicative repertoires. We modified the Communicative Developmental Inventories (CDI) to explore how vocabulary size and composition are impacted by considering non-spoken, as well as spoken, expressive vocabulary (AAC-modified CDI: Words & Gestures).

***Methods*:** Our initial sample consisted of 16 minimally speaking autistic children, three to nine years old, whose caregivers completed our modified CDI after taking part in an AAC intervention. Our final sample included 15 participants, after removing an outlier.

***Results*:** Accounting for both spoken and non-spoken communication significantly increased participants' reported expressive vocabulary by an average of 14 words (z = -2.61, p = 0.009, r = 0.75). Verbs made up a sizable portion (13.3 percent) of vocabulary when accounting for all modalities, while nouns made up the majority (51.5 percent).

Conclusions: We demonstrated the value of including both spoken and non-spoken modalities of communication when assessing the expressive vocabulary of minimally speaking autistic children. Prior work has shown that minimally speaking autistic children's spoken vocabulary was prominent in verbs (i.e., contained proportionally more verbs than that of vocabulary-matched typically developing children). In our sample, which used a broader definition of minimally speaking, we found that the proportions of verbs and nouns

were consistent with what has been reported for typically developing children with similar-sized productive vocabularies.

Introduction

Though progress has been made over the past decade, much has yet to be learned about the communicative abilities of minimally speaking autistic children. These children are loosely defined as having little to no spoken language and makeup approximately one-third of individuals on the autism spectrum (Rose et al., 2016; Tager-Flusberg & Kasari, 2013). However, within this subgroup, there is considerable variation in both the content of their spoken language repertoires, and in their language usage (e.g., level of independence, consistency and flexibility with which they employ their repertoire). For example, one child might have a spoken vocabulary of 40 words but only use them to identify pictures, while in contrast, another child may have a much smaller spoken vocabulary (e.g., five words), but achieve a range of communicative functions relevant to daily life, such as making requests, basic comments, and answering questions, with this limited number of words.

With respect to variability in communicative repertoires, it is also important to consider all communication modalities used by minimally speaking autistic children. Focusing on spoken language alone is likely to leave out valuable information since they often use non-spoken forms of communication such as adapted signs, gestures, communication boards, and speech-generating devices [also known as Augmentative and Alternative Communication (AAC) systems] (Beukelman & Light, 2020). Given that spoken language is by definition limited in this subgroup, providing access to non-spoken modalities such as AAC can support social inclusion by providing a stand-in for, or compliment to, spoken communication (Logan et al., 2017).

Given the variability in language usage and the diversity of modalities contributing to the communicative repertoires of minimally speaking autistic populations, it is critical that assessment tools are adapted for use with them. In particular, Kasari et al. (2013b) recommended the Communicative Developmental Inventories (CDI; Fenson et al., 2007) as one potential tool for use with this autistic subgroup. The CDI includes a series of two checklists, based on the language development of typically developing children between the ages of 8 to 30 months, that allow for the assessment of spoken receptive and expressive vocabulary. There are adaptations of the CDI available in multiple languages.[20] The first CDI Words and Gestures form targets a developmental age of 8 to 18 months. Consequently, items on this vocabulary checklist in English are mostly nouns, and words for routines, but also include many verbs and adjectives and some closed-class words such as pronouns, questions, quantifiers, and prepositions.

When looking at the full autism spectrum with a broad range of language skills, autistic children's vocabularies have been reported to be delayed, but syntactic classes (e.g., nouns, verbs, adjectives) and semantic categories (i.e., words grouped according to their meaning), have been found to develop in a similar sequence to their neurotypical peers. That is, when compared to typically developing children, the percentages of words in different semantic categories on the CDI were quite similar in autistic children (Charman et al., 2003; Luyster et al., 2007). Ellis Weismer et al. (2011) also found a pattern of delayed

[20] Multiple of adaptations of the CDI also exist in other languages or dialects including French, Spanish, Arabic, Mandarin (https://mb-cdi.stanford.edu/adaptations.html).

emergence but similar proportion of words in different semantic categories between late-talking toddlers and vocabulary-matched autistic toddlers.

In contrast, however, Jiménez et al. (2021) compared an autism sample with varied language skills (vocabulary size *M* = 74.9 words) to children who were either typically developing (vocabulary size *M* = 72.7 words) or late-talking (vocabulary size *M* = 43.1 words). They found that autistic children with a spoken vocabulary of between 1-25, 26-50, and 51-75 words had proportionally more verbs (1-25 group *M* = 11.0 percent, 25-50 group *M* = 8.4 percent, 51-75 group *M* = 8.5 percent) on the CDI than typically developing children with the same vocabulary sizes (1-25 group *M* =1.8 percent, 25-50 group *M* = 3.1 percent, 51-75 group *M* = 4.6 percent). A similar pattern of greater verb prominence in autistic children was found when comparing them to late-talking children with vocabularies between 1-25 (*M* = 2.5 percent) and 25-50 words (*M* = 4.2 percent). This therefore suggests that autistic children with smaller vocabularies exhibit greater verb prominence relative to their typically developing and late-talking peers.

Moreover, verb prominence on the CDI in autistic children with smaller vocabularies was also reported by Haebig et al. (2021). Their autism sample included preverbal and minimally speaking autistic children who were reported to have between 1 and 10 spoken words (vocabulary size *M* = 4.6 words). Compared to their vocabulary-matched younger neurotypical (TD) counterparts (vocabulary size *M* = 4.5 words), the minimally speaking autistic children produced a significantly larger proportion of verbs (autism sample *M* = 8.0 percent, TD *M* = 1.0 percent) [i.e., words from the CDI category, ‘Action Words’] and ‘Food

and Drink' words (autism sample *M* = 9.0 percent, TD *M* = 2.0 percent).[21] Finally, Butler et al. (2023) who analyzed the language samples of six- to 21-year-old autistic individuals with fewer than 200 spoken words found that verbs made up a prominent portion of expressive vocabulary across a range of vocabulary sizes (i.e., less than 50 words = 12.3 percent verbs and 26.6 percent nouns, 51–100 words = 12.5 percent verbs and 22.4 percent nouns, 101–200 words = 13.1 percent verbs and 22.9 percent nouns).

It is important to note that, similar to the neurotypical and late-talking comparison groups, nouns made up the largest lexical category (and verbs made up the smallest) for autistic participants in the samples of Jiménez et al. (2021), Haebig et al. (2021), and Butler et al. (2023). Yet, against this background, verb prominence in autistic children with limited spoken language seems to be a stable feature which stands in contrast to what has been reported for typical development where verb proportion only begins to increase past the 100-word stage (Bates et al., 1994).

These studies provide important insights into the vocabulary development of minimally speaking autistic children and highlight the prominence of verbs in their lexical compositions. However, they only account for spoken vocabulary, leaving out the potentially valuable contributions of non-spoken modalities. As recommended by Kasari et al. (2013b), parent report measures, such as the CDI, should be modified to allow caregivers to report on all modalities (i.e., spoken and non-spoken) in which their child produces vocabulary. This type of modification would align with previous work by Courchesne et al.

[21] It is important to note that CDI lexical composition proportions in their sample were based on a particularly small number of words, given their level of lexical development (one to ten spoken words), so proportions could be heavily influenced by only one or two words.

(2015 and 2019) where cognitive assessment tools were selected to highlight areas of strength and decrease floor effects. As such, we modified the CDI to capture children's communicative capacity across spoken and non-spoken modalities, and sought to answer the following questions:

1. Does including the non-spoken, as well as spoken, modality allow us to more fully capture the expressive communicative repertoires of minimally speaking autistic children?
2. When considering all the modalities of minimally speaking children, do verbs emerge as a prominent feature of lexical composition for their spoken repertoires, as previously reported in the literature?

These data were collected at the end of a caregiver-mediated AAC intervention study, where minimally speaking autistic children had access to, and were trained in the use of, an AAC system. As such, for the first research question, it was hypothesized that allowing caregivers to report on both their child's spoken and non-spoken vocabulary would significantly increase the number of words reported in their expressive vocabularies. When comparing the vocabulary composition of spoken words only, and words expressed in any modality, it was hypothesized that the lexical composition of minimally speaking autistic children would remain stable, and would reflect high verb prominence in line with the findings of Jiménez et al. (2021), Haebig et al. (2021), and Butler et al. (2023).

Methods

Participants

Our sample consisted of 16 children between the ages of three and nine years old (range = 3 years; 1 month - 9 years; 10 months), including eleven males and three females (biological sex by caregiver report). They were taking part in a remote AAC caregiver-coaching intervention study conducted in English. The McGill Faculty of Medicine and Health Sciences Institutional Review Board approved the study.

A screening questionnaire completed by the caregiver was used to assess eligibility for the study based on various criteria (e.g., age, language exposure and ability, diagnosis). Confirmation of our criterion of *minimally speaking* was done by the first author[22] through a review of caregiver-child interaction videos as described in detail below.

To be included as *minimally speaking,* children's spontaneous spoken language abilities had to be less developed than consistent phrase speech (e.g., they did not speak, used single words only, or used at most simple two-word utterances) during 10 minutes of caregiver-child interaction video obtained at the start of the study. This criterion is used in the Autism Diagnostic Observation Schedule, 2nd edition manual (ADOS-2 manual; Lord et al., 2012, pg. 9-13) to assign children to the lowest language level (i.e., module 1 of the ADOS-2)[23]. However, this criterion is typically used with children who are five years and older (Bal et al., 2016; Chen et al., 2023), as children younger than age five may present with

[22] A speech-language pathologist with over a decade of expertise in working with autistic children and trained to administer the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012).
[23] This is the most commonly used criterion in the autism research literature to identify *minimally speaking* children (Bal et al., 2016).

language delays that they will not retain at age five. To address this concern, children who were between the ages of 3;1 and 4;11 years old (n = 4) had to meet a more stringent criterion to be included as *minimally speaking*. In addition to being identified as an ADOS-2 module 1 candidate, they needed to speak 20 or fewer different words across the 10 minutes of video available. Pizzano et al. (2024) used the criterion just described to characterize children as young as three years old as minimally speaking.

