ASSESSING LANGUAGE AND COMMUNICATION SKILLS OF YOUNG CHILDREN WITH COMPLEX COMMUNICATION NEEDS

By

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ABSTRACT

Background. Accurate and meaningful assessment of language and communication skills to monitor child progress is the cornerstone to appropriate intervention for children with complex communication needs (CCN; Brady et al., 2016; Rowland et al., 2012). Despite this need, there is a lack of high quality and validated measurement of young children with CCN who are beginning communicators and have heterogeneous underlying etiology.

Research Aims. This dissertation aims to understand the measurement of language and communication skills for children with CCN who use AAC through a scoping review. Specific research aims include: (a) describe what measures have been used, who were measured, and what language and communication skills were measured; (b) summarize how the identified measures measured language and communication skills of children with CCN; (c) identify reliability and validity evidence for these measures in children with CCN.

Methods. This study employed a scoping review approach (Tricco et al., 2018). The systematic search and screening on four databases included a total of 282 studies published in peer-reviewed journals.

Results. A total of 65 published measures were identified from this review. Existing studies that measured language and communication skills of children with CCN heavily depended on self-developed measures and published measures that do not have any validity evidence within children with CCN. Diagnoses of participants included a broad range; however, children with cerebral palsy were under-represented in single case design (SCD) studies. This study found existing studies primarily measured expressive aspects of language and communication skills, with only a few studies measuring receptive skills. Domain specific skills included pragmatics (84% of studies), semantics (52%), syntax (38%), and morphology (26%).

Additionally, 7% of studies reported measuring AAC related operational skills and AAC symbol recognition skills. This study provides tree-maps summarizing how existing measures measured these domain specific skills. In terms of reliability evidence, most previous studies provided sufficient reliability evidence for self-developed measures; however, only 10 out of 65 published measures reported reliability evidence within children with CCN. Only 15 out of 65 published measures reported validity evidence for children with CCN with a primary focus on convergent validity and children with cerebral palsy.

Conclusions. This study highlights the needs to measure receptive language skills and linguistic complexity, and to consider the influence of AAC related skills in future measures and interventions. Existing measures that showed validity evidence should be further tested with validity evidence from (a) other sources, such as content validity and construct validity, and (b) children with different etiologies in addition to cerebral palsy. Testing stimuli identified from the tree map could be explored in future tests and semi-structured observational measures.

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CHAPTER 1: INTRODUCTION AND REVIEW

Language and communication skills are important for children with complex communication needs (CCN) who use augmentative and alternative communication (AAC) systems to maximize their learning opportunities, build relationships, and engage in meaningful activities (Light & McNaughton, 2012; Mandak et al., 2018; O'Neill & Wilkinson, 2020). In the last two decades, there has been a proliferation of studies exploring intervention effects on language and communication outcomes of young children who have CCN. Accurate and meaningful assessment of language and communication skills to monitor child progress is the cornerstone to appropriate intervention for children with CCN (Brady et al., 2016; Rowland, 2011). However, measuring language and communication skills is especially difficult for young children with CCN who use multiple modes of communication and are often beginning communicators. Additionally, there is a lack of agreement on what language and communication skills should be monitored and how to measure these skills for children with CCN who use AAC systems. The purpose of this dissertation is to understand what should be measured and how to measure language and communication skills of beginning communicators who have CCN. Chapter one presents a review of literature that provides background information on the following areas: (a) children with CCN who use AAC, (b) theoretical background of language and communication skills of children with CCN, and (c) measuring language and communication skills of children with CCN.

Children with CCN Who Use AAC Systems

Children with CCN constitute a heterogeneous population with different etiologies and varied language skills (Lund et al., 2017; Rowland, 2011). As a result, the challenges these children face related to speech have wide variance in severity and length (Light, McNaughton, Beukelman, et al., 2019). Moreover, the verbal language difficulties they experience may also be accompanied by social communication, receptive language, cognitive, and/or motor speech difficulties (Lund et al., 2017; Romski & Sevcik, 1996; 2003; Van Balkom & Verhoeven, 2010). Such difficulties make it challenging for children with CCN to participate in meaningful social and academic activities, which in turn limit their opportunities to further develop communication and language skills (Lund et al., 2017).

Due to their limited speech, children with CCN often communicate through multiple modalities including gestures, objects, vocalizations, signs, picture symbols, speech-generating devices, and others (Quinn et al., 2021; Sennott et al., 2016). These communication modalities that can replace or supplement speech (and/or writing) for children to communicate are called augmentative and alternative communication (AAC, Barker et al., 2013; Beukelman & Light, 2020; Light, McNaughton, & Caron, 2019). AAC systems include unaided (e.g., gestures, sign language) and aided systems (e.g., picture-based communication boards, speech generating devices).

AAC systems vary greatly in their complexity, linguistic functions, symbol design, and operational systems (Light, McNaughton & Caron, 2019). Symbol representation includes line-drawing, picture-based, and ideographic symbols (Lin & Chen, 2018). Additionally, AAC systems can be operated through direct selection, such as touching with a finger, as well as eye movement to meet different needs. Some AAC systems may only accommodate the inclusion of a small number of symbols on a single page with limited selection, while others support more symbol storage and allow multiple symbol selection from various pages. As described by Light (1989), the ultimate goal of using AAC is to meet the individual's needs and communication with efficiency (Light, 1989; Woll & Barnett, 1998). To achieve this goal, more advanced AAC technologies were developed to support flexible symbol addition with grammatical features or writing functions that allow children to create more complex sentences and communicate with more accuracy.

In the U.S., approximately 12% of children in early childhood special education settings have CCN and would benefit from the use of AAC systems (Binger & Light, 2006). The number of children who can benefit from AAC systems is continuously increasing with higher prevalence of developmental disabilities (Boyle et al., 2011), increased survival rate of children with severe disabilities (Light & McNaughton, 2012), and advances in AAC technologies that can benefit an expanded range of children with disabilities (Light et al., 2019).

To date, a robust number of studies have shown that AAC systems could be effective to help children meet their communication needs. Specifically, the use of aided AAC modeling along with other interactive intervention strategies (e.g., creating a communication opportunity, wait for a response, prompt, respond to communication; Douglas et al., 2022; Beukelman & Light, 2020) are effective in supporting language, communication, and literacy skills of children with CCN (Ganz et al., 2012; Machalicek et al., 2010; Therrien et al., 2016). However, the outcomes are often limited to single symbol communication, production, or comprehension with a limited range of vocabulary. Such limitation is partly because of the lack of measurement systems that could accurately represent language and communication skills of children who use aided AAC systems. An accurate language and communication assessment that provides comprehensive and clear depiction of what the emerging aided communicator can do is essential to better understand the process of language acquisition, provide better intervention planning, and expand learning outcomes (Batorowicz et al., 2018; Chen et al., 2009; Lloyd et al., 1997; Rowland, 2005; 2011).

Language and Communication Skills: Theoretical Frameworks

In this section, I first define language (Chomsky, 1957; Honig, 2007; Wing, 1982) and communication skills (Bernstein & Tiegerman-Farber, 2009; Owens, 2016; Sperber & Wilson, 1986). Then I introduce the communicative competence model that integrates both language and communication skills specific to children with CCN (Light & McNaughton, 2014).

Language and Communication Skills: Use, Content, and Form

The terms language and communication are often used interchangeably in practice (Bernstein & Tiegerman-Farber, 2009) and literature (Landa, 2005) given the many commonalities. In fact, language and communication are interrelated yet distinct concepts (Frith & Happe, 1994). Careful definition of these terms is essential to measure content validity - ensuring the behavior being measured is a true reflection of the construct of interest (AERA, APA, & NCME, 2014).

Language is a rule-governed system (Chomsky, 1957) that includes both receptive (i.e., comprehension) and expressive (i.e., expression) use of spoken, written, and other communication symbol systems (American Speech-Language-Hearing Association, ASHA, n.d.; Honig, 2007; Wing, 1982). The comprehension and expression of language consists of five subdomains: pragmatics, semantics, phonology, syntax, and morphology (Bernstein & Tiegerman-Farber, 2009; Bloom & Lahey, 1989; Smith, 2015; Wing, 1982). Specific definitions and descriptions of the five domains will be discussed in the following section. According to Bloom and Lahey (1989), the pragmatic domain concerns language ***use*** in social contexts; the semantic domain concerns language ***content***; and the syntax, morphology, and phonology domains concern language ***form***.

Communication is the process by which individuals exchange information and convey ideas (Bernstein & Tiegerman-Farber, 2009; Frith & Happe, 1994; Owens, 2016; Sperber & Wilson, 1986). This process involves a sender who encodes (i.e., formulates) a message and a receiver who decodes (i.e., comprehends) the message (Bernstein & Tiegerman-Farber, 2009). From a social pragmatic approach, communication is a social behavior (Rowland, 2011) that can be accomplished using both language systems (e.g., oral, written, and augmented language) and non-formal language systems, such as gestures, signs, eye gaze, objects, and so on (Bernstein & Tiegerman-Farber, 2009; Light, 2003; Frith & Happe, 1994). One needs to acquire language skills (i.e., receptive and expressive knowledge of language ***form*** and ***content***) as well as communication skills (i.e., being able to ***use*** language content and form and nonlinguistic modes in social context) in order to communicate effectively. Therefore, this study conceptualizes language skills as skills related to form and content aspects of language, and conceptualizes communication skills as pragmatic skills which emphasize the use aspects of language along with non-linguistic modes in social situations.

Use: Pragmatics

Pragmatics refers to rules that govern the use of language along with non-linguistic behaviors in social contexts for the purpose of communication (Iacono, 2003; Roberts et al., 2007). Pragmatics skills are also called ***pragmatic communication skills*** or ***social communication skills*** (Dillon et al., 2021; Prutting, 1982; Turkstra et al., 1996). Therefore, I conceptualize pragmatic skills as communication skills in this study. Pragmatics comprise a number of subdomains reflecting communicative skills (Toppelberg & Shapiro, 2000), including the reasons for communicating (also called communicative functions or communicative intentions, such as requesting, calling, commenting, teasing, informing), the choice of expressions, and rules of conversation/discourse (e.g., turn-taking nature of conversation, eye contact; Bernstein & Tiegerman-Farber, 2009; Bloom & Lahey, 1978; Landa 2005). Some children with CCN may have disabilities that impact social interactional skills (e.g., ASD), which in turn impacts their ability to receive social cues of communication, demonstrate eye contact with communication partners, and respond to communication turns (Frith & Happe, 1994; Lord et al., 2020). Research has demonstrated that children with CCN can fulfill a wide range of communication functions using multiple modalities in addition to language modes (Smith, 2015). When measuring communication skills in children with CCN in intervention studies, communication skills are often measured as communicative acts that include multiple modes of communication (e.g., Douglas et al., under review) and requesting skills (e.g., Ganz & Simpson, 2004). Recently, many studies have used a comprehensive measure, the Communication Matrix (Rowland, 2011), to document the expressive communication skills of children with CCN. The Communication Matrix is an indirect measure (i.e., completed by someone who is familiar with the child) that includes developmental levels of communication, purposes for communicating, communicative functions, and modes of communication.