Caregivers reported English to be the dominant language for 15 of the 16 children with one child reported to be equally proficient in English and Romanian. Seven of the sixteen children were from visible minority[24] groups. With the exception of one child who was on the waitlist for an autism evaluation[25] at the time of the study, all had a confirmed diagnosis of Autism Spectrum Disorder from a qualified licenced professional [i.e., physician or psychologist] (American Psychiatric Association, 2013). Caregivers reported that their children had fine motor abilities sufficient to participate in the AAC intervention study (i.e., able to point to and/or remove a Velcro picture-symbol from a low-tech communication board). They also confirmed the absence of any significant visual or hearing impairments. Please see **supplemental materials, section one**, **Table S1** for more details on participant demographics and baseline characteristics.

[24] A visible minority is term used by the Canadian government to describe a person who is non-white in colour or non-Caucasian in race (Statistics Canada, 2021).

[25] Following participation in the study, the participant received an official diagnosis of autism (as shared by the family through personal communication). This first author confirmed behaviours consistent with an autism diagnosis through the caregiver-child interaction videos.

Augmentative and Alternative Communication – Modified Communicative Development Inventory: Words and Gestures

For this study, we modified the vocabulary checklist section of the MacArthur-Bates Communicative Development Inventory - Words and Gestures, English Long Form (CDI: Words and Gestures; Marchman et al., 2023) to assess the expressive communicative repertoires of our participants. The CDI: Words and Gestures is a well-validated assessment tool that provides a list of commonly used words produced by English-speaking children between eight and 18 months who are typically developing. The CDI Words & Gestures form was normed using a typically developing sample of more than 1000 infants and toddlers (Fenson et al., 2007). The CDI was chosen because, as discussed earlier, it is frequently used to study vocabulary in autistic children, it contains a large variety of vocabulary used by emergent communicators, and it was recommended by Kasari et al. (2013b) as a potential tool to measure language in minimally speaking autistic children.

Since the CDI measures only spoken vocabulary where caregivers can check off if a vocabulary item is either understood (i.e., '*Understands*' column) or understood and said (i.e., '*Understands and Says'* column), two additional columns were added to give them the opportunity to report on non-spoken modalities of communication (i.e., '*Understands and Uses Non-spoken Methods to Say*' and '*All of the Above'* columns). See **Figure 1** for an example of the layout of responses on the AAC-modified CDI: Words and Gestures. Non-spoken expression was defined as using adapted signs, gestures, pictograms, a communication board or communication app on a tablet or iPad. A caregiver was instructed to check off the '*All of the Above'* column when their children understood and expressed the

word through both spoken and non-spoken modalities. Definitions for the two new response columns were added. Instructions remained otherwise unchanged to preserve standardization. Caregivers were restricted to selecting only one column (i.e., *'Understands', 'Understands and Says', 'Understands and Uses Non Spoken Methods to Say', and 'All of the Above'*) per vocabulary item. Finally, two open-ended questions (e.g., 'Are there other spoken (or non-spoken) words not listed that your child uses to express themselves?'*)* were added at the end of the checklist section given the prominence of idiosyncratic special interests in this population. It was hypothesized the addition of these questions would allow us to capture a few additional words not in the conventional vocabulary list. These modifications were approved by the CDI Advisory Board for use in our study (MacDonald-Prégent & Nadig, personal communication, July 27, 2023).

Figure 1. *AAC-modified CDI: Words & Gestures - Columns in Vocabulary Checklist Section – Example (n = 15)*

	Understands only	Understands and says	Understands and uses nonspoken methods to "say"	All of the above
Bite	○	○	○	○
Blow	○	○	○	○
Break	○	○	○	○

As previously mentioned, these data were collected as part of a caregiver-coaching AAC intervention study. Caregivers filled out the AAC-modified CDI: Words and Gestures at pre- and post-intervention using the online survey platform *Limesurvey* version 3 (*Limesurvey*, 2017). Children in the study were required to have little to no experience using an AAC system at baseline. Therefore, to allow for a richer exploration of our research

questions which are related to non-spoken communication, we focused our analyses on CDI data provided at post-intervention following 12-week one-hour individual AAC coaching sessions. It is however acknowledged that this represents an ideal situation where all participants had access to a formal AAC system in an environment supportive of AAC use, which unfortunately does not reflect the daily reality of all minimally speaking autistic children.

Analysis Plan

To address our first research question, two measures of expressive vocabulary size were computed for each participant. First, *non-spoken+spoken vocabulary* included any words for which a child's caregiver checked '*Understands and Says'*, '*Understands and Uses Non-spoken Methods to Say'*, or '*All of the Above'*. In contrast, *spoken vocabulary* consisted solely of spoken words. This score included any words for which a child's caregiver checked '*Understands and Says'* or '*All of the Above'*. When *'All of the Above'* was selected (as defined in the previous section), this implied that a word was understood, expressed using non-spoken methods, and spoken. As a result, it was also included in the total for *spoken vocabulary*.

In preparing data for analysis, a discrepancy was noted between the total spoken vocabularies reported on a multiple-choice screening questionnaire at baseline versus on the AAC-modified CDI: Words and Gestures at post-intervention**.** Many of the caregivers (i.e., 11 of the 16) reported a substantially higher number of spoken words on the AAC-modified CDI: Words and Gestures in comparison to the screening questionnaire **See Table**

1. These discrepancies are likely not due (only) to gains in spoken or non-spoken repertoires from baseline to post-intervention, but rather to the wording of the instructions and the way the questions are posed. The screening questionnaire explicitly asked caregivers to estimate the size of their child's spoken vocabulary that is produced *independently and consistently* using multiple choice categories, whereas the AAC-modified CDI: Words and Gestures asked caregivers to report on each word on a checklist their children can communicate (without specification of how the word is used). Consequently, the AAC-modified CDI: Words and Gestures count may be higher for some participants because it allows for reporting words a child produces by echoing/repeating, or uses very infrequently (e.g., child said the word *balloon* once at a birthday party several years ago but hasn't since). Moreover, an outlier was observed whereby one participant was reported to have a very large non-spoken vocabulary of 384 words out of the 396 possible vocabulary options on the AAC-modified CDI, which was not consistent with clinical observation during the 12 weeks of intervention[26]. This participant was removed from further analysis, resulting in a revised sample of 15 children.

[26] It is suspected that this participant's very large reported non-spoken vocabulary stemmed from their caregiver accounting for all non-spoken vocabulary items available on their AAC system, and not what non-spoken AAC words their child was directly observed to use (e.g., counting all the animal picture-symbols on the child's communication board even though the child only uses the *Pig* and *Dog* picture-symbols when communicating). It is also possible that the caregiver counted prompted (i.e., not independent) AAC use.

Table 1. *Range of Spoken Words Reported in the Screening Questionnaire versus the AAC-modified CDI: Words & Gestures*

Participant	***Spoken Words Reported in Screening Questionnaire***	***Spoken Words Reported in AAC-modified CDI: Words & Gestures***
1	0	**50+**
2	0	**50+**
3	1-25	**50+**
4	1-25	1-25
5	**50+**	**50+**
6	26-50	**50+**
7	0	1-25
9	26-50	**50+**
10	26-50	**50+**
11	1-25	26-50
13	1-25	1-25
14	26-50	**50+**
15	0	0
16	26-50	**50+**
17	**50+**	**50+**
18	0	1-25

We then divided the sample into two groups based on their spoken vocabulary size reported on the AAC-modified CDI: Words and Gestures (see **Table 2**). Children with 50 spoken words or less were allocated to the *First 50* spoken words group (five participants), whilst those with more than 50 reported spoken words were allocated to the *50+* spoken words group (ten participants). This approach allowed us to examine whether accounting for non-spoken modalities had a larger impact on the assessment of vocabulary for those with fewer reported spoken words. The 50-word mark was chosen as it represents an inflection point in typical language development when children begin to combine words and language growth accelerates (Anisfeld et al., 1998; Hoff, 2009). Additionally, previous studies employing the CDI have demonstrated that the early word development stage (i.e., under 50 words) represents a stage of particularly large variability among typically developing and autistic children (Bates et al., 1994; Jiménez et al., 2021).

Table 2. *Participant Spoken Vocabulary Size Reported on AAC-modified CDI: Words and Gestures*

Vocabulary Size	*Number of Participants*	*Range of Spoken Words M (range)*
< 50 reported spoken words	5	11.2 (1-40)
> 50 reported spoken words	10	192.5 (58-383)

To address our second research question, as in previous studies using the CDI to analyze lexical composition of children on the autism spectrum (Charman et al., 2003; Luyster et al., 2007), we investigated both the syntactic class and semantic category

distributions of our sample. Given the sample's small vocabulary size, and the importance of nouns and verbs in emerging lexical development, we focused our syntactic class analysis on only nouns and verbs, as was done by Jiménez et al. (2021) and Haebig et al. (2021). Words were classified according to Bates et al. (1994) who defined **nouns** as words from the following CDI categories: 'Animals', 'Vehicles', 'Toys', 'Food and Drink', 'Clothing', 'Body Parts', 'Furniture and Rooms', and 'Small Household Items'. **Verbs** were taken from the 'Action Words' category. All other words were classified in the syntactic class '**Other**'. The percentage of vocabulary in these three syntactic classes was compared between *spoken vocabulary* and *non-spoken+spoken vocabulary*. Finally, for our semantic analysis, putting aside the CDI category of 'Action Words', we outline the percentage of vocabulary in the 18 other CDI semantic categories, which are subgroupings of nouns and words from the syntactic class "Other".

Due to non-normal distributions of the two related samples, we conducted non-parametric pairwise comparisons using the Wilcoxon signed rank test with continuity correction to examine the effect of including (or not including) non-spoken communication in the assessment of participants' overall expressive vocabulary, as well as participants' expressive verb vocabulary use. The effect size *r*, which is appropriate for comparing two related samples when using non-parametric tests, is reported.[27]

[27] The effect size *r* (i.e., a rank bi-serial correlation) is interpreted using the following thresholds: $r < 0.1$ = small, $r \approx 0.3$ = medium, $r > 0.5$ = large effect (Tomczak & Tomczak, 2014).

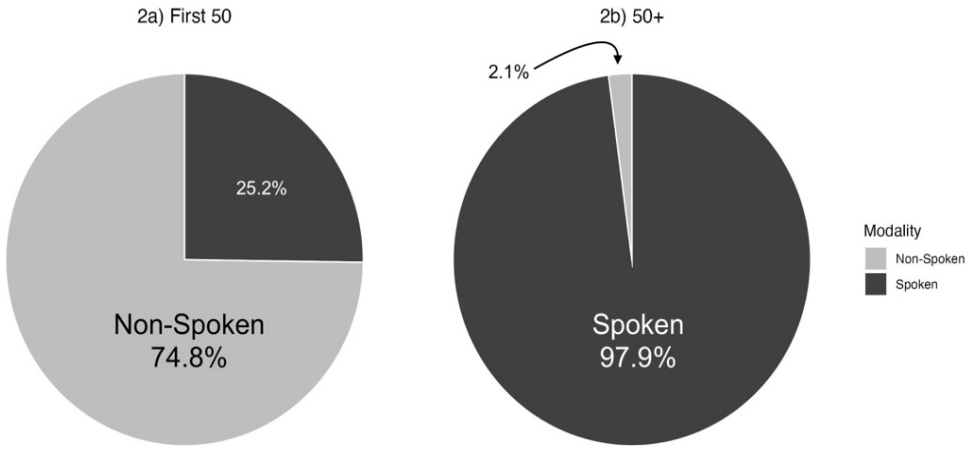
Results

To answer our first research question, we assessed the percentage of all participants' *non-spoken+spoken vocabulary* accounted for by spoken and non-spoken communication. On average, words expressed using non-spoken modalities accounted for 9.5 percent of participants' *non-spoken+spoken vocabulary*. Nine out of the 15 participants had between 1 to 58 additional words when vocabulary from all modalities was considered, versus spoken vocabulary only. No additional words were reported for six participants.[28] Including the number of words that participants could communicate using non-spoken modalities significantly increased their expressive vocabulary size by an average of 13.8 words (*spoken M* = 132.1 words, *non-spoken+spoken M* = 145.9 words), considered to be a large effect ($V = 0$, $p = 0.009$, $Z = -2.61$, $r = 0.75$).

We explored whether the increase in expressive vocabulary from considering non-spoken communication was different depending on expressive vocabulary size, e.g., for children in the *First 50* group versus *50+* group. For those in the *First 50* spoken words group, 74.8 percent of participants' total vocabulary was communicated using non-spoken modalities, compared to just 2.1 percent for those with more than 50 reported spoken words (see **Figure 2a and b**). The mean *spoken vocabulary* for the *First 50* group was 11.2 words (as reported in **Table 2**) which increased to a mean of 44.4 words when accounting for both spoken and non-spoken modalities (i.e., *non-spoken+spoken vocabulary)*. The mean spoken vocabulary for the 50+ group was 192.5 words and increased by 4.1 words to a mean *non-spoken+spoken vocabulary* of 196.6.

[28] A majority (i.e., five) of these six participants were from the *50+* group.

Figure 2. *Spoken vs. Non-Spoken Modalities - Percentage of Vocabulary Words Produced by First 50 (n = 5) and 50+ (n = 10) Groups*



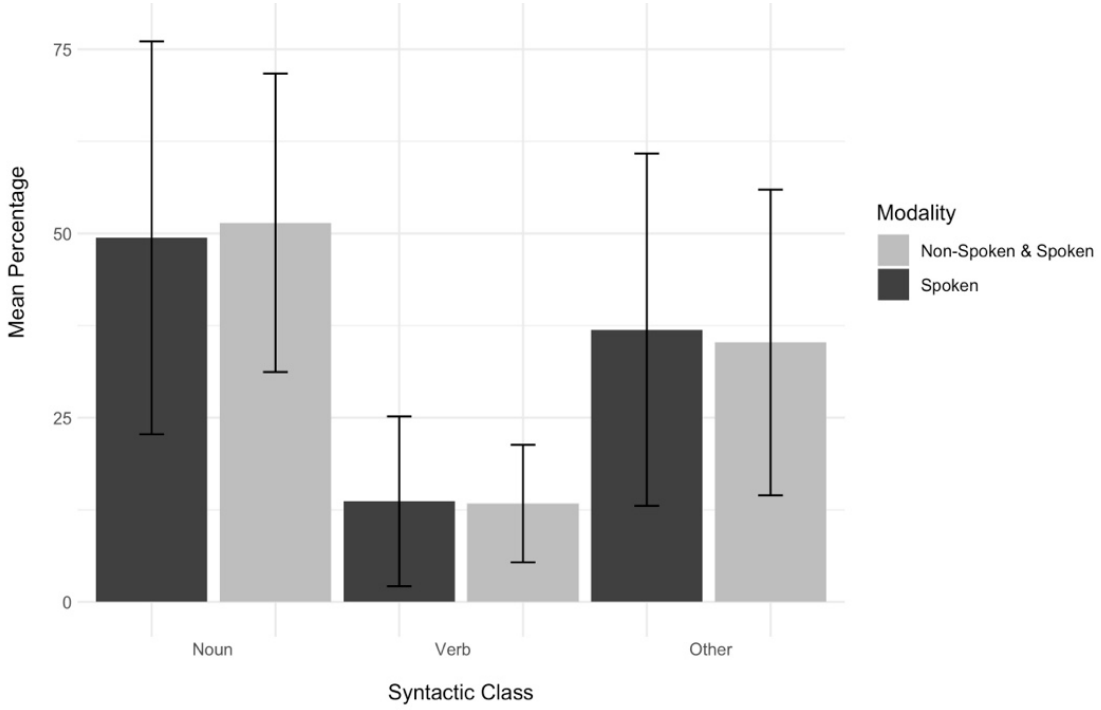
Lexical Composition

To answer our second research question, we examined the prominence of verbs in the lexical composition of our minimally speaking autistic sample in the context of multiple modalities. We also investigated verbs with respect to 1) syntactic classes on the CDI and 2) when compared to the CDI's 18 other semantic categories.

Nouns made up the largest proportion of their *non-spoken+spoken vocabulary* (i.e., 51.5 percent) as well as their spoken vocabulary (i.e., 49.4 percent). See **Figure 3**. When accounting for all modalities across all participants, on average, the syntactic class of verbs made up a sizable portion (13.3 percent) of their *non-spoken+spoken vocabulary* (see **Figure 3**). Similar percentages were found when examining only spoken verb vocabulary (i.e., verbs: 13.6 percent), indicating that this is a stable finding across modalities. Given the broad chronological age (i.e., three to nine years) of our sample, Spearman's correlation was carried out to determine if an association exists between age and verb use. Significant correlations were found between whereby older children had greater spoken verb use (r_s =

0.71, p = 0.003, strong correlation). This was also the case for *non-spoken+spoken* verb use (r_s = 0.58, p = 0.02, moderate correlation). In contrast, no significant correlations were found between age and production of nouns or the 'Other' syntactic class.

Figure 3. *Spoken Only vs. Non-Spoken and Spoken Modalities - Percentage of Vocabulary Words Produced Via Syntactic Class (n = 15)*



The mean number of verbs spoken by all participants was 18 words (range = 0 - 54). When accounting for both non-spoken and spoken expression, there was a large and significant mean increase of two words, going from 18 to 20 words (*V = 0*, *p* = 0.02, *Z* = -2.30, *r* = 0.68). The mean number of verbs expressed by *First 50* participants increased from two to eight verbs, compared to an increase of just 0.70 verbs for those in the *50+* spoken words group. Overall, as would be anticipated, these findings demonstrate a greater impact of

incorporating non-spoken modalities in vocabulary assessment for those with fewer reported spoken words.

A majority (i.e., at least eight or more) of participants could say at least seven different verbs from the CDI 'Action Word' category: 10/15 participants could say 'Drink', 9/15 participants could say 'Finish', 'Eat', and 'Go'. Finally, 8/15 participants could say the verbs 'Look' and 'Sleep'. When factoring non-spoken modalities as well, a majority of the sample could express at least 13 different verbs: 11/15 could express 'Drink', 'Finish', 'Eat', and 'Open', 10/15 could express 'Hug' and 'Go', 9/15 could express 'Look', 'Sleep', 'Jump', 'Kiss' and 'Stop', and finally 8/15 could express: 'Close' and 'Tickle'. See **supplemental materials, section two, Table S2** for an exhaustive list.