Content: Semantics/Lexicons

Semantics refers to the meaning of words, sentences, and the links that connect the words (Bernstein & Tiegerman-Farber, 2009), including skills such as vocabulary knowledge (i.e., the words that individual has for language comprehension and production). Lexicon refers to the set of vocabulary words of language an individual has (Bernstein & Tiegerman-Farber, 2009; Nelson, 1992). For children who use AAC, lexical proficiency requires understanding the relation among spoken words, symbols, words or symbol meaning, and their referents (Bernstein & Tiegerman-Farber, 2009; Smith, 2015). Additionally, children's understanding of words depends highly on the context and their AAC systems. Children who use AAC systems often find it difficult to build lexical knowledge due to restrictions within many AAC systems (Light, McNaughton, & Caron, 2019), such as the limited number of words and symbols. Previous studies measuring children's semantic knowledge often include receptive (e.g., Vandereet et al., 2010) or expressive (e.g., Soto & Dukhovny, 2008) vocabulary knowledge in both spoken words and AAC symbols. However, since children who use AAC may use limited symbols to represent extended meaning, measuring semantic knowledge through expressive language tasks may not be accurate (Blockberger & Sutton, 2003). Furthermore, children's understanding of a certain word in one familiar AAC system may not be demonstrated the same way when using another system (Nelson, 1992), which makes measuring semantic and lexical skills even more difficult.

Form: Phonology

Phonology refers to the organization and patterning of the sounds of a language (Whitehead, 2007). Therefore, phonology is specific to spoken language (Honig, 2007). Skills related to phonology include phonological awareness (i.e., the ability to recognize, discriminate, and manipulate the sound units of spoken language; Hart et al., 2007; Larsson et al., 2008) and phoneme awareness (i.e., the ability to attend to and manipulate individual sounds of words; Ehri et al., 2001; Hart et al., 2007), which are essential skills that can assist the learning of reading and writing (Nelson, 1992). Children with CCN who have limited speech have difficulties producing or manipulating sounds of a language and may therefore be at risk for phonological awareness impairment (Light, McNaughton, Beukelman, et al., 2019; Hart et al., 2007). Despite only limited attention given to phonological aspects of language for children with CCN, research has demonstrated that children with severe speech impairments can develop phonological awareness skills (Card & Dodd, 2006; Light & Kent-Walsh, 2003). However, these children may have difficulties in applying phonological knowledge to reading and spelling tasks (Hart et al., 2007). To date, the nature of how children who use AAC develop phonological knowledge and how phonological awareness skills support later reading and writing remains unclear (Erickson & Clendon, 2005). Additionally, since children with CCN have limited access to speech, traditional phonological awareness measures that require speech responses are not appropriate to reflect phonological awareness skills of children with CCN. There are recently developed measures of phonological awareness skills adapted to meet the needs of children who have limited speech (e.g., Skibbe et al., 2020).

Form: Syntax

Syntax refers to grammatical and sentence structures of language (Bernstein & Tiegerman-Farber, 2009; Nelson, 1992). Common syntactic knowledge includes understanding and using the proper order of words (e.g., "I want to eat a sandwich" vs. "I want to sandwich eat") and different sentence structures (e.g., "I want to eat a sandwich" vs. "Can I have a sandwich?") to express meanings. Research has demonstrated that children with CCN from 2 to 7 years old have the ability to combine multiple graphic symbols to communicate (Binger et al., 2010; 2017). However, children who use AAC systems often omit key words and modify word orders when communicating (Smith & Grove, 2003; Nelson, 1992). AAC systems are often limited to primarily nouns and verbs (Banajee et al., 2003; Dark & Balandin, 2007), which constrains the users' ability to compose complete sentences with diverse syntactic structures (Sutton et al., 2002; Mngomezulu et al., 2019). Additionally, because of the additional time it takes to send messages using AAC, children may use incomplete sentences or simplified phrases as long as they can convey their needs (Smith, 2015). Given the limits in AAC systems and the goal of production efficiency, a child's symbol production that does not conform to spoken language syntactic features cannot be seen as a reflection of their limited syntactic competence (Blockberger & Sutton, 2003; Sutton & Morford, 1998). There is preliminary evidence suggesting that measures of syntactic skills using expressive methods may be valid using the dynamic measurement approach (King et al., 2015).

Form: Morphology

Morphology refers to the rules that govern word formation (i.e., internal structure of words and how they are constructed from morphemes; Bernstein & Tiegerman-Farber, 2009). Morphemes are the smallest linguistic units with meaning (Nelson, 1992; Bernstein & Tiegerman-Farber, 2009), including features such as prefixes, suffixes, verb tense endings, and plurals. There is some evidence that children with CCN are likely to face challenges in the acquisition of inflectional morphology (i.e., word endings that fulfill a grammatical role, e.g., cat vs. cats) and there is not yet evidence on derivational morphology (i.e., morphemes that modify meaning, e.g., sad vs. sadness; Blockberger and Johnston, 2003; Sutton & Morford, 1998; Binger & Light, 2008). Blockberger and Johnston (2003) found that children who use AAC made more errors in grammatical judgement tasks compared to their peers with language delay. Despite advances in AAC technologies that support morphology functions, children who use AAC systems often have limited access to and develop limited morphological skills. Additionally, many phrases with morphological features in AAC systems are preprogrammed with the desire to help preliterate children express ideas quickly and efficiently. Children may have few opportunities to adjust or manipulate these morphemes according to the communication context (Blockberger & Johnston, 2003). As with syntax, there are limited studies exploring intervention and measurement targeting morphology aspects of language skills (Binger & Light, 2008).

Expanding Language and Communication Skills: Communicative Competence Model

For children with CCN who use AAC systems, mastery of language and communication skills may not be sufficient for them to become competent communicators. Light (1989) proposed the original communicative competence model, which was expanded and updated twice (Light, 2003, Light & McNaughton, 2014). According to Light and McNaughton (2014). Communicative competence is a relative and dynamic interpersonal construct that includes both intrinsic and extrinsic factors that impact the attainment of communicative competence of an individual who uses AAC. First, communicative competence rests on the intrinsic characteristics of an individual with CCN that include knowledge, judgment, and skill in four related areas: (a) linguistic competence, (b) operational competence, (c) social competence, (d) strategic competence (defined in the next section). Second, the attainment of linguistic competence, operational competence, social competence, and strategic competence will be affected by a variety of intrinsic psychosocial factors, including motivation, attitudes, confidence and resilience. Third, communication competence is context dependent and influenced by extrinsic environmental supports (e.g., policy, practice, attitude, knowledge, skills).

Knowledge, Judgment, and Skill in Four Areas

Linguistic Competence. Linguistic competence refers to knowledge and understanding of spoken and AAC language, which was discussed in the 5-domain language skills. Linguistic competence includes language skills related to language form and content mentioned above. For children with CCN, understanding and being able to use basic language skills is fundamental for their communicative competence (Light & McNaughton, 2014). As mentioned earlier, the measurement of linguistic competence may not be accurately reflected by expressive tasks.

Instead, receptive tasks may be more effective for accurate representation of children's linguistic competence (Light, 2003).

Operational Competence. Operational competence refers to the ability to produce, navigate, operate, and maintain the aided and unaided AAC accurately and efficiently to support communicative competence. For example, operational competence includes a child's understanding about the need to pick up a symbol and hand it to a communication partner to complete a communication turn when using the Picture Exchange Communication System (PECS; Frost & Bondy, 2002) to communicate. A child's operational competence may vary across AAC systems. Children may find navigating from page to page difficult when using picture exchange books (Borg et al., 2015), or using a complex or unfamiliar system (Thistle & Wilkinson, 2013). For example, recent research indicates that visual scene displays may make it easier for children to locate symbols compared to grid-displays, thus increasing operational competence (Beukelman et al., 2014). Additionally, children who have not yet developed operational competence for a specific AAC system may not be able to identify vocabulary words that they need when communicating. Therefore, when measuring a child's language and communication skills, the AAC system used during the assessment may influence performance due to types of AAC and the child's familiarity to this AAC system.

Social Competence. Social competence refers to the ability to communicate during social situations. There are two types of social skills: sociolinguistic skills and social relational skills. According to Light and McNaughton (2014), sociolinguistic skills are pragmatic skills, which were mentioned in the previous section and include discourse strategies (e.g., taking turns) and communicative functions (e.g., request for objects, request for attention, or response to questions). Social relational skills include interpersonal skills for participating in interactions with the aim of building positive relationships with multiple partners. As mentioned earlier, pragmatic skills are often targeted in intervention studies and measured using both observational measures and indirect measures (e.g., Communication Matrix, Rowland, 2011). Despite the important influence of social relational skills on a child's communicative competence, it is not currently directly assessable using observational measures.

Strategic Competence. Strategic competence refers to adaptive strategies that are required to overcome barriers in the environment and confront limitations in linguistic, operational, and social competence. Strategic competence helps the child to be understood despite limitations. For example, a child may use strategies like using multiple modes of communication, directing communication partners, or requesting additional vocabulary from the communication partner to communicate. Children's strategic competence may be influenced by their age, experience, environment, and communication partners' support. Even though strategic competence is an important consideration, there are not yet measures quantifying or summarizing strategic competence because it appears to be highly dependent on the context in which communication is occurring.

Psychosocial Factors

In addition to the child's intrinsic skills in the four areas that reflect the child's communicative competence, psychosocial factors may also influence the attainment of communicative competence. These psychosocial factors include motivation to communicate, attitude toward AAC, communicative confidence, and resilience of the child (Light & McNaughton, 2014; Light, 2003). To evaluate communicative competence of children with CCN, psychosocial factors may need to be taken into consideration. For example, children may be more motivated to communicate when they are engaged in their favorite activities (Douglas et al., 2013). Therefore, the child's communicative performance in a motivating activity (e.g., the child's favorite activity) may be different from the performance during a less interesting activity. Some of these psychosocial factors may be short term and highly dependent on the situation, such as motivation and communicative confidence; others may be long term, such as attitude to AAC and resilience. To accurately capture a child's overall language and communication skills it is important to consider short term psychosocial factors that may cause performance differences.

Environmental Supports and Barriers

In addition to intrinsic factors, communicative competence is also influenced by extrinsic factors from the environment including policy, public service, societal attitudes toward AAC, and communication partner's knowledge and skills about supporting communication interactions and AAC (Light & McNaughton, 2014). First, the broader environment including policies and available services may influence whether children with CCN are supported with AAC and are able to use AAC in school and public areas. For example, when AAC services are not well designed to support children from culturally and linguistically diverse backgrounds, there will be a lack of appropriate AAC access to children from culturally and linguistically diverse backgrounds in their everyday environments (Soto, 2012). However, such broad environmental factors and their impact on performance in a specific task are difficult to measure and evaluate. A child's communicative competence can also be influenced by communication partners from their immediate environment. Communication is a reciprocal process that involves the child's interaction with a communication partner (Bernstein & Tiegerman-Farber, 2009). An experienced partner may help assist the child to communicate better by providing lots of communication opportunities, waiting for the child's response, and help allocating symbols from their AAC systems. To assess a child's communicative competence, it is important to take the partner's skills and behaviors into consideration. In standardized measures, communication partner behaviors are well controlled. In observational measures used in intervention studies, the changes in child behaviors may reflect both the child's communication growth and the partner's skills. Some observational measures attempt to control for communication partner behavior by reporting rates rather than how many times a behavior occurs, such as the rate of child communicative responses to communication opportunities provided by the communication partner.