For the 18 other CDI semantic categories, after verbs, the two categories which formed the second and third largest percentages of participants' *spoken vocabulary* were: 'Animal Names': 12.8 percent and 'Body Parts': 11.9 percent. On average, the top three categories constituted 38.3 percent of participants' spoken vocabulary (see **supplemental materials, section three, Table S3** for an exhaustive list of the proportion of spoken words per CDI semantic category). A slightly different pattern emerged when accounting for non-spoken modalities. The two semantic categories which formed the second and third largest percentages of participants' *non-spoken+spoken vocabulary* were: 'Animal Names': 12.4 percent and 'Food & Drink': 11.6 percent. On average, the top three categories constituted 37.4 percent of *non-spoken+spoken* vocabulary (see **supplemental materials, section four, Table S4**). Overall, accounting for non-spoken expression increased the mean number

of words recorded in all but two of the semantic categories (Pronouns and Questions) (see **Table 3**).

Table 3. *Mean Number of Words Reported in Each CDI Semantic Category for Spoken Only vs. Non-Spoken and Spoken Vocabulary.*

	CDI Semantic Category *(n = total # of checklist items available in the category)*	***M # of Spoken***	***M # of Non-Spoken and Spoken***	***M Difference***
1	Action Words (n = 55)	17.73	20.20	**+2.47**
2	Food and Drink (n = 30)	13.40	15.80	**+2.40**
3	Games and Routines (n = 19)	6.93	8.33	**+1.40**
4	Small Household Items (n = 36)	9.80	10.93	**+1.13**
5	Furniture and Rooms (n = 24)	6.53	7.33	**+0.80**
6	Toys (n = 8)	3.67	4.47	**+0.80**
7	Clothing (n = 19)	6.87	7.67	**+0.80**
8	Outside Things and Places to Go (n =27)	9.13	10.0	**+0.87**
9	Animal Names (n = 36)	19.47	20.20	**+0.73**
10	Body Parts (n = 20)	9.00	9.53	**+0.53**
11	Description Words (n = 37)	7.20	7.67	**+0.47**
12	Propositions and Locations (n = 11)	2.73	3.20	**+0.47**
13	People (n = 20)	5.33	5.80	**+0.47**
14	Quantifiers (n = 8)	0.87	1.07	**+0.20**

15	Vehicles (n = 9)	4.07	4.20	**+0.13**
16	Sound Effects and Animal Sounds (n = 12)	5.67	5.73	**+0.07**
17	Words About Time (n = 8)	1.27	1.33	**+0.07**
18	Pronouns (n = 11)	1.73	1.73	0.00
19	Question Words (n = 6)	0.67	0.67	0.00

Discussion

This study sought to determine how including non-spoken modalities, alongside spoken language, alters our capacity to comprehensively capture a minimally speaking autistic child's vocabulary. Accounting for all methods of communication had a large effect, significantly increasing participants' expressive vocabulary size, particularly for those with fewer than 50 reported spoken words.

With respect to lexical composition, verbs made up 13.3 percent of their spoken and non-spoken combined vocabulary (nouns: 51.5 percent). The percentages of verbs and nouns when accounting for spoken words only was similar (verbs = 13.6 percent, nouns = 49.4 percent). This ran counter to our hypothesis and contrasts with previous findings from Jiménez et al. (2021) and Haebig et al (2021) and aligns with what is seen in neurotypical children who have similar vocabulary sizes (i.e., 100-400 words).

Our findings highlight the importance of accounting for minimally speaking autistic children's non-spoken expression, in particular for those children in the *First 50* spoken

word group, where the modifications to the CDI were found to account for a majority of their vocabulary (74.8 percent). In contrast, non-spoken expression only accounted for a small percentage (2.1 percent) of children in the *50+* spoken word group's vocabulary. This disparity could potentially parallel what is observed in typical development, albeit at a much later age, whereby toddlers who are developing their first 50 words and do not yet make word combinations, initially use gestures (in our sample, communication board with some gesture use) to supplement their spoken communication, but for children with higher spoken language abilities, use of non-spoken modalities decreases (Goldin-Meadow, 2015; Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005). With that said, care should be taken when comparing the language development of autistic children using AAC with that of typically developing children, as there are limitations.

Based on these results, we would recommend using the AAC-modified CDI: Words and Gestures for minimally speaking autistic children. For profiling vocabulary use in this population, it is, to our knowledge, the only parent report vocabulary measure modified to include non-spoken expression. The simple modifications of this parent report measure provided us with significantly more information on the expressive vocabulary of this autistic subgroup, particularly for those with fewer than 50 spoken words. Furthermore, allowing caregivers to report on non-spoken expression highlights potential strengths, increasing inclusivity of the measure.

In addition, based on our findings, we added a clarifying statement for use with minimally speaking autistic children to the instructions of the AAC-modified CDI: Words and Gestures. Since this group of children can produce spoken words only inconsistently (e.g.,

said it once 2 years ago and never again) or exclusively through immediate echolalia (i.e., not independently), we hypothesize that the standard CDI instructions for the vocabulary checklist section led caregivers to account for any words produced, whether they be consistent, independently, or not. This most likely led to differential reporting in spoken vocabulary in comparison to our screening questionnaire as shown in **Table 3**. Therefore, we added two sentences to the instructions to state that vocabulary items should only be reported if usage is both consistent and independent[29]. This wording is similar to other measures adapted for use with this specific autistic subgroup, such as the Low Verbal Investigatory Screener (LVIS: Naples et al., 2022). This addition to the instructions allows researchers and clinicians to profile and track the consistent and independent language use of minimally speaking autistic children. See **supplemental materials, section five** for a sample of the AAC-modified CDI: Words and Gestures[30].

For our second question regarding lexical composition, we hypothesized that our minimally speaking autistic sample would exhibit high verb prominence consistent with the findings of Jiménez et al. (2021), Haebig et al. (2021), and Butler et al. (2023). However, our results contradicted this hypothesis. Nouns made up most of our minimally speaking autistic sample's spoken vocabulary (49.4 percent), and their vocabulary when accounting for all modalities (51.5 percent). They also had a sizable mean portion of verbs that made up their lexical repertoire (13.3 and 13.6 percent; **see Figure 3**). However, the minimally

[29] "To check off a word as said verbally (or expressed using non-spoken methods), you should have heard (or seen) your child say (or express) the word more than one time in recent memory. The word should have also been produced independently (e.g., not repeated immediately after someone said it)."
[30] The AAC-modified CDI: Words and Gestures is freely available on the MacArthur Bates-CDI website at https://mb-cdi.stanford.edu/ or by emailing angela.t.macdonald@gmail.com.

speaking autistic children in our sample are likely at a more advanced stage of development where there is more verb learning, compared to the autism samples from Jiménez et al. (2021) and Haebig et al (2021) who also used the CDI. The mean vocabulary size of our sample [spoken only *M* = 132.1 words, spoken and non-spoken = *spoken M* = 145.9 words] was much larger than the Jiménez et al. (2021) [*M* = 74.9 words] and Haebig et al. (2021) [*M* = 4.56 words] autism samples and falls into what Bates et al. (1994) refer to as the "second wave of lexical re-organization" whereby verb growth accelerates when vocabulary size is between 100-400 words. Although we did not have a typically-developing sample, looking to the literature the percentage of verbs and nouns of typically developing toddlers with vocabularies between 101-200 words reported by Bates et al. (1994, as cited in Butler et al., 2023) were 15 percent and 57 percent, respectively, quite similar to our minimally speaking autistic sample.

In addition, unlike Haebig et al. (2021) who did not find a correlation between age and verb use, in our sample, significant correlations were found whereby older children had greater spoken verb use (r_s = 0.71, p = 0.003, strong correlation). This was also the case for verb use when factoring in both spoken and non-spoken modalities (r_s = 0.58, p = 0.02, moderate correlation). These correlations could be attributed to our sample's higher mean age (*M* = 6 years; 2 months, range = 3 years; 1 month – 9 years; 10 months) compared to that of Haebig's autism sample (*M* = 3 years; 11 months, range = 1 year; 7 months – 9 years; 11 months). Overall, our findings demonstrate that the verb and noun composition of older minimally speaking autistic children with vocabularies above 100 words (as per caregiver report), more closely resembles what is seen in typical development, although for

minimally-speaking with vocabularies below 100 words a prominence in the representation of verbs has been reported.

Limitations

As the vocabulary measure is based on a caregiver-report, and the AAC intervention was implemented by caregivers, this could have led to an overestimation of non-spoken vocabulary. An alternative to using a parent report measure such as the CDI would be to capture the expressive vocabulary produced during a caregiver-child interaction using a standardized protocol, such as the Eliciting Language Sample For Analysis (Barokova et al., 2021). Once completed, the child's expressive vocabulary could be transcribed and analyzed in software programs such as Computerized Language Analysis (MacWhinney, 2018) or Systematic Analysis of Language Transcripts (Miller & Iglesias, 2015). Language samples allow for the analysis of directly observable vocabulary communicated by the child during a specific time-period which may, in some situations, provide a more accurate snapshot of the child's vocabulary abilities. Also, language sample transcription protocols used in studies such as Kasari et al. (2014) and La Valle et al. (2024a, 2024b) have been adapted to transcribe and code non-spoken modalities, such as communication boards and speech-generating devices.

On the other hand, this type of method is much more time- and resource-intensive than the CDI, as it requires the collection of a video sample, as well as the transcription and analysis of usually 50 utterances or more, depending on the length of the sample collected (Heilmann et al., 2010). However, it is worth noting that automatic speech-recognition tools

have been developed to expedite the transcription process, which is traditionally done manually by trained transcribers (McGonigle et al., 2024). Also, most standard language sample transcription protocols are not adapted to transcribe and code non-spoken modalities (e.g., communication board, speech generating device) and may only provide a brief window into the children's abilities. In contrast, though caregivers of minimally speaking autistic children may be limited to the vocabulary checklist selection of the AAC-modified CDI: Words and Gestures, such a tool provides a quick holistic overview of the child's expressive vocabulary, accounting for all modalities, using the knowledge of a familiar listener, specifically their caregiver.