Summary of the Theoretical Frameworks

Theoretical frameworks inform the present study by revealing what aspects of language and communication skills were measured and how existing measures evaluate the language and communication skills of children with CCN. Furthermore, use of frameworks can help identify gaps in the literature and future measurement needs. Terminologies used in describing language and communication skills of children with CCN vary across theoretical frameworks. Therefore, clear definitions and theory-driven conceptualizations are necessary in guiding accurate understanding of what skills were measured.

Figure 1.1 Theoretical Frameworks for Language and Communication Skills of Children with CCN

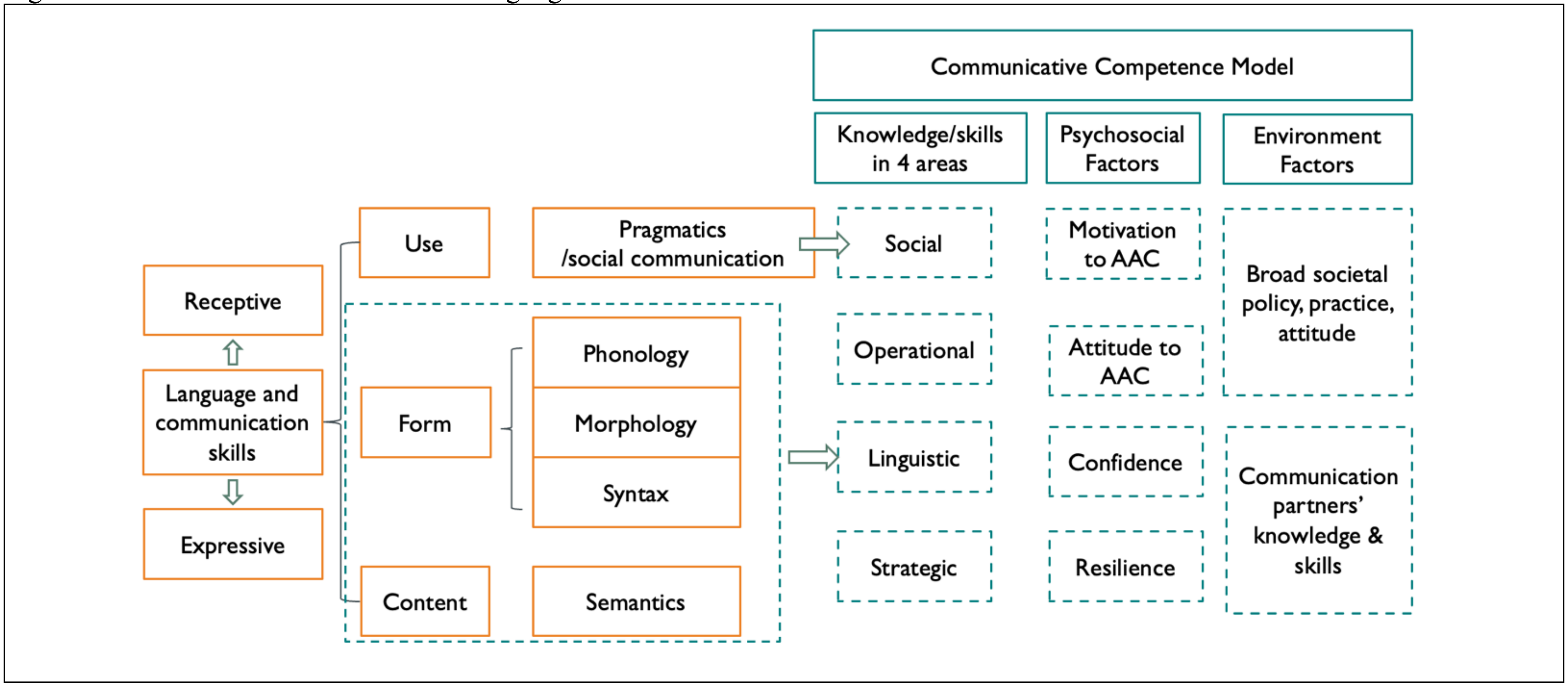


Figure 1.1 integrates the theoretical frameworks discussed previously. Each of the three theories discussed have shared agreement that language skills should be conceptualized as skills related to form and content aspects of spoken or augmented language. Being able to understand and produce language does not necessarily ensure effective use of language in a social context (i.e., communication skills). To achieve communication skills, one not only needs to understand the form and content of language, but also demonstrate social pragmatic skills such as reading the environment, understanding communication cues, demonstrating eye contact, and understanding the rule of politeness. Language and communication skills can be measured as the overall level of language or communication skills; or can be measured as domain specific skills such as vocabulary knowledge, grammatical knowledge, and communicative functions; or it can also be measured as more specific behaviors, such as mean length of utterance and the number of communicative acts.

In addition to knowledge and skills in language and communication (i.e., linguistic competence and pragmatic competence), the communicative competence model (Light & McNaughton, 2014) identified additional intrinsic and extrinsic factors that might influence communicative competence of children with CCN, including: operational competence, social (interpersonal) competence, strategic competence, psychosocial factors (e.g., confidence, motivation), public environmental factors and communication partners factors. As discussed earlier, many of these factors are context-dependent and could produce short-term influence on the child’s language and communication performance. Therefore, these factors should be carefully addressed in the measure of language and communication skills of children with CCN.

Measuring Language and Communication Skills of Children with CCN

Measurement refers to the process of quantifying attributes of interest (i.e., language and communication skills in the context of this study; Bakeman & Quera, 2011; Snyder et al., 2013; Walford et al., 2010). Comprehensive and accurate measurement of language and communication skills is critical to (a) intervention planning, (b) the provision of services to individuals with complex communication needs, and (c) to determine intervention effects (Binger et al 2012; Johnson et al., 2006; Theodorou & Pampoulou, 2022). Due to the heterogeneity of children who use AAC, learning and development may be influenced by variations in motor, speech, social communicational, and cognitive difficulties (Batorowicz et al., 2015; von Tetzchner, 2018). Therefore, traditional methods of language and communication measures are less appropriate and valid for children with CCN and need accommodations to meet these heterogeneous needs. This makes comprehensive assessment of language and communication skills for children with CCN difficult and less common (Batorowicz et al., 2018; Geytenbeek et al.,2010; Yin Foo et al., 2013).

There is no gold-standard method for assessing the language and communication skills of children with CCN. Many approaches have been used, typically within one of 3 different broad methods: (1) indirect assessment, (2) standardized tests that were originally designed for typically developing children, and (3) observational measurement systems. I provide an overview of each type of assessment and identify research gaps.

Indirect Assessment

Indirect assessment refers to a measurement that is completed by someone who is familiar with the child such as a teacher, parent or other caregiver. Indirect assessments can include interviews, questionnaires, checklists, etc. For children with CCN indirect assessments can be informal, such as gathering the size of the child's vocabulary from a brief interview, or formal using measures such as the MacArthur-Bates communicative development inventories (Fenson, 2007), the Vineland Adaptive Behavior Scale-Second Edition (Sparrow et al., 2005), or the Communication Matrix (Rowland, 2011). Indirect assessment is especially useful in applied settings since it is less time consuming compared to direct standardized tests or observational measures. However, when the behavior of interest is within social situations (e.g., child's language response to a particular intervention strategy or communicative functions), indirect assessments may be less accurate than direct observation (Yoder et al., 2018).

Standardized Tests

Standardized tests present assessment items in a uniform way with the assessor recording the child's response to each item (Snyder et al., 2013). Standardized tests have been used to measure language and/or communication skills of children with CCN (e.g., Thiemann-Bourque et al., 2018; Yoder & Stone, 2006). Some studies use measurements that directly target language or communication skills, but were originally designed for typically developing children; examples include: Preschool Language Scale-Fifth Edition (PLS-5, Zimmerman et al., 2011), Clinical Evaluation of Language Fundamentals-Preschool, 2nd Edition (CELF Preschool-2, Wiig et al., 2004), and Peabody Picture Vocabulary Test (PPVT-3, Dunn & Dunn, 1997; PPVT-4, Dunn & Dunn, 2007). Other standardized assessments focus on development broadly, but include domains focused on communication, such as the Mullen Scales of Early Learning (MSEL; Mullen, 1995).

It is critical to recognize that most standardized assessments were not designed for children with CCN who use AAC systems and may be problematic to administer with young children with CCN (Ross & Cress, 2006). Many standardized assessments require verbal responses from the child, which is not ideal for children with CCN who have limited verbal language skills. Additionally, the administration procedures are designed for typically developing children and may take too long for children with CCN who often have shorter attention spans and take longer to complete the assessment. Accommodations to these standardized measures must be applied in order to ensure accurate measurement of language and communication skills in children with CCN. Such accommodations can impact the standardized nature of these measures, and therefore may not be reliable and valid. Therefore, it is important to review what existing measures were used, what adaptations were provided, and if reliability and validity evidence exists for children with CCN.

Observational Measurement

Observational measurement is a systematic approach to detect, quantify, and interpret behavior by assigning behaviors to codes or a rating based on a predetermined coding manual (Girard & Cohn, 2016; Bakeman & Quera, 2011). Systematic observational measures use trained observers to make quantitative judgments about behaviors of interest according to observational coding systems (Girard & Cohn, 2016).

Observational measurement systems have been used in a variety of ways within studies targeting language and communication skills of children with CCN. Some studies used observational measures to provide direct counts of communicative acts, such as the number of requests, responses, picture exchanges, and verbal utterances in line with the learning targets of each study (e.g., Douglas et al., under review; Simpson & Keen, 2010; Fleury & Schwartz, 2017). Other studies systematically reported children's language use during a session through language sampling analysis with the function of each communicative act noted (e.g., requesting, responding, number of different words; Peredo et al., 2018), or recorded the rate of trial-based behavior (e.g., examiner prompted the child: "show me [bear]" 10 times per trial while the number times the child correctly pointed to the [bear] was recorded; Lane et al., 2016).

Observational measurement systems must have evidence of validity in order to identify evidence-based practices that support language and communication skills of children with CCN (Cooper et al., 2020; Horner et al., 2005). Additionally, as indicated earlier, existing intervention studies have reported a variety of behaviors or subskills of language and communication skills of children with CCN, and little consensus exists related to what language and communication behaviors should be measured and how to best measure these skills. The heterogeneity of study outcomes offers challenges in comparing and summarizing intervention effects using methods such as meta-analysis.

Rationale

Despite the need for a comprehensive and accurate measurement system assessing language and communication skills for children who use AAC, there is a dearth of high quality, validated measures targeting children with CCN (Batorowicz et al., 2018; Quinn et al., 2021). Additionally, there is little consensus on what should be measured and what measures should be used. To develop a comprehensive and accurate measurement system, it is essential to understand what measures have been used, how the measures have assessed language and communication skills, and what limitations exist within measures. Summarizing the state of knowledge related to language and communication measurements for children with CCN who use AAC can help inform both AAC research and practice about what aspects of language and communication skills should be measured and how to measure these skills. Thus, this dissertation aims to understand the measurement of language and communication skills for children with CCN who use AAC through a systematic scoping review. Specific research questions are listed below.