The CDI: Words and Gestures, from which the AAC-modified CDI: Words and Gestures was derived, was created and normed for use with neurotypical infants and toddlers. Given the older age and intense special interests of our autistic participants (e.g., computer software programs, cleaning supplies), it may not capture all the possible vocabulary of these children. Though our modified measure included open-ended questions to list additional vocabulary words expressed, it was rarely answered and thus may have led to under-estimations of vocabulary size. Therefore, future work should focus on creating a vocabulary assessment tool that is specifically developed for, and normed using, autistic children, to evaluate the diverse range of spoken and non-spoken abilities seen in this population.

Additionally, while the instructions in the AAC-modified CDI: Words and Gestures did not explicitly state that caregivers should only report English words, this may have been implied since the form was in English. Many of the children in our sample were dominant in

English but also communicated in and/or were exposed to other languages (see **Table S1**), which may have led parents to omit words from those languages. As a result, this could have further contributed to an underestimation of vocabulary.

As the data used in this study were collected in the context of an AAC intervention and used a small sample size, our findings are potentially less generalizable to settings outside of an AAC-rich environment, as many minimally speaking autistic children do not have access to formal AAC systems, such as a communication board. Therefore, the AAC-modified CDI: Words and Gestures would benefit from further validation and reliability testing to ensure its sensitivity in capturing communication outcomes accurately across the full range of minimally speaking autistic participants. However, with that said, our results are useful in demonstrating why AAC should be more widely available, as it may lead to increases in the number of words these children are able to express.

Finally, due to the low-tech nature of the AAC communication boards used in the intervention study, caregivers had to manually add new picture-symbols as intervention progressed. These symbols were selected from a bank of AAC picture-symbols created using the vocabulary checklists of the CDI: Words and Gestures and CDI: Words and Sentences. Since this current analysis examines data collected at the end of this intervention period, there may be an increased likelihood that caregivers reported their children as using non-spoken words found on the AAC-modified CDI: Words and Gestures. Additionally, AAC systems in general have a fixed number of available vocabulary items, which could have limited the children's ability to produce certain words as they were not available within their system.

Future Directions

Future studies should investigate the use of the AAC-modified CDI: Words and Gestures with a larger representative sample of minimally speaking autistic children who are and are not participating in any type of spoken language or AAC intervention. As was done in this study, this method would allow *minimally speaking* participants to be selected using the ADOS-2 module assignment guidelines. As highlighted by Bal et al. (2016), this method creates a more broadly defined minimally speaking group of participants with a wider variety of communicative repertoires profiles that supports our understanding of the spoken language difficulties experienced by this group. More broadly, future work with this modified CDI tool could be potentially useful for assessing spoken and non-spoken vocabulary in other populations who use AAC, such as children with Global Developmental Delay, children with Down Syndrome, etc. Given we found that the proportion of verbs and nouns was in line with that reported in Bates et al. (1994, as cited in Butler et al., 2023) for typically developing-children who have similar productive vocabularies**,** future research should seek to confirm this finding through replication and direct comparison with an vocabulary matched sample.

Conclusion

In this study, we have demonstrated the value of including both spoken and non-spoken modalities of communication when assessing the expressive vocabulary of minimally speaking autistic children. Prior studies reported a prominence of verbs in the vocabulary of minimally speaking autistic children who had parent-reported vocabularies of fewer than 100 words. In contrast, in our minimally speaking sample (who had slightly larger

vocabularies despite experiencing significant language delays) we observed the representation of verbs (and nouns) to be similar to reports for vocabulary-matched typically-developing children and autistic children in general (Bates et al., 1994; Ellis Weismer et al., 2011).

These findings support the use of strengths-based adaptations to vocabulary assessment in both research and clinical practice. By accounting for non-spoken expression, clinicians can conduct more comprehensive assessments of their clients' abilities and needs, and researchers can better characterize the potentially different language development of minimally speaking autistic children.

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Data Availability Statement

The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

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Supplemental Materials

Value added by assessing non-spoken vocabulary in minimally speaking autistic children

Angela MacDonald-Prégent[a,b], Lauren McGuinness[c], Aparna Nadig[a,B]

[a]School of Communication Sciences and Disorders, McGill University

[b]Centre for Research on Brain, Language, and Music

[c]School of Psychology, University of Kent

Supplemental Section 1 - Table S1. *Participant Characteristics at Baseline for Main Sample (n = 16)*

Participant #	*Age*[a]	*Sex*	*Visible Minority*[b]	*Dominant Language*	*Other Language(s)*[c]	*Non-Verbal Cognition*[d]	*Receptive Language Ability*[e]	*Social Ability*[f]	*Motor Ability*[g]
1	5;3	Male	No	English	French, Italian	<5	59	61	84
2	9;10	Male	Yes	English	N/A	50	56	57	59[h]
3	5;5	Female	Yes	English	Chinese, French	<5	48	59	72
4	6;10	Male	No	English[i]	Romanian[i]	5	40	55	59
5	8:7	Male	No	English	N/A	<5	40	50	59
6	4;7	Male	Yes	English	N/A	<5	69	66	75
7	6;9	Male	No	English	N/A	<5	40	57	72
9	5;10	Male	No	English	N/A	10	78	59	64
10	4;11	Male	Yes	English	N/A	37.5	63	59	81
11	8;0	Male	Yes	English	Cebuano	<5	40	55	59[g]
13	3;1	Female	No	English	Serbian	N/A[j]	52	59	75
14	3;1	Male	Yes	English	N/A	N/A[j]	60	74	97
15	5;4	Male	No	English	N/A	<5	53	53	61
16	8;3	Male	No	English	French, Spanish	<5	40	50	59[g]
17	5;2	Female	Yes	English	N/A	<5	41	63	75
18	7;0	Male	No	English	French, Arabic, Portuguese	25	40	53	59 [g]

Note. Standardized tests were administered remotely, a) chronological age in year; month, b) term used by the Canadian government to describe a person who is non-white in colour or non-Caucasian in race (Statistics Canada, 2021), c)other languages the child was reported to understand and/or communicate in, d) Raven's 2 Coloured Progressive Matrices percentile, e) Peabody Picture Vocabulary Test, 5th edition standard score, f) Vineland Adaptive Behaviour Scales, 2nd Edition, Survey Interview Form (Vineland-II) socialization domain standard score, g) Vineland-II motor domain standard score, h) oldest possible 6;9-6;11 norms used to calculate the standard score, i) reported to be equally proficient in English and Romanian, j) test not administered as participant did not meet minimum age cut off age of 4;0

Supplemental Section 2 - *Number and Percentage of Participants' (n = 15) Spoken Only vs. Non-Spoken and Spoken Verbs from the Action Word Category of AAC-modified CDI: Words and Gestures*.

Table S2.

Verb	***Spoken Only*** *(n and % of sample)*	***Non-Spoken and Spoken*** *(n and % of sample)*	***Difference***
Drink	**10 (66.6%)**	**11 (73.3%)**	**+1**
Finish	**9 (60.0%)**	**11 (73.3%)**	**+2**
Eat	**9 (60.0%)**	**11 (73.3%)**	**+2**
Go	**9 (60.0%)**	**10 (66.6%)**	**+1**
Hug	**8 (53.3%)**	**10 (66.6%)**	**+2**
Look	**8 (53.3%)**	**9 (60.0%)**	**+1**
Sleep	**8 (53.3%)**	**9 (60.0%)**	**+1**
Help	**7 (46.7%)**	**7 (46.7%)**	**=**
Jump	**7 (46.7%)**	**9 (60.0%)**	**+2**
Kiss	**7 (46.7%)**	**9 (60.0%)**	**+2**
Push	**7 (46.7%)**	**7 (46.7%)**	**=**
Run	**7 (46.7%)**	**7 (46.7%)**	**=**
Blow	**6 (40.0%)**	**6 (40.0%)**	**=**
Clean	**6 (40.0%)**	**6 (40.0%)**	**=**
Close	**6 (40.0%)**	**8 (53.3%)**	**+2**

Cry	**6 (40.0%)**	**7 (46.7%)**	**+1**
Draw	**6 (40.0%)**	**6 (40.0%)**	**=**
Read	**6 (40.0%)**	**6 (40.0%)**	**=**
Open	**6 (40.0%)**	**11 (73.3%)**	**+5**
Stop	**6 (40.0%)**	**9 (60.0%)**	**+3**
Tickle	**6 (40.0%)**	**8 (53.3%)**	**+2**
Walk	**6 (40.0%)**	**7 (46.7%)**	**+1**
Bite	**5 (33.3%)**	**5 (33.3%)**	**=**
Give	**5 (33.3%)**	**5 (33.3%)**	**=**
Love	**5 (33.3%)**	**5 (33.3%)**	**=**
Play	**5 (33.3%)**	**5 (33.3%)**	**=**
Pull	**5 (33.3%)**	**5 (33.3%)**	**=**
Sing	**5 (33.3%)**	**5 (33.3%)**	**=**
Wash	**5 (33.3%)**	**7 (46.7%)**	**+2**
Bump	**4 (26.7%)**	**4 (26.7%)**	**=**
Say	**4 (26.7%)**	**5 (33.3%)**	**+1**
Show	**4 (26.7%)**	**4 (26.7%)**	**=**
Swim	**4 (26.7%)**	**4 (26.7%)**	**=**
Swing	**4 (26.7%)**	**4 (26.7%)**	**=**
Wipe	**4 (26.7%)**	**4 (26.7%)**	**=**
Drive	**3 (20.0%)**	**4 (26.7%)**	**+1**

Get	**3 (20.0%)**	**3 (20.0%)**	**=**
Kick	**3 (20.0%)**	**3 (20.0%)**	**=**
Put	**3 (20.0%)**	**3 (20.0%)**	**=**
Ride	**3 (20.0%)**	**3 (20.0%)**	**=**
See	**3 (20.0%)**	**3 (20.0%)**	**=**
Smile	**3 (20.0%)**	**3 (20.0%)**	**=**
Throw	**3 (20.0%)**	**5 (33.3%)**	**+2**
Touch	**3 (20.0%)**	**3 (20.0%)**	**=**
Watch	**3 (20.0%)**	**3 (20.0%)**	**=**
Write	**3 (20.0%)**	**3 (20.0%)**	**=**
Break	**2 (13.3%)**	**2 (13.3%)**	**=**
Dance	**2 (13.3%)**	**3 (20.0%)**	**+1**
Fall	**2 (13.3%)**	**2 (13.3%)**	**=**
Feed	**2 (13.3%)**	**3 (20.0%)**	**+1**
Hurry	**2 (13.3%)**	**2 (13.3%)**	**=**
Splash	**2 (13.3%)**	**3 (20.0%)**	**+1**
Take	**2 (13.3%)**	**2 (13.3%)**	**=**

Supplemental Section 3 - Spoken *Vocabulary Distribution of Sample (n=15): Mean Percentage Reported in Each CDI Semantic Category from AAC-modified CDI: Words and Gestures*.

Table S3.

Order of Prominence	***Semantic Category*** *(n = total # of checklist items available in the category)*	***M % of Spoken Words***
1	Action Words (n = 55)	13.6%
2	Animal Names (n = 36)	12.8%
3	Body Parts (n = 20)	11.9%
4	Food and Drink (n = 30)	8.9%
5	Games and Routines (n = 19)	8.3%
6	People (n = 20)	7.2%
7	Outside Things and Places to Go (n = 27)	5.7%
8	Description Words (n = 37)	5.0%
9	Small Household Items (n = 36)	4.8%
10	Sound Effects and Animal Sounds (n = 12)	4.8%
11	Clothing (n = 19)	3.7%
12	Furniture and Rooms (n = 24)	2.9%
13	Vehicles (n = 9)	2.3%
14	Toys (n = 8)	2.1%
15	Quantifiers (n = 8)	2.0%
16	Pronouns (n = 11)	1.9%

17	Propositions and Locations (n = 11)	1.5%
18	Words About Time (n = 8)	0.5%
19	Question Words (n = 6)	0.3%

Supplemental Section 4 - *Non-Spoken and Spoken Vocabulary Distribution of Sample (n=15): Mean Percentage Reported in Each CDI Semantic Category from AAC-modified CDI: Words and Gestures*.

Table S4.

Order of Prominence *(change in order from Table S4)*	***Semantic Category*** *(n = total # of checklist items available in the category)*	***M % of Words Expressed in Non-Spoken and Spoken Modality***
1 (=)	Action Words (n = 55)	13.3%
2 (=)	Animal Names (n = 36)	12.4%
3 (+1)	Food and Drink (n = 30)	11.6%
4 (+1)	Games and Routines (n = 19)	9.5%
5 (+1)	People (n = 20)	6.6%
6 (+3)	Small Household Items (n = 36)	6.6%
7 (=)	Outside Things and Places to Go (n =27)	6.1%
8 (-5)	Body Parts (n = 20)	5.7%
9 (+2)	Clothing (n = 19)	5.2%
10 (-2)	Description Words (n = 37)	4.3%
11 (+1)	Furniture and Rooms (n = 24)	4.0%
12 (+2)	Toys (n = 8)	3.6%
13 (-3)	Sound Effects and Animal Sounds (n = 12)	3.5%
14 (+3)	Propositions and Locations (n = 11)	2.6%
15 (-2)	Vehicles (n = 9)	2.3%

16 (=)	Pronouns (n = 11)	1.0%
17 (-2)	Quantifiers (n = 8)	0.8%
18 (=)	Words About Time (n = 8)	0.5%
19 (=)	Question Words (n = 6)	0.3%

Supplementary Section 5 – *The AAC-Modified CDI: Words and Gestures – Sample*

Augmentative and Alternative Communication – Modified

Communicative Development Inventory:

Words & Gestures

SAMPLE ONLY

Angela MacDonald-Prégent, M.Sc.
Aparna Nadig, Ph.D.
School of Communication Sciences and Disorders,
Faculty of Medicine and Health Professions,
McGill University

A copy of the full form is available upon request at the MacArthur-Bates CDI website: mb-cdi.stanford.edu or by emailing corresponding author, Angela MacDonald-Prégent at angela.t.macdonald@gmail.com

This questionnaire is a modification of the MacArthur-Bates Communicative Development Inventory: Words & Gestures (Marchman, Dale & Fenson, 2023), for children who use Augmentative and Alternative Communication (e.g., non-spoken) methods to communicate. The modifications have been made with the permission of the CDI Advisory Board.

June 2024, Version 2

This questionnaire will take an inventory of your child's vocabulary (both words that are expressed using spoken and non-spoken methods as well as your child's understanding of these words). This list is based on words used by typically developing children as they begin to learn to speak in English. This questionnaire should take approximately 15-20 minutes to complete, at your convenience.

Part I: Early Words

A. First Signs of Understanding

Before children begin to speak, they show signs of understanding language by responding to familiar words and phrases. Below are some common examples. Does your child do any of these?

		yes	no
1.	Respond when name is called (e.g., by turning and looking at source).	○	○
2.	Respond to "no" (by stopping what they are doing, at least for a moment).	○	○
3.	React to "There's mom/dad" by looking around for them.	○	○

B. Phrases (28)

1. In the list below, please mark the phrases that your child seems to understand.

	understands		understands		understands		understands
Are you hungry?	☐	Daddy's/ mommy's home.	☐	Give me a kiss.	☐	Sit down.	☐
Are you tired/sleepy?	☐	Do[illegible] want [illegible]?	☐	Go get ____.	☐	Sp[illegible]it.	☐
Be careful.	☐	Do[illegible]	☐	Good girl/[illegible]y.	☐	Sto[illegible].	☐
Be quiet.	☐	Don't touch.	☐	Hold still.	☐	Time to go night night.	☐
Clap your hands.	☐	Get up.	☐	Let's go bye bye.	☐	Throw the ball.	☐
Change diaper.	☐	Give it to mommy.	☐	Look/look here.	☐	This little piggy.	☐
Come here/come on.	☐	Give me a hug.	☐	Open your mouth.	☐	Want to go for a ride?	☐

2. Are there any other phrases not listed that your child can understand?

C. Starting to Talk

		Never	Sometimes	Often
1.	Some children like to "parrot" or imitate things they've just heard (including new words that they are just learning, and/or parts of sentences, for example, repeating "work now" after mother says "Mom's going to work now." How often does your child imitate words?	○	○	○
2.	Some children like to go around naming or labeling things, as though proud of knowing the names and wanting to show this. How often does your child do this?	○	○	○

D. Vocabulary Checklist

The following is a list of typical words in children's vocabularies as they learn to speak/ communicate. This is a "catalogue" of words that are used by many different children. Don't worry if your child knows only a few words.

Understand only: for words your child understands but does not yet say, place a mark in the 1st column (understands only).

Understands and says: For words that your child understands and also says using spoken language, place a mark in the 2nd column (understands and says). If your child uses a different pronunciation of a word (for example, "raffe" for "giraffe" or "sketti" for "spaghetti"), mark the word anyways.

Understands and uses non-spoken methods to "say": For words your child understands and is also able to communicate using non-spoken expressions which includes the use of adapted sign language, pictograms, a communication board, a communication app (i.e. AAC) on an iPad, etc., place a mark in the 3rd column (understands and uses non-spoken methods to "say").

All of the above: If your child understands and is able to communicate vocabulary item(s) using both spoken language and non-spoken expression.

IMPORTANT: To check off a word as said verbally or expressed using non-spoken methods, you should have heard or seen your child say or express the word more than 1 time in recent memory. The word should also have been produced independently (e.g., not repeated immediately after someone else said it).

1. Sound Effects and Animal Sounds (12)

	understands	understands and says	understands and uses non-spoken methods to "say"	all of the above		understands	understands and says	understands and uses non-spoken methods to "say"	all of the above
baa baa	○	○	○	○	ouch	○	○	○	○
choo choo	○	○	○	○	quack quack	○	○	○	○
cockadoodledoo	○	○	○	○	uh oh	○	○	○	○
grr	○	○	○	○	vroom	○	○	○	○
meow	○	○	○	○	woof woof	○	○	○	○
moo	○	○	○	○	yum yum	○	○	○	○

2. Animal Names (Real or Toy) (36)

	understands	understands and says	understands and uses non-spoken methods to "say"	all of the above		understands	understands and says	understands and uses non-spoken methods to "say"	all of the above
animal	○	○	○	○	goose	○	○	○	○
bear	○	○	○	○	horse	○	○	○	○
bee	○	○	○	○	kitty	○	○	○	○
bird	○	○	○	○	lamb	○	○	○	○
bug	○	○	○	○	lion	○	○	○	○
bunny	○	○	○	○	monkey	○	○	○	○
butterfly	○	○	○	○	mouse	○	○	○	○
cat	○	○	○	○	owl	○	○	○	○
chicken	○	○	○	○	penguin	○	○	○	○
cow	○	○	○	○	pig	○	○	○	○
deer	○	○	○	○	pony	○	○	○	○
dog	○	○	○	○	puppy	○	○	○	○
donkey	○	○	○	○	sheep	○	○	○	○
duck	○	○	○	○	squirrel	○	○	○	○
elephant	○	○	○	○	teddy bear	○	○	○	○
fish	○	○	○	○	tiger	○	○	○	○
frog	○	○	○	○	turkey	○	○	○	○
giraffe	○	○	○	○	turtle	○	○	○	○

General Discussion

Thesis Objectives

The main objective of this thesis was to contribute to the literature on Augmentative and Alternative Communication (AAC) interventions and language assessment tools for minimally speaking autistic children. Specifically, we aimed to expand our knowledge of what components (AAC display, theoretical approach) maximize AAC learning. In addition, we sought to test the value of modifying an existing tool to make it capable of capturing the full range of this autistic subgroup's communicative repertoire, including AAC use.