Goals and Research Questions

This study will use a scoping review approach (Munn et al., 2018) to summarize the language and communication measures that have been used for children with complex communication needs (CCN) and identify implications for future research. Specific research aims include, in previous studies assessing language and communication skills of 2-6 years old children with CCN who use aided AAC systems: (1) to describe what measures have been used, who were targeted, and what language and communication skills were measured; (2) to identify how the existing measurements measured language and communication skills of children with CCN; (3) to identify reliability and validity evidence of these measures in children with CCN.

CHAPTER 2: METHODS

I detail the methods for conducting this scoping review including: (1) study design; (2) search methods (information sources); (3) study selection (selection of source of evidence & reliability); (4) data extraction (data charting & reliability); and (5) data analysis.

Study Design

This study employed a scoping review methodology, which is a systematic means to review the extent, scope, and nature (characteristics) of available research on a topic (Tricco et al., 2018). For example, in the context of the present study, the goal is to understand the scope and characteristics of available measures being used for children with CCN. The scoping review method differs from systematic reviews in that it only provides descriptive evidence synthesis (Munn et al., 2018) and is more suitable in answering exploratory research questions (Colquhoun et al., 2014). As suggested by Munn et al. (2018), scoping review methodology is appropriate in reviewing research methodologies in a particular field, for example, measurement (e.g., Meyer et al., 2022; Wallace et al., 2022). Additionally, the use of scoping review is especially helpful in identifying research gaps and informing the planning of future research (Tricco et al., 2016). The design and reporting of this study follows the PRISMA Extension for Scoping Reviews Checklist (PRISMA-ScR, Tricco et al., 2018) and scoping review guidance (Peters et al., 2020).

Search Methods

Information Sources

With the goal of locating all relevant studies, searches focused on several databases and publication types. The following databases were used: (a) ERIC (1966 – current), (b) ProQuest (Research Library), (c) APA PsycInfo®, and (d) Linguistics and Language Behavior Abstracts (LLBA). Only peer-reviewed studies were included. There was no restriction on publication date. Any study published up until September 12, 2022 was included. Only studies published in English were included.

Search Terms

The following combinations of search terms that defined (a) child characteristics of children with CCN, (b) AAC use, (c) and outcome measures of language and communication skills were used. Searches were limited to anywhere but not full text (noft). Search terms included:

a. Complex communication need* or Autism* or Language disorder* or Language delay or Speech language impairment or language impairment or Down syndrome or Cerebral palsy or pervasive developmental disorder or developmental delay or developmental disorder* or apraxia or intellectual disabilit*
b. AAC or (Augmentative and alternative communication) or picture exchange* or assistive technology or picture symbol
c. Communication* or Language* or Verbal* or Vocabular* or synta* or morpho*

Study Selection

Eligibility Criteria

Eligibility criteria for study selection included: (a) inclusion of child participants with CCN age 2-6, who had developmental disabilities and used aided AAC systems at the entry of the study; (b) inclusion of at least one quantitative measurement system to evaluate skills or behaviors within constructs of language or communication skills of children with CCN (definition of language and communication constructs is attached in appendix); and (c) employed one of the following study designs: single case design, group experimental design (two data points or longitudinal), correlational design (cross-sectional or longitudinal), quantitative descriptive studies, and measurement development studies. Details for the eligibility criteria are presented in Appendix A. Studies that were qualitative, reviews, or meta-analyses were excluded. Although reviews and meta-analyses were not included in this review, an ancestral search was performed of relevant reviews and meta-analyses to locate additional studies.

Procedures

First, screening was conducted in Covidence® and included (1) abstract screening and (2) full-text screening. Two graduate students independently reviewed 100% of study records for both abstract screening and full-text screening. Agreement was reached if both reviewers made the same decision on a study. All disagreements were resolved through discussion. Interrater reliability (IOA) was calculated by using total number of agreements divided by the total number of agreements plus disagreements. IOA for abstract screening and full-text screening were 93% and 88% respectively. Reasons for study exclusion are reported in Chapter 3. Second, reference lists from relevant systematic reviews were reviewed to identify additional studies.

Data Extraction

Given the large number of studies included, and various measures used in these studies, data extraction procedures included two steps: general information and measure details.

Data Extraction for General Information

Data extraction for general information was performed using a pre-determined data extraction form (see Appendix B) for the following three areas of information: (1) study characteristics, (2) participant characteristics, and (3) general measurement information. First, ***study characteristics*** included study design (e.g., single case design, group experimental design, correlational study, quantitative descriptive study, or measurement study). Second, ***participant characteristics*** included number of participants, age (e.g., mean, range), diagnoses, gender, and their AAC systems. For single case studies which reported individual information, participant characteristics were extracted for each participant who has CCN age 2-6 years old. For group studies, participant information was reported based on groups. Third, ***general measurement information*** primarily revealed information on what measures have been used (e.g., the name of measurements or the target behavior that was defined as dependent measures). Specific codes included the type of measurement (e.g., direct test, indirect measure, and observational measure), in text citation of the measure (if available), subtests of the measure, purpose of use within the study (e.g., variable measure vs. demographic information), and page number to locate the measurement information in the manuscript.

Data Extraction for Measurement Details

This step focused on extracting information for each language and communication measure identified from the previous step (i.e., general measurement information).

Direct Tests

For direct tests, following the name of the measurement and subtests, the language and communication skills and/or domain specific skills being measured were recorded. Specifically, the domain specific skills included semantics, syntax, morphology, pragmatics, operational skills, and other skills based on the theoretical framework of language and communication skills identified in Chapter 1. Though phonology is an important component of language, phonological awareness is often conceptualized as an early literacy skill that is related to spelling and reading (National Early Literacy Panel [NELP], 2008). Therefore, it was not included in this scoping review. Other information included study test procedures, test length, test settings, item numbers, test administrators, child response mode, adaptations to the original test (i.e., yes/no and what adaptations), validity evidence (i.e., yes/no and what validity evidence), and reliability evidence (i.e., yes/no and what reliability evidence). Since many studies reported the use of published tests to inform demographic information and did not provide details specific to the test, an ancestral search of the original measure was performed and testing procedures were recorded.

Indirect Measures

For indirect measures, following the name of the measure and subtests, the language and communication skills and/or domain specific skills being measured were recorded based on the theoretical framework of language and communication skills mentioned above. Other information included: test item descriptions, respondent to the indirect measure (e.g., parent, teacher, others), number of items of the measure, validity evidence (i.e., yes/no and what validity evidence), and reliability evidence (i.e., yes/no and what reliability evidence).

Observational Measures

For each variable measured by observational measures, data extraction included the following information: Expressive or receptive skills, domain specific skills (semantic, syntax, morphology, pragmatics, AAC related non-linguistic skills), definition of the skills, mode of child behavior, whether the behavior was prompted, whether the behavior was imitated, quantity or linguistic complexity (i.e., quantity, accuracy, linguistic complexity), structure of the measure (e.g., structured, semi-structured, unstructured), measurement contexts (e.g., settings, administrators/communication partners, AAC materials, activities), measurement length for each session, segmenting rules, start and stop coding rules (e.g., unobservable sessions), sampling method (continuous or discontinuous), recording system (e.g., event, timed-event, interval), scoring system (e.g., count, rate, proportion), inter-rater reliability evidence (e.g., % of videos for reliability report; IOA range and average), validity evidence.

Reliability of Data Extraction

More than 30% of included studies were independently coded by two coders. IOA was calculated by using total number of agreements divided by the total number of agreements plus disagreements. I performed all primary coding. Three graduate students and a post-doctoral researcher were trained to perform secondary coding for more than 30% of the studies. Each coder received initial training with information provided in the coding manual. Then, coders practiced extraction for 2-6 studies until 90% of agreement is reached. Disagreements were discussed until agreement is reached. For general study information for SCD studies, IOA was 99% for participant and study information and 92% for measurement information; for group design studies, IOA was 92% for participant and study information, and 92% for measurement information. After any disagreement was discussed to resolution, the coders then started coding for measurement details. IOA was 93% for observational measures and 98% for tests and indirect measures.

Data Analysis Plan

I organized all coded results into four tables with quantitative descriptive synthesis and narrative synthesis. Specific table and synthesis plans are described below.

The first aim was to describe what measures have been used, who was targeted, and what language and communication skills were measured. First, to understand what measures have been used**,** measures were analyzed based on whether they were published or self-developed measures. For published measures, their original purpose of use was summarized; additional information coded included: the number of studies that used these tests; how they were used (i.e., for demographic use or informing results); and whether the measure had validity evidence. For self-developed measures, the structure of the observational measurement procedure was summarized. Second, to understand what language and communication skills were measured, I first summarized the count and percentage of studies that reported the receptive and expressive aspects of language and communication skills. Second, the count and percentage of studies that reported domain specific skills was summarized. Gaps were then identified based on what aspects of language and communication skills should be measured according to theory. Third, descriptive counts of participants' etiologies and their AAC systems were summarized to reveal who was targeted within the included studies.

The second aim of this study was to summarize how the identified measures measured language and communication skills of children with CCN. This result was organized based on the five domains: semantic knowledge, grammatical knowledge (i.e., syntax and morphology), pragmatic skills, and AAC related skills. Measures that reflected the same domain specific skills were summarized by their types and structures (i.e. test, observational measures, and indirect measure). A tree graph depicting how each type of measure measured the domain specific skills were developed. Descriptive count and examples of studies that used each measurement method was provided. I then provided a narrative summary of similarities and differences among these measures.

The third aim of this study was to identify psychometric properties of the measure within children who have CCN. Regarding psychometric properties of the identified measures, I presented the reliability and validity evidence for children with CCN for each measure that reported validity evidence within children who have CCN. Then, I analyzed, for each domain specific skill, what measures were provided with validity evidence.