Thesis Results Summary

In Chapter 1, results demonstrate both the naturalistic developmental behavioural AAC intervention that used a consistent-symbol location design (CSL-NDBI), and the modified Picture Exchange Communication System intervention (mod-PECS), significantly increased AAC use in minimally speaking autistic children who were not yet using AAC consistently or independently. Specifically, both remotely coached caregiver-implemented interventions led to similar increases in AAC acts when directly prompted by their trained caregiver. Children in both groups produced AAC utterances that were on average one picture-symbol in length, with no significant differences in the number of different picture-symbols used. These results indicate that the consistent-symbol design used in the CSL-NDBI condition, when used at an early stage of AAC development, does not lead to significantly more complex AAC use than the mod-PECS intervention. Finally, caregivers from the CSL-NDBI and mod-PECS groups increased their ability to implement their

assigned AAC intervention from pre-, mid- and post-intervention. However, at mid-intervention, the percent implementation mastery of the caregivers in the CSL-NDBI condition was significantly higher than caregivers in the mod-PECS group, highlighting that the CSL-NDBI intervention was learned more quickly.

In Chapter 2, the Augmentative and Alternative Communicative Development Inventory: Words and Gestures (AAC-modified CDI: Words and Gestures; MacDonald-Prégent & Nadig, 2024), a modified version of the MacArthur-Bates Communicative Development Inventory: Words and Gestures (Marchman et al., 2023) was created and allowed us to more comprehensively capture minimally speaking children's expressive vocabulary. Accounting for all methods of communication (non-spoken and spoken) had a large effect, significantly increasing participants' expressive vocabulary size, particularly for those with fewer than 50 reported spoken words.

Visual-Scene Display – Another Potential AAC Design Display Strategy

Consistent-symbol location design is hypothesized to maximize the efficiency at which a grid-based aided AAC system is learned (Dukhovny & Thistle, 2019). In our study, we hypothesized that using a consistent-symbol location design would act to support AAC learning leading to the production of more complex AAC use (e.g., longer AAC utterances and/or higher number of different picture-symbols). However, by the end of the 12-week intervention, counter to our hypothesis, children using a consistent-symbol location design did not differ from those using a variable-symbol location design with respect to AAC complexity. Therefore, based on these results, using a consistent-symbol location design

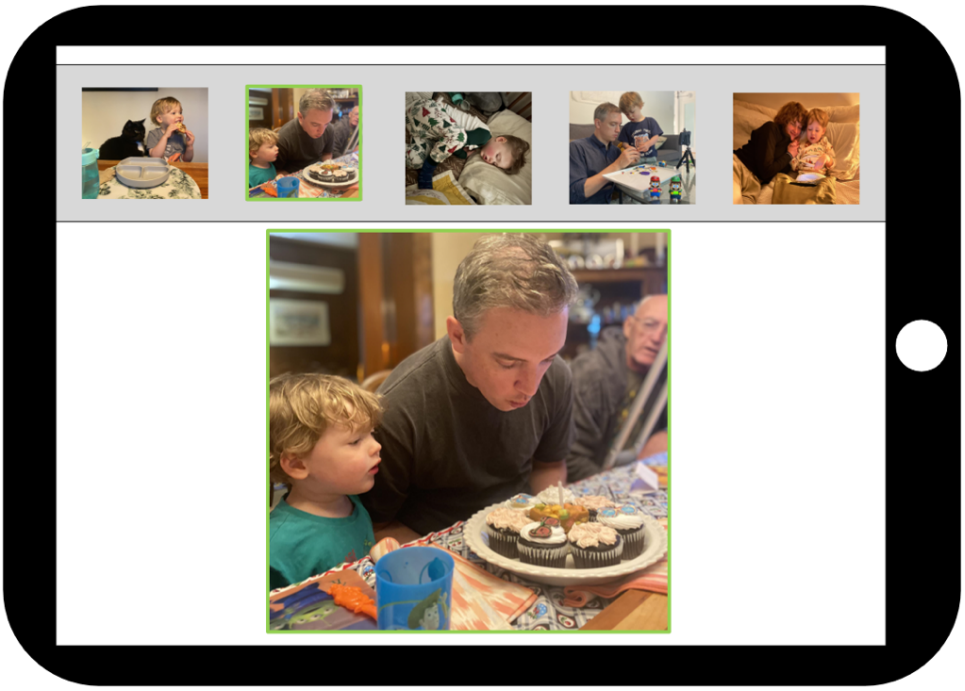
did not lead to more effective learning compared to a variable-symbol location design when applied to minimally speaking autistic children who are emerging communicators at the early stages of AAC use.

It is also important to note that only one of five mod-PECS participants in our study advanced to Phase 3 and mastered the PECS visual discrimination teaching procedure. As a reminder, the variable-symbol location design of PECS is purposely employed to support a visual discrimination teaching process (completed in Phase 3a and 3b) to ensure the child can associate the picture-symbol with their preferred item or activity without relying on other cues such as it being placed in a consistent location. Comparing the progress made by our mod-PECS participants to PECS participants included in a systematic review by Forbes et al. (2024), individuals learning PECS fared slightly better, but still only 48 percent of participants who reached Phase 3b (which targets visual discrimination) mastered it by the end of their respective intervention study. Therefore, based on our study and this recent comprehensive review of the PECS literature, a majority of emerging AAC users are not learning to visually discriminate using variable symbol location (i.e., mastering the PECS Phase 3b protocol). Given the limitations of the PECS visual discrimination procedure, and our preliminary results indicating that consistent-symbol location design does not lead to more complex AAC use compared to a variable-symbol location design, could there be another type of aided AAC display that could improve the rate of learning for emerging communicators as they adopt an AAC system?

Less commonly used than grid-display **(see the general introduction for more details)**, a visual scene display is another type of aided AAC system layout. Typically applied

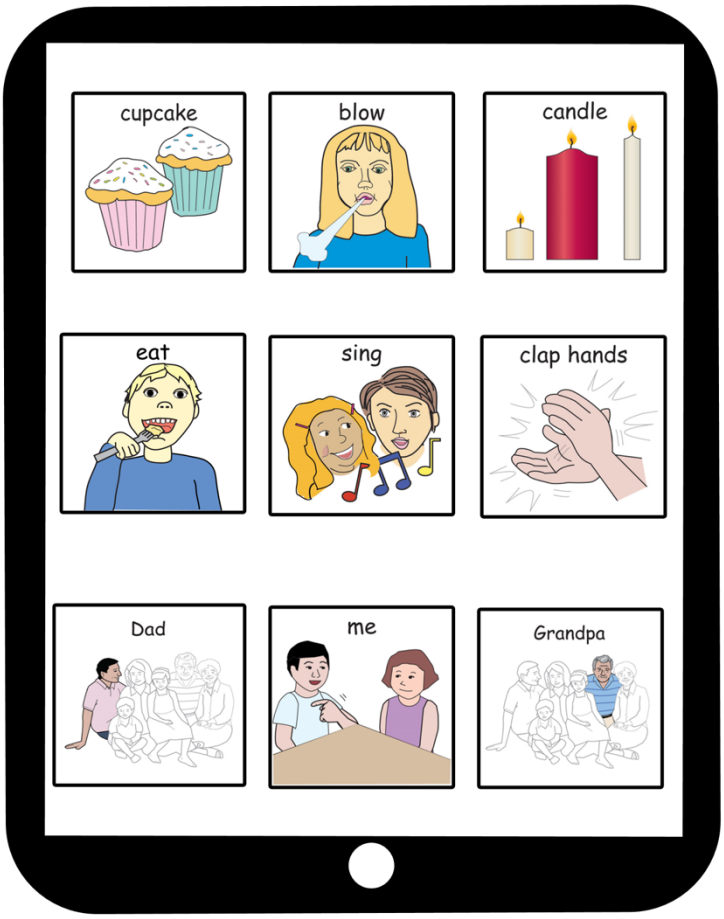
to a high-tech aided AAC system (e.g., speech-generating device), a visual scene display is created on a touch screen device such as an iPad or tablet where multiple language "hot spots" are embedded within a scene such as a photograph (Blackstone, 2004). When a child selects a hot spot, an audio of a corresponding language concept is heard. For example, a visual scene (i.e., photograph) of the child attending their parent's birthday party might include the following language concept hot spots: 1) *the parent's mouth,* if selected, plays the word, "blow", 2) *the child's face,* if selected, plays the word, "me" or 3) *the cupcake,* if selected, plays the word, "cupcake". Multiple other visual scenes can be accessed using a thumbnail on the high-tech aided AAC device. See **Figure 7.**

Figure 7. *Example of Aided AAC System that Uses a Visual Scene Display: Main Visual Scene "Birthday Party" with Thumbnails of Other Visual Scenes*



In a review conducted by Patenaude et al. (2024), the authors found positive improvements in social communication and interaction in early communicators with complex communication needs when using a visual scene display (Chapin et al., 2022; Laubscher et al., 2019; Pope, 2024). Light et al. (2019) hypothesize that visual scene displays may be beneficial for children who are emerging communicators (such as the ones in our study) as the language concepts are contextualized within a familiar social context. In contrast, a grid-display (what was used in our study in Chapter 1), the language concept (i.e., symbol) is not contextualized but presented in isolated cell on a clear background on a grid organized into rows and columns (Light et al., 2019; Thistle & Wilkinson, 2015). See **Figure 8.**

Figure 8. *Example of Aided AAC System that Uses Grid Display: Current Grid "Birthday Party"*



The AAC - Modified CDI: Words and Gestures – Additional Context and Rationale This Tool

Assessment methods such as language sampling and caregiver report can yield reliable and detailed information on minimally speaking autistic children. A natural and, a direct observation measure, is one of the most robust assessment methods to evaluate the language abilities of minimally speaking autistic children (Kasari et al., 2013a). A natural language sample involves the recording, transcription, and coding of a natural interaction for language and/or social communication variables of interest. A natural language sample offers a flexible method capable of capturing robust information on the communication and language abilities of a minimally speaking autistic child.