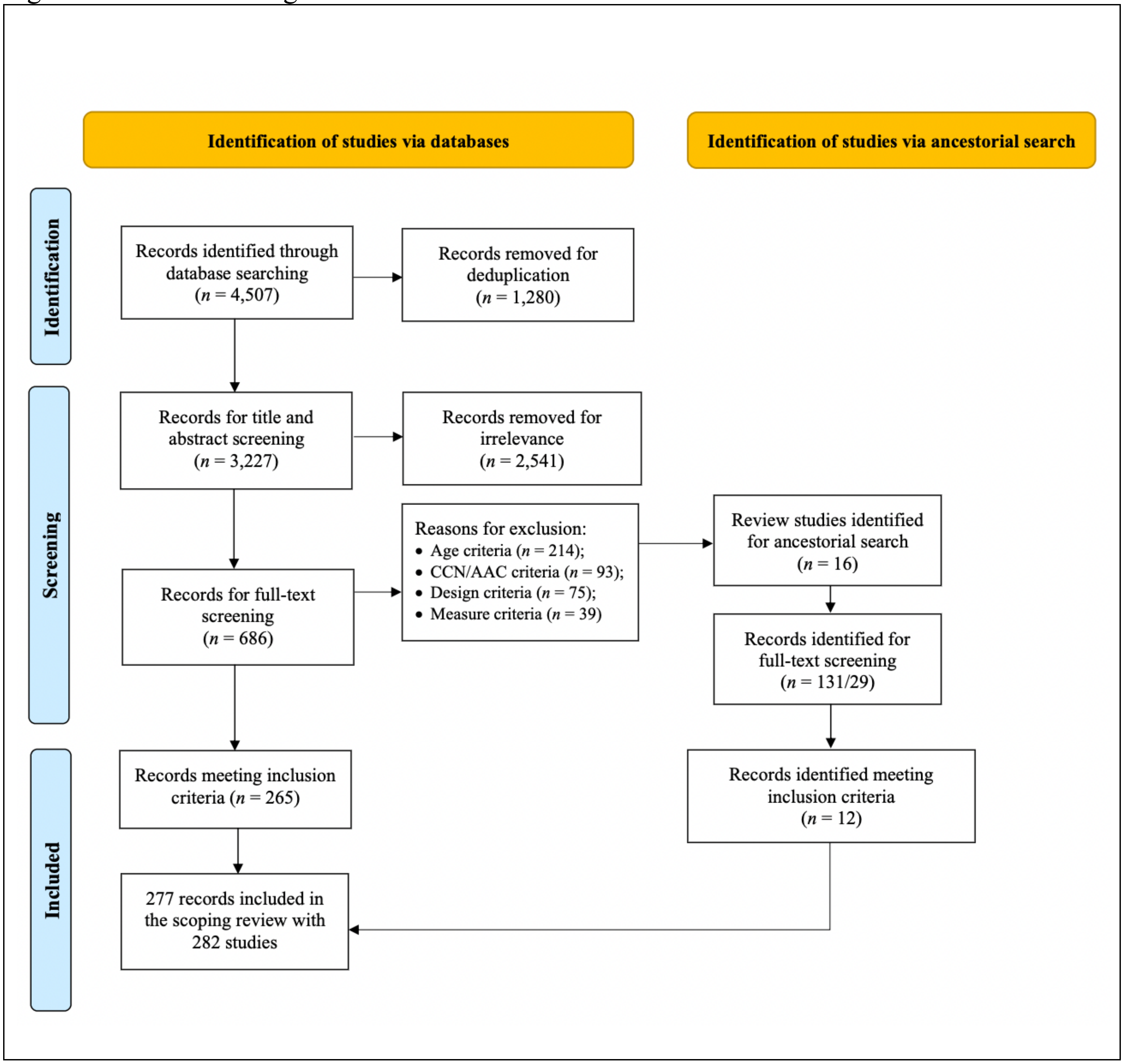
CHAPTER 3: RESULTS

Search Results

The initial search in four electronic databases yielded 4507 records. After removing duplications, 3227 records were included for initial title and abstract screening. This step yielded 686 studies for full-text screening. After full-text screening, 416 records were excluded because they involved the wrong age group ($N = 214$), did not include children with CCN who use aided AAC ($N = 93$), had the wrong study design ($N = 75$), or had no language or communication measures ($N = 34$). As a result, 270 records were included in this review. Additionally, ancestral search from relevant systematic reviews identified 12 additional records meeting the inclusion criteria. After the full-text review, an additional 5 studies were excluded because the included measures did not reflect language and communication skills. Therefore, a total of 277 records with 282 studies were identified and moved to study extraction. Figure 3.1 presents the PRISMA diagram for the search procedures and results.

In terms of study design, among 282 studies, 186 were single case design (SCD) studies and 96 were group design studies, including 29 group experimental, 25 correlational, 23 quantitative descriptive, and 19 measurement studies.

Figure 3.1 PRISMA Diagram for the Search Procedure



Summary of Descriptive Results

What Measures Have Been Used?

Research question 1 aimed to identify what measures have been used in previous studies assessing language and communication skills of 2-6 years old children with CCN who use aided AAC systems. A total of 121 SCD studies and 83 group studies reported the use of published measurement instruments with 65 different instruments used, and a total of 175 SCD studies and 59 group studies reported self-developed measures (including direct tests and observational measures).

Published Measures

A list of abbreviations of published measures, their full name, and in-text citations is presented in Table 3.1.

Table 3.1 Published Measure Abbreviations and Citations

Abbreviations	Measurement names	In-text citations
ABAS-2; ABAS-3	Adaptive Behavior Assessment System	Harrison & Oakland, 2003; 2015
ACLC	Assessment of Children's Language Comprehension	Foster et al., 1983
ADOS	Autism Diagnostic Observation Schedule	Lord et al. 1997; 1999; 2000
ADST	Australian Development Screening Test	Burdon, 1993
APPL	Assessment of Phase of Preschool Language	Flanagan & Smith, 2019
ASBC checklists	Aspect Building Blocks communication checklists	Ulliana & Mitchell, 1997
ASRS	Autism Spectrum Rating Scale	Goldstein & Naglieri, 2009
ATEC	Autism Treatment Evaluation Checklist	Rimland, 2000
BAC	Becoming Aided Communicator	von Tetzchner 2018; Batorowicz et al., 2018
BDI; BDI-2	Battelle Developmental Inventory	Newborg et al., 1984; Newborg, 2005
Bayley-2	Bayley Scales of Infant Development	Bayley, 1993
BDIED-R	Brigance Diagnostic Inventory of Early Development	Brigance, 1991
BESA	Bilingual English-Spanish Assessment	Peña et al., 2014
BLAF	Behavioral Language Assessment Form	Sundberg & Partington, 1998

Table 3.1 (cont'd)

Abbreviations	Measurement names	In-text citations
BPVS-2; BPVS-3	British Picture Vocabulary Scale	Dunn et al., 1997; 2009
BTAIS-2	Birth to Three Assessment and Interventions System—Comprehensive Test of Developmental Abilities	Ammer & Bangs, 2000
C-BiLLT	Computer-based instrument for low motor language testing	Geytenbeek et al., 2010; Geytenbeek et al. 2014
CALC	Clinical Assessment of Language Comprehension	Paul & Miller, 1995
CARS	Childhood Autism Rating Scale	Schopler et al., 2010
CCC-2	Children's Communication Checklist	Bishop, 2003
CCS	Communication Complexity Scale	Brady et al., 2012
CELF–P	Clinical Evaluation of Language Fundamentals–Preschool	Wiig et al., 1992
CFCS	Communication Functioning Classification System	Hidecker et al., 2011
Communicatio n Matrix	Communication Matrix	Rowland, 2004; 2010; 2013
Communicatio n profile-Z	Communication profile	Willems & Verpoorten 1996
CSBS	Communication and Symbolic Behavior Scales	Wetherby & Prizant, 1993; 2002
DAYC	Developmental Assessment of Young Children	Voress & Maddox, 1998
Developmental Profile II	Developmental Profile II	Alpern, Boll, & Shearer, 2000
EIDP	Early Intervention Developmental Profile	Rogers & D'Eugenio, 1981
ELAP (LAP; E-LAP)	Early Learning Accomplishment Profile	Glover et al., 1995; Tager-Flusberg et al., 2009
EOWPVT	The Expressive One Word Picture Vocabulary Test	Gardner, 1990
ESCS	Early Social Communication Scales-Abridged	Mundy et al. 1996
EVT; EVT-2	Expressive Vocabulary Test	Williams, 1997; Williams 2007
FCP-R	Functional communication profile-revised	Kleiman, 2003
GARS-2	Gilliam Autism Rating Scale	Gilliam, 2006
Gesell	Gesell Expressive Language Scale	Not identified (reported in Durand, 1993)
GMDS	Griffiths' Mental Developmental Scales	Griffiths 1984
HELP	Hawaii Early Learning Profile	Furano et al., 1988
IPCA	Identifying potential communicative acts	Sigafoos et al., 2000; 2006
KSPD-2	Kyoto Scale of Psychological Development	Ikuzawa et al., 2001

Table 3.1 (cont'd)

Abbreviations	Measurement names	In-text citations
LAP; LAP-R	Learning Accomplishment Profile	Sanford & Zelman, 1981; Glover et al., 1995
M-CDI	MacArthur Communication Development Inventory	Fenson et al., 1993; Fenson et al., 2007
MSEL	Mullen Scales of Early Learning	Mullen, 1995
MY	Miller-Yoder language comprehension test	Miller & Yoder, 1984
PEP-R	Psycho-Educational Profile – Revised	Schopler et al., 1990
PLS-3; PLS-4; PLS-5	Preschool Language Scales	Zimmerman et al., 1992; 2002; 2011
PPVT; PPVT-3; PPVT-4	Peabody Picture Vocabulary Test	Dunn & Dunn, 1981; 1997; 2006
RDLS-2; RDLS-3	Reynell Developmental Language Scales	Reynell & Huntley, 1985; Reynell & Huntley, 1987
REEL-2	Receptive-Expressive Emergent Language Scale	Bzoch & league, 1991
RITL	Rossetti Infant-Toddler Language Scale	Rossetti, 2006
ROWPVT; ROWPVT-4	Receptive One-Word Picture Vocabulary Test	Gardner, 1985; Martin & Brownell, 2010
SCQ	Social Communication Questionnaire	Rutter et al., 2003
SETK-2	*Sprachentwicklungstest für drei bis fünfjährige Kinder* [Test of language acquisition]	Grimm, 2001
SICD	Sequenced Inventory of Communication Development	Hedrick et al., 1984
Sprakligh	Sprakligh Impressivt test	Hellquist, 1982
STLP	Schlichting Test for Language Production	Schlichting et al., 2003
TACL-3	Test for Auditory Comprehension of Language	Carrow-Woolfolk, 1999
TASP	Test of Aided-Symbol Performance	Bruno, 2006
TELD	Test of Early Language Development	Hresko et al., 1991
TOLD-P-4	Test of Language Development-Primary	Hammill & Newcomer, 2008
TPBA	Transdisciplinary Play Based Assessment and Intervention	Linder, 1993
TROG; TROG-2	Test for Reception of Grammar	Bishop, 1989; 2003
VABS; VABS-2; VABS-3	Vineland Adaptive Behavior Scales	Sparrow et al., 1984; Sparrow et al., 2005; Sparrow et al., 2016
VB-MAPP	Verbal Behavior Milestones Assessment and Placement Program	Sundberg, 2008
WPPSI-3	Wechsler Preschool and Primary Scale of Intelligence	Wechsler, 2008

In terms of relevance of language and communication skills from published measures, previous studies employed the following types: (1) measures that target specifically on language and communication skills (N = 40; e.g., PPVT; PLS; TACL; M-CDI), (2) subtests measuring language and communication skills from a global developmental assessment (N = 19; e.g., MSEL; BDI; VABS), and (3) a subscale focusing on communication skills from an ASD related diagnostic assessment (N=5; e.g., ADOS; ASRS). One study had an unknown source (i.e., Sprakligh Impressivt test, Hellquist, 1982). These measures were used to provide demographic information and/or to inform study results. A brief summary of measures, studies that reported the measure, measurement use, and validity information is reported in Tables 3.2 and 3.3 for direct and indirect measures.

In terms of structure and respondents of published measures, these measures included: (1) standardized direct tests that follow standardized procedures (e.g., BPVT; ROWPVT; ADOS), (2) non-standardized assessments that collect information from multiple sources, including direct test, parent interview, and direct observation (e.g., RITL; CSBS; CCS), and (3) indirect measures using parent or teacher completed checklists or questionnaires (e.g., M-CDI). Specific measurement procedures are discussed in RQ 2.