As was done in Chapter 1, Kasari et al. (2014), and La Valle et al. (2024a, 2024b), natural language sample transcription and coding protocols were adapted to include non-spoken methods such as augmentative and alternative communication system use. Furthermore, the natural language sample elicitation protocol, Eliciting Language Samples for Analysis (ELSA) was specifically developed for autistic children and youth who have a range of spoken language abilities, including those who have limited spoken language abilities (Barokova et al., 2021). With that said, the natural language sample process is time-intensive and requires specialized training and supervision. Furthermore, they provide only a snapshot in time and can leave out valuable first-hand information from familiar informants such as the child's caregiver.

Currently, there are caregiver report measures appropriate for use with minimally speaking autistic children such as the Low Verbal Investigator Survey (LVIS; Naples et al., 2022), the Communication Matrix (Rowland, 2008), and the Observed Reported Communication Ability measure (ORCA; Reeve et al., 2020). Importantly, these measures enable caregivers to report on their child's communicative abilities across both spoken and non-spoken modalities, including augmentative and alternative communication. These measures provide valuable information on the child's overall communicative and language capacities, but they do not provide in-depth information on specific language domains such as expressive vocabulary.

The importance of vocabulary selection for early symbolic AAC users is often highlighted in the literature (Bean et al., 2019; Fallon et al., 2001; Laubscher & Light, 2020). However, AAC intervention studies with autistic children focus mostly on tracking outcomes related to the communicative function of requesting (e.g., how many times does the child use their AAC system to make a request?) and often neglect outcomes tracking related to vocabulary acquisition (e.g., how many different AAC symbols does the child use?) (Syriopoulou-Delli & Eleni, 2022). Though learning how to use AAC for basic communicative functions such as requesting is important, it is critical that we also track vocabulary outcomes so autistic children who use AAC can learn to communicate flexibly and become full-fledged communicators who use a diversity of AAC symbols to communicate a variety of communicative functions, such as requesting, question asking, and commenting.

In a meta-analysis, O'Neill et al. (2018) examined the effects of aided AAC interventions on the communication (including vocabulary) abilities of people with

developmental disabilities including autism. Interventions that used AAC had strong positive effects in increasing expressive and receptive vocabulary (e.g., the number of different symbols used and understood) across both spoken and non-spoken modalities. For example, Kasari et al. (2014) found that adding an AAC device to naturalistic developmental behavioural intervention (NDBI) sessions with autistic children with limited spoken language abilities significantly increased the total number of different words[31] they produced, in comparison to the NDBI session that did not use an AAC device. Similarly, Romski et al. (2010) demonstrated that children with developmental disabilities produced a significantly higher total number of different words[32] in two AAC intervention conditions in comparison to a spoken language-only intervention condition.

Overall, these findings suggest that vocabulary production does increase in individuals with complex communication needs following AAC intervention, highlighting the value of tracking vocabulary outcomes in minimally speaking autistic children.

Vocabulary production can be tracked via direct observation using natural language sampling (as we did in Chapter 1), but no existing measure allows for detailed caregiver report of their child's spoken as well as non-spoken vocabulary expression. Therefore, the AAC-modified CDI: Words and Gestures (MacDonald-Prégent & Nadig, 2024) was created through basic modifications of the CDI: Words and Gestures (Marchman et al., 2023). Please see **Table 1** for a summary of all assessment tools properly adapted for use with minimally speaking autistic children.

[31] Combined total of different spoken words and AAC symbols used.
[32]Combined total of different spoken words and AAC symbols used.

General Conclusion

This thesis contributes to the Augmentative and Alternative Communication (AAC) intervention and language assessment tools knowledge base for minimally speaking autistic children. In Chapter 1, we found that both caregiver-implemented aided AAC interventions (i.e., a naturalistic developmental behavioural AAC intervention that used a consistent-symbol location design and a modified version of Picture Exchange Communication System) significantly increased AAC use in minimally speaking autistic children who were not yet using AAC consistently or independently. Furthermore, our findings indicate that caregivers in the naturalistic developmental behavioural AAC intervention condition mastered their intervention more quickly than the caregivers implementing the modified version of Picture Exchange Communication System.

The findings from Chapter 1 enhance our understanding of AAC display design strategies (i.e., consistent- versus variable-symbol location design) and imply that at this early stage of AAC use, aided AAC interventions that use a consistent- or variable-symbol location both increase AAC use to a similar degree. However, as this was the first study to test this contrast in the context of an AAC intervention with children with complex communication needs, specifically minimally speaking autistic children, more research is needed to confirm this conclusion.

Importantly, our findings from Chapter 1 indicate that when delivered by caregivers who were coached remotely via telehealth, an aided AAC intervention that uses a naturalistic developmental behavioural approach (versus one that uses a behavioural methodology such as Picture Exchange Communication System) might be easier for

caregivers to learn. Given that some research indicates that higher communication skills are associated with lower caregiver stress in minimally speaking autistic children (Suswaram et al., 2024), there is likely a lot of value in training caregivers to implement strategies that can be quickly and easily incorporated into their daily lives.

More broadly, the findings from Chapter 1 add to the literature on caregiver-implemented AAC interventions by demonstrating the effectiveness of both intervention approaches. Notably, there are only a few empirical studies (Elmquist et al., 2023) on caregiver-implemented AAC interventions that use a naturalistic developmental behavioural approach, so this is an important addition to the literature.

In Chapter 2, we tested the value of modifying the MacArthur-Bates Communicative Development Inventory: Words and Gestures (Marchman et al., 2023) to make it capable of capturing the full range of this autistic subgroup's communicative repertoire, including AAC use. The Augmentative and Alternative Communication - Modified Communicative Development Inventory: Words and Gestures (MacDonald-Prégent & Nadig, 2024) allowed us to more comprehensively capture the capacity of minimally speaking children's expressive vocabulary. Accounting for all methods of communication had a large effect size, significantly increasing participants' expressive vocabulary size, particularly for those with fewer than 50 reported spoken words.

By using this modified assessment tool, we were able to profile the lexical composition of our sample. Prior work has shown that minimally speaking autistic children's spoken vocabulary was prominent in verbs, that contained proportionally more verbs than that of vocabulary-matched typically developing children. However, in our sample, we did

not find verb prominence or over representation of verbs. We found that the proportion of nouns (approximately 50 percent) and verbs (approximately 13 percent) was in line with that reported elsewhere for typically developing children who have productive vocabularies of a similar size (Bates et al., 1994).

These findings support the use of strengths-based adaptations to vocabulary assessment in both research and clinical practice. By accounting for non-spoken expression, clinicians can conduct more comprehensive assessments of their client's abilities and needs, and researchers can better characterize the potentially different language development of minimally speaking autistic children.

Table 1. *Assessment Tools That Capture Information on Spoken and Non-Spoken Modalities Adapted for Use with Minimally Speaking Autistic Children*

Name	Method Used	Domain(s) Assessed	Main Strength	Main Weakness
Language Samples[ab]	Transcription of directly observed language and communicative behaviours in natural contexts	-Social Communication (e.g., number of communicative turns, etc.) -Expressive Language (e.g., MLU[c], NDW[d], etc.)	Highly adaptable methodology that collects robust data that can be analyzed for several different expressive language and communication variables	Time and resource intensive
Communication Matrix[e]	Questionnaire filled out by caregiver or teacher	-Social communication (intentional communication, interactions with others)	Generates a one-page summary "matrix" of child's intentional communication	Does not collect information on receptive language
Observed Reported Communication Ability measure[f]	Questionnaire filled out by caregiver	-Social communication (intentional communication, interactions with others) -Expressive language (e.g., approx. of MLU[c], total vocabulary) -Receptive language (e.g., understanding of basic instructions)	Samples many relevant areas related to the social communication and language for early communicators	Does not provide in-depth information
Low Verbal Investigator Survey[g]	Questionnaire filled out by caregiver	-Social communication, expressive and receptive, speech production, and reading	Succinct one page form that takes five minutes (or less) to fill out	Does not provide in-depth information
AAC-modified Communicative Development Inventory: Words and Gestures[h]	Questionnaire filled out by caregiver	-Expressive language: vocabulary -Receptive Language: vocabulary, basic phrases -Surveys child's imitation skills, use of early gestures, engagement in games and routines, etc.	Generates a comprehensive inventory of vocabulary that is used and understood	Does not collect information on intentionality of expressive language

Note. a) The Eliciting Language Samples for Analysis protocol (ELSA; Barokova et al., 2021) can be used as a standardized method of eliciting the language sample. b) measure citation = see methods section of Kasari et al. (2014), La Valle et al. (2024a, 2024b), and Chapter 1, c) MLU = mean length of utterance, d) DRW = different number of words, e) measure citation = Rowland (2008), f) measure citation = Reeve et al. (2020), g) measure citation = Naples et al. (2022), h) measure citation = MacDonald-Prégent & Nadig (2024

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