Table 3.2 Published Direct Measures

Measure	# of studies	SCD studies		Group studies		Source	Validity evidence	Reliability evidence
		Demo	Results	Demo	Result			
PPVT	44	23	2	7	12	L	1	
BPVS	11	1			10	L	1	
TROG	8			2	6	L	1	
BDI	7	4			3	G	1	
SICD	7	2		3	2	L	1	
BAC	5				5	L	1	1
RDLS	5	2		1	2	L	1	1
C-BiLLT	4				4	L	1	1
CCS*	4	1	1		2	L	1	
PLS	23	13	1	4	5	L		
MSEL	17			9	8	G		
TACL	15	11		3	1	L		
VB-MAPP*	13	12		1		L		
ADOS	7	1		3	3	D		
ROWPVT	4	2	1		2	L		
EOWPVT	3		1		2	L		
EVT	3	2	1			L		
LAP	3	3				G		
WPPSI	3	2			1	G		
ESCS*	3				3	L		
MY	2	1			1	L		1
ABAS	2	1		1		G		
GMDS	2				2	G		
TELD	2	1		1		L		
ELAP*	2	2				G		
STLP	1				1	L		1
ACLC	1			1		L		
ADST	1	1				G		
Bayley	1				1	G		
BESA	1				1	L		
CALC	1			1		L		
CARS	1	1				D		
CELF	1	1				L		
EIDP	1	1				G		
KSPD	1	1				G		
SETK-2	1	1				L		
Spraklighe	1				1			
TASP	1				1	L		
TOLD	1	1				L		
TPBA	1			1		G		
PEP-R*	1				1	G		

Note. * Include other sources of data collection: observation or indirect checklist. L = Language or communication measure. G = Global development measure. D = ASD diagnostic measure.

Table 3.3 Published Indirect Measures

Measure	#	SCD studies		Group studies		Source	Validity evidence	Reliability evidence
		Demo	Results	Demo	Results			
VABS*	46	31		6	9	G	1	1
M-CDI	24	13		5	6	L	1	
CFCS	8			3	5	L	1	1
Communication Matrix*	8	4			4	L	1	1
CSBS*	7	3	1	2	1	L	1	
APPL*	1				1	L	1	
ASRS	5	5				D		
REEL	3	3				L		
IPCA	2				2	L		1
Communication profile	2				2	L		
DAYC*	2	2				G		
RITL*	2	2				L		
BDIED-R	1				1	G		1
ATEC	1				1	D		
BLAF	1	1				L		
CCC	1			1		L		
BTAIS-2	1			1		G		
Developmental Profile II	1	1				G		
SCQ	1	1				L		
ASBC checklists	1		1			L		
FCP-R*	1	1				L		
HELP*	1	1				G		
GARS*	1	1				D		
Gesell*	1	1				L		

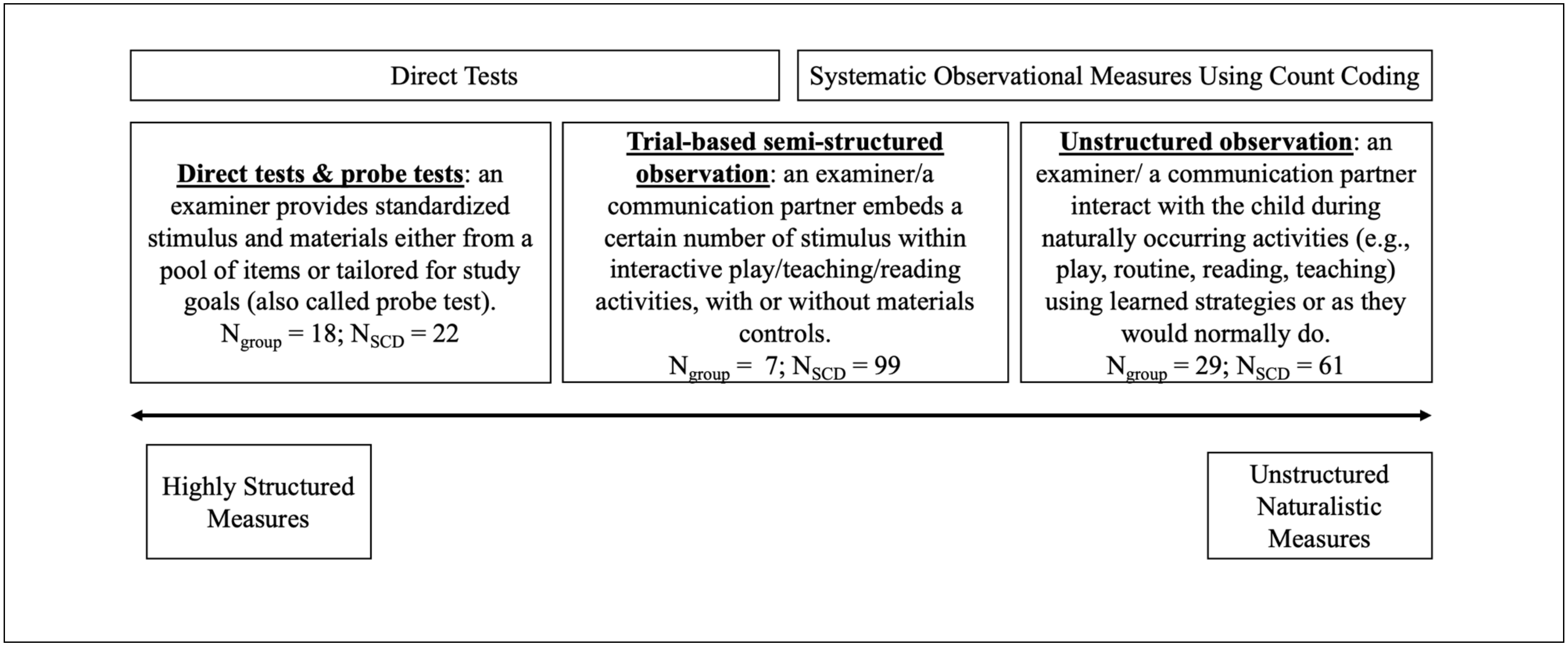
Note. * Include other sources of data collection: observation or indirect checklist. L = Language or communication measure. G = Global development measure. D = ASD diagnostic measure.

In terms of target examinees, the majority of existing published language and communication measures were originally developed and normed with children who displayed typical development (e.g., PLS, Battelle) or developed for the purpose of screening to identify children with disabilities (e.g., ADST). As a result, these measures and the studies that employed them used only spoken language responses to estimate the child's language and communication skills, even though children with CCN used multiple modalities to communicate. In order to accurately reflect their language and communication skills, there were a small number of recently developed measures targeting specifically children who used AAC (e.g., C-BiLLT, BAC) as well as some measures that allowed for multiple modalities for communication (e.g., CFCS; Communication Matrix).

Self-developed Tests and Observational Measures

Due to the lack of existing measures that accommodated the response mode needs of children who use AAC (i.e., non-verbal), self-developed measures were reported in most studies (80.50%, N = 227) as the primary method of measurement to inform study results (80.14%, N = 226) as well as to provide demographic information (6.74%, N = 19). These measures fell on a spectrum based on the structure of administration, where on the one end were highly structured direct tests that followed standardized procedures, and on the other end were measures that used systematic observation through naturalistic free-structured or unstructured interactions. Figure 4.2 illustrates this spectrum. At the left end lies the structured tests. Examiners in these tests provided a certain number of standardized stimuli and materials. Child responses were rated based on pre-determined criteria. In between tests and observational measures, there were trial-based observational measures or dynamic assessment. Examiners or communication partners in these measures provided a number of stimuli in loosely structured play or learning activities, and sometimes provided ongoing prompts. Count coding of child correct responses were typically transformed into percentage scores based on the number of stimuli provided. At the far right are the unstructured observational measures. Communication partners interacted with the child in naturally occurring activities without stimulus, activity, or material controls. Count coding or language sample analysis was used to estimate the child’s language and communication skills.

Figure 3.2 The Spectrum of Testing Structures of Self-Developed Tests and Observational Measures



What Skills Were Measured?

Receptive and Expressive Language Skills

According to its definition, language is a rule-governed system (Chomsky, 1957) that includes both receptive (i.e., comprehension) and expressive (i.e., expression) use of spoken, written, and other communication symbol systems (American Speech-Language-Hearing Association, ASHA, n.d.; Honig, 2007; Wing, 1982). Therefore**,** each included measure was coded as receptive and/or expressive language. Table 3.4 summarizes the number of studies that reported the expressive and receptive aspects of language and communication and the usage of measures as either informing results or demographic information. The majority of studies reported expressive aspects of language and communication skills (91.84%, N = 259). Among these studies, 93.75% of group design studies and 95.53% of SCD studies reported expressive language and communication skills as variables informing study results (e.g., outcome variables, grouping variables, independent variables, descriptive variables in results). However, only 62.06% studies (N = 175) reported receptive aspects, among which only 56.25% of group design and 16.35% SCD studies used these measures as informing study results. Such results indicate that for preschool aged children who use AAC, studies primarily focus on expressive language skills rather than receptive language skills.

Table 3.4 Number of Studies that Reported Receptive and Expressive Skills

Study Design	Expressive *N* = 259		Receptive *N* = 175	
	Results N (%)	Demographic N (%)	Results N (%)	Demographic N (%)
SCD (*N* = 186)	171 (91.94%)	102 (54.84%)	17 (9.14%)	95 (51.08%)
Group (*N* = 96)	75 (78.13%)	37 (38.54%)	54 (56.25%)	34 (35.42%)

Domain Specific Skills

According to the theoretical framework proposed in Chapter 1 of this study, language and communication skills are conceptualized as linguistic skills (i.e., semantics, morphology, & syntax), pragmatic skills (i.e., social communication skills), and AAC operational skills. Linguistic skills were further broken down into semantics, morphology, and syntax. Therefore, each measure was coded as reflecting one or multiple of these aspects of language and communication skills. Global measures that require multiple sub-domain skills were coded for all relevant skills. Some global measures were not readily categorized under a particular domain specific skill: First, I chose to categorize mean length of utterances as reflecting syntax skills, which is consistent with reporting in previous studies (Binger & Light, 2008); Second, global measures that reported total language scores (e.g., Battelle, PLS) which included diverse test items were coded as reflecting all aspects of linguistic and pragmatic skills. Third, a small number of global measures for which the original coding manual was not identified or for which information on the content of the test items was not provided were not coded (N = 12, e.g., KSPD). In summary, the majority of the studies reported pragmatic (84.40%, N_{Group} = 72, N_{SCD} = 166, G = 75%, SCD = 89.25%) and semantic (52.48%, N_{Group} = 66, N_{SCD} = 82, G = 68.75%, SCD = 44.09%) skills, while only a small portion reported syntax (37.59%, N_{Group} = 52, N_{SCD} = 54, G = 54.17%, SCD = 29.03%), morphology (25.53%, N_{Group} = 52, N_{SCD} = 54, G = 44.79%, SCD = 15.59%), and AAC related skills (7.09%, N_{Group} = 14, N_{SCD} = 6, G = 14.58%, SCD = 2.13%).

Who was Targeted?

This review included a total of 449 child participants who use AAC and were 2-6 years old identified from SCD studies; and included a total of 5391 child participants who may use AAC and may fall within the age range of 2-6 year old identified from group studies.

This review found studies that measured language and/or communication skills of children with CCN included a broad range of diagnoses. Table 3.5 presents participant diagnosis information. In SCD studies with known age range (i.e., 2-6), more studies included child participants who have ASD (51%) and developmental delay or disabilities (11%), with only 3% of participants diagnosed with physical disabilities (i.e., including cerebral palsy and other physical disabilities). However, in group studies that included children who were older in age, a majority of participants had physical disabilities (62%), with fewer participants having ASD (23%), and even fewer with other diagnoses.

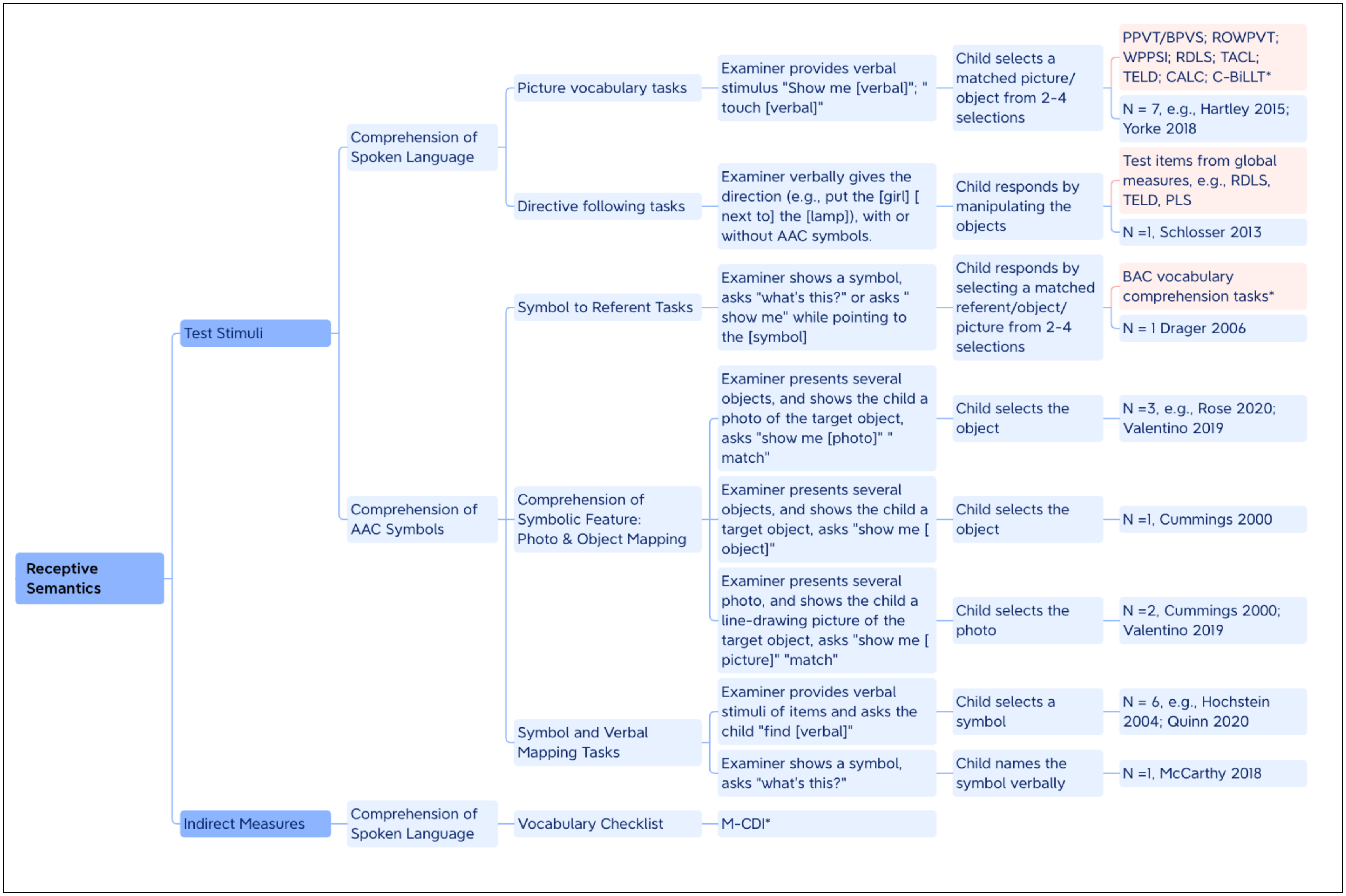
Table 3.5 Diagnoses of Child Participants

Study Design	ASD	DS	ID	SLI	DD	CP & other physical	Apraxia	Other
SCD	286 63.70%	27 6.01%	21 4.68%	47 10.47%	67 14.92%	17 3.79%	25 5.57%	79 17.59%
Group	1401 23%	77 1%	41 1%	40 1%	275 5%	3782 62%	6 0%	449 7%

Note. ASD = Autism spectrum disorders, DS = down syndrome, ID = intellectual disabilities, SLI = speech language impairment, DD = developmental delay or disorders, CP = cerebral palsy, Apraxia = childhood apraxia of speech.

AAC systems reported in existing studies included a variety of display types with varying level of technology support. In SCD studies, 255 individuals used low tech paper based AAC systems and 264 used digitized AAC systems. In terms of display, 40 children used visual scene displays, 229 used grid display, 243 used displays that were not organized by grids or visual scene (single picture exchange or binder selection), and 3 children used AAC with typing functions. The AAC systems used in group studies were not consistently reported, so a summary is not provided in this review.

Figure 3.3 Receptive Semantic Measure



Measurements of Semantic Knowledge

Semantics refers to the meaning of words, sentences, and the links that connect the words (Bernstein & Tiegerman-Farber, 2009). Language and communication skills related to semantics include receptive and expressive vocabulary knowledge of spoken words, expressive use and receptive understanding of AAC symbols, and, more broadly, estimation of lexical knowledge (i.e., all vocabulary words a child has). Figures 4.3 and 4.4 present tree graphs summarizing what semantic skills were measured, what measures were used, how these skills were measured, and measures that had validity evidence in receptive and expressive semantic knowledge.

Receptive Semantic Knowledge of Spoken Language

Receptive semantic knowledge of spoken language was only measured through tests and indirect measures.

Test Stimuli

Two types of testing stimuli were identified to measure semantic knowledge of spoken language: (1) picture vocabulary tests and (2) directive following tests.

Picture Vocabulary Tests. To measure comprehension of spoken words, the most frequently used method was picture vocabulary tests. Such tests are often conducted by asking the child to match drawings/objects to spoken words. That is, the examiner presents a verbal stimulus (e.g., "show me the car"), and asks the child to select a drawing or an object from 2-4 selections.

Published measures that used this method of measurement include three receptive vocabulary measures: PPVT (N = 44), BPVS (N = 11), and ROWPVT (N = 4); and five receptive vocabulary subtests from broader language measures: WPPSI (N = 3), RDLS (N = 4), TACL (N = 15), TELD (N = 2), CALC (N =1). These measures were often administered by researchers and trained SLPs in a clinic or in the child's home setting. The tests typically took 10-20 minutes to complete. The tests yielded raw scores (usually reported as the number of items with correct response), age equivalent scores compared to typically developing children, standard scores generated from a norming sample, and/or percentile rank. Since these tests do not require a verbal response, children with limited verbal skills were able to complete the tests. Although the measures were not originally developed for children who use AAC to communicate, scores were reported informing both participant demographic information and study results. In addition to pointing to symbols or objects, eye gaze/tracking and partner-assisted scanning were also provided to accommodate physical needs for children who have motor impairments with the BPVS (Kurmanaviciute & Stadskleiv, 2017), PPVT (Brady et al., 2014), and WPPSI (Kurmanaviciute & Stadskleiv, 2017).

In addition to the existing published tests that were originally developed for children with speech, a recent test, C-BiLLT (Geytenbeek et al., 2010; Geytenbeek et al., 2014), was developed to measure spoken vocabulary and sentence comprehension for children with cerebral palsy who have limited motor skills. This test was computer assisted and verbal stimuli were in Dutch. The computerized test contains 10 items addressing vocabulary knowledge by presenting verbal stimuli of the target spoken word with two images presented on the screen. The child used an eye-tracking system or touchscreen to make a selection.

Self-developed receptive vocabulary tests using the same method (i.e., examiner presents verbal stimuli and child responds by pointing to pictures/object) were reported in seven studies (Brady, 2000; Brady et al., 2015; Hartley & Allen, 2015a; Harris et al., 2004; Ninci et al., 2018; Still et al., 2015; Yorke et al., 2018). The tests were often developed with a focus on vocabulary words that are important learning targets of children with CCN. Such tests are often short in length (less than 10 items) and administered by researchers or SLPs rather than educational professionals.

Direction Following Tests: Comprehension of Spoken Words and Sentences. A few direction following tests were used to examine the child's comprehension of words and sentences. During direction following tests, the test examiner provides directive verbal stimuli (e.g., put the [girl] [next to] the [lamp]) with objects, and asks the child to manipulate objects. The child's behavior when following the directions was considered reflective of comprehension. One self-developed probe test was identified that used this method (Schlosser et al., 2013). In addition, test items from global language and communication measures also used this method, such as RDLS (N = 4), TELD (N = 2), PLS (N = 21), BDI (N =7), MSEL (N = 16), and SICD (N = 6).

Indirect Measures

Child's vocabulary knowledge of spoken language was also measured through caregiver checklists, most commonly with the M-CDI (N = 24). The word and gesture sub-scale from M-CDI (Fenson et al., 2007) is a vocabulary checklist containing words frequently used by typically developing children. Caregivers check words that the child can understand and/or can speak to indicate children's receptive and expressive semantic knowledge. M-CDI was usually completed by parents (N = 12); other respondents included teachers (N =1, Muttiah et al., 2022), a school psychologist (N=1, Harris & Reichle, 2004), and a researcher following direct observation (N =1, Walters et al., 2021).

Receptive Semantic Knowledge of AAC Symbols with or without Spoken Words

Receptive vocabulary was also measured as symbol comprehension as AAC symbols are an important form of linguistic output for children with CCN. Receptive semantic knowledge of

AAC symbols was only measured through direct tests or semi-structured observational measures with embedded stimuli that can elicit child response. Three types of testing stimuli were identified to measure semantic knowledge of AAC symbols: (1) symbol to referent tasks; (2) photo and object mapping tasks; (3) symbol and verbal mapping tasks. I describe each of the three tasks below.

Symbol to Referent Tasks

In symbol to referent tasks, the examiner presents the child with an AAC symbol, says “show me” or “what’s this” while pointing to the symbol; the child is asked to select the objects/pictures that match with the symbol stimuli.

BAC Vocabulary Comprehension Tasks. One recently developed test was identified that measured semantic understanding of AAC symbols by presenting AAC symbol stimuli and asking the child to respond by selecting matched pictures. The BAC vocabulary comprehension sub-test was reported in two studies using this format (Batorowicz et al., 2018; Deliberato et al., 2018). The BAC vocabulary comprehension test follows a standardized testing procedure and includes 63 items. Each AAC symbol item was designed to include one target picture with three foil pictures. The child responds by selecting a picture from 4 selections that represent the AAC symbol stimuli. This method of testing measures the child’s ability to directly link AAC symbols to their referents.

Self-developed Test. One study (Drager et al., 2006) measured symbol comprehension by presenting the child “show me” while pointing to the [symbol]; correct child responses included manipulating the object as shown in the symbol or selecting a target object that matched with the symbol. The authors also provided the test in two additional conditions: (1) providing symbol stimuli with verbal description during intervention sessions (e.g., examiner says “show me [verbal word of the target]" and points to the [symbol]), and (2) providing verbal stimuli only as generalization trials (e.g., examiner says "show me [verbal word of the target]" without showing the symbol). Results did not show clear differences between the three methods.

Photo & Object Mapping Tasks

Demonstrating the ability to map between photos and objects is considered a prerequisite skill for making picture exchange (Valentino et al., 2019). Three studies (Cummings & Williams, 2000; Rose et al., 2020; Valentino et al., 2019) reported one or multiple of the following mapping tests: (1) selecting a 2-D photo that matches with a 2-D photo stimulus (i.e., say "show me" while holding a symbol), (2) selecting a 3-D object that matches with a 2-D photo stimulus, (3) selecting a 3-D object that matches with a 3-D object stimulus (i.e., say "show me" while holding an object), and (4) selecting a 2-D photo or 3-D object that matches with an AAC symbol stimulus. These tests aimed to measure the child's ability to demonstrate connections or association between AAC symbols and their referents (object/photo of the object).

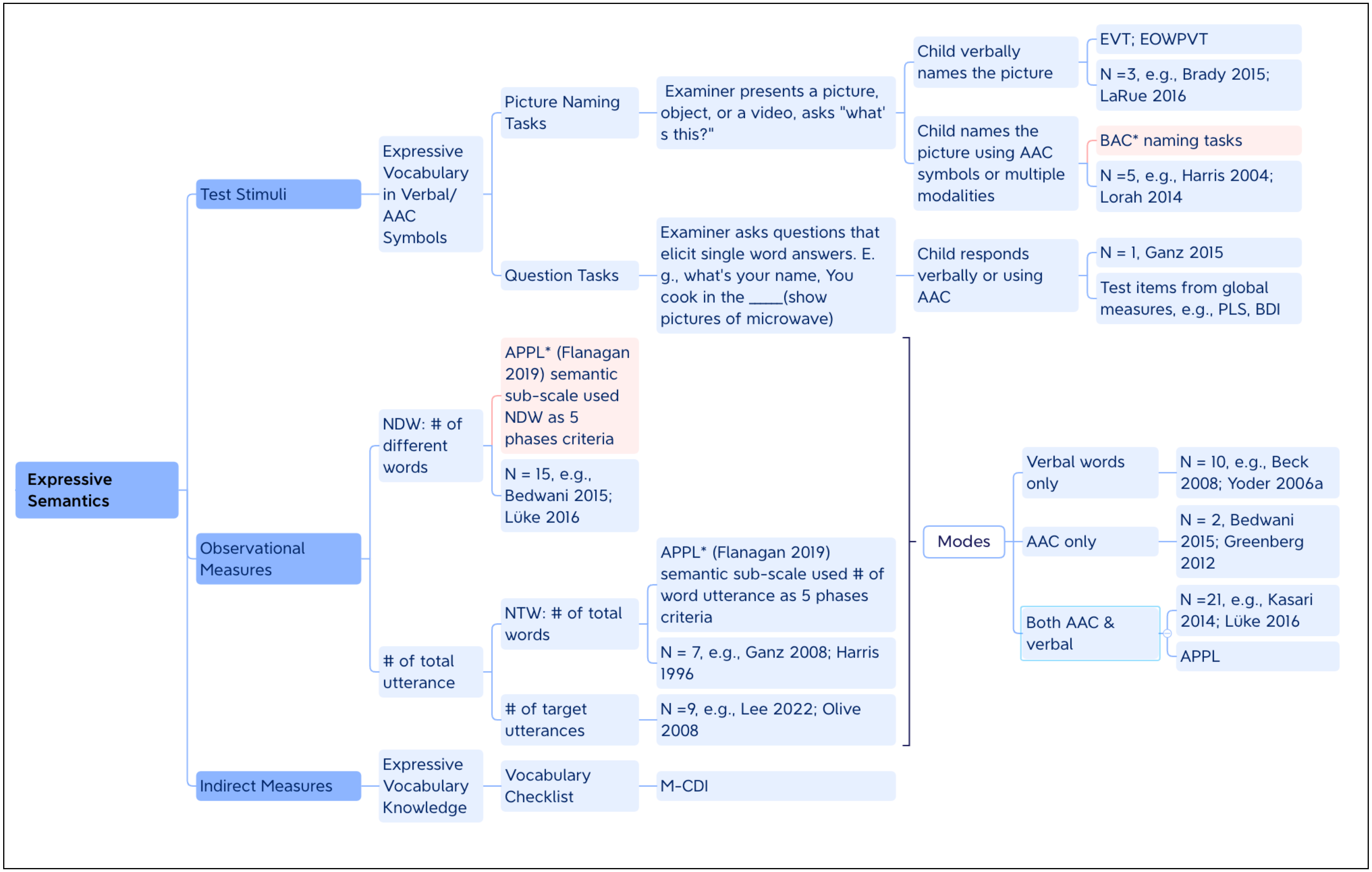
Symbol and Verbal Mapping Tasks: Symbol Recognition Skills

Symbol and verbal mapping tasks contain two forms: (1) mapping symbols to verbal stimuli and (2) verbally describing symbols. Both forms involve the child's understanding of the verbal meaning of a target word as well as the symbol used to represent it. Therefore, a child failing to make a correct selection may indicate the child is either not able to recognize the spoken word, or not able to comprehend the AAC symbol (i.e., link the AAC symbol to the spoken words). Given the fact that these tests require the child to be able to understand the verbal stimuli and also recognize AAC symbols that represent the verbal words, skills measured by these tests were conceptualized as non-linguistic symbol recognition skills. For example, some studies only selected child familiar words (e.g., Hochstein et al., 2004; McCarthy et al., 2018) so that the results reflected child symbol recognition skills.

Mapping Symbols to Verbal Stimuli. A total of four studies reported self-developed tests (Ganz et al., 2015; Hetzroni & Belfiore, 2000; Hochstein et al., 2004; Quinn et al., 2020) that involved presenting verbal stimuli: "show me [verbal]" or "find [verbal]," and asking the child to select the matched AAC symbols. In addition to these direct tests, two studies (Huist et al., 2020; Hetzroni et al., 2002) used semi-structured observational measures, in which verbal stimuli were embedded into interactive activities or intervention sessions. Responses to the verbal stimuli were then observed as target skills. For example, in Huist et al. (2020), children were observed during a play activity with researchers. The child was presented with a field of four symbols (1 target concept, 1 visually similar symbol, 1 conceptually similar symbol, 1 random symbol) and asked to identify a target concept when prompted by the researcher (e.g., "Look at the pictures, show me [in]"). Test administrators were often parents, teachers, or researchers who also served as interventionists/communication partners.

Verbally Describing AAC Symbol Stimuli. Only one study (McCarthy et al., 2018) measured symbol comprehension by presenting the AAC symbol and asking the child to verbally name the symbol. Symbols included picture communication symbols (i.e., colored line-drawing symbols) and children's own drawings. Participants were 15 children from 4 to 13 year old with ASD. Only two of them used an AAC system before the start of this study; other children were able to communicate with verbal language.

Figure 3.4 Expressive Semantic Measures



Expressive Semantic Knowledge of Spoken Words or AAC Symbols

Expressive vocabulary knowledge of spoken words and/or AAC symbols was measured using: (a) direct tests or semi-structured observational measures with testing stimuli, (b) observational measures, and (c) indirect measures.

Direct Tests or Semi-Structured Observational Measures with Testing Stimuli

Expressive vocabulary knowledge was measured in some studies with direct tests or semi-structured observational measures that used standardized testing stimuli. These stimuli were either picture naming tasks or question answering tasks.

Picture Naming Tasks. In picture naming tasks, the examiner presents the child a picture and asks the child "What's this?" Children can respond using spoken words or AAC symbols.

Picture Naming Tasks Using Spoken Words. In order to measure expressive vocabulary knowledge, published expressive vocabulary tests or subtests of existing measures typically present a child with a picture and ask the child to verbally name the picture. The current review identified two standardized tests (i.e., EVT, EOWPVT) and three self-developed tests that used this format (e.g., curriculum-based vocabulary test, vanderSchuit et al., 2010; expressive word production trials, Brady et al., 2015; Still et al., 2015). This testing procedure requires a verbal response; therefore, only a few studies in this review (N = 9) reported using such tests. Due to limited verbal language skills, the majority of children who were given expressive vocabulary tests could not establish basal levels on the tests. Because of the lack of basal levels, there was little variability in children's scores in order to perform proper data analysis. As expected, these results indicate that picture naming tasks requiring spoken word response from the child are not appropriate for children who have limited verbal skills.

Picture Naming Tasks Using AAC symbols. Only one recently developed standardized test provided a measure of expressive vocabulary focused on AAC symbols. In the BAC naming task (Batorowicz et al., 2018), an examiner presents a total of 20 drawings of common objects and asks the child to use a single AAC symbol or multiple symbols to name the object. Three studies reported the use of BAC naming tasks, with the number of correct responses reported as the score. In this BAC naming task, each child responded using their own AAC systems. Children's own AAC systems may vary in the number of symbols, types of displays, and organization of their symbols, which may result in variations in responses.

Four other studies used self-developed tests or semi-structured observational measures with stimuli that followed similar procedures to examine expressive vocabulary with AAC symbols (Drager et al., 2006; Harris & Reichle, 2004; LaRue et al., 2016; Lorah, Parnell, et al., 2014). During these procedures, the examiner presented an object and asked, "What's this?" The child was asked to select a matched symbol from an array of two to six AAC symbols. Unlike the BAC naming tasks, these studies controlled the number of symbols presented to the child.

Answering Question Tasks. One study used a semi-structured observational measure with 10 testing trials embedded in a story book reading activity (Ganz et al., 2015a). The examiner asked relevant questions related to the story book that elicited single word answers. Testing items from standardized global language measures also often included similar tasks, such as PLS (N =21) and BDI (N =7).

Observational Measures

Number of Intelligible Verbal Word Utterance. The number of intelligible verbal word utterances was in both semi-structured (N = 5) and unstructured (N = 11) observational measures to reflect expressive spoken vocabulary knowledge. In semi-structured observational sessions, a number of communication opportunities (e.g., 15 trials of PECS exchange opportunities, Ganz & Simpson, 2004) are provided, and studies reported either the number of verbal word utterances throughout the session (N = 4) or the number/percentage of trials with a verbal utterance (N = 1). In unstructured sessions, communication partners were engaged in interactive activities with the child and either the total number of word utterances (N = 3) or the total number of occurrences of target words (N =8) was used to indicate expressive vocabulary knowledge. These studies varied in how they defined what counts as an intelligible verbal word utterance. Some studies reported only accurately produced words without error (i.e., percentage of accurately produced words, N = 2), while other studies also included verbal approximations (N =4). One important consideration was whether and how verbal utterances were distinguished from imitation. Only one study clearly defined that only non-imitated utterances were counted (Romski 2010) and four studies reported that only spontaneous or independent utterances were coded (Barker et al., 2019; Chong, 2006; Gevarter et al., 2020; Whitmore et al., 2014). In terms of observational length, each observation lasted 10-30 minutes. The majority of communication partners were researchers (N = 6) and parents (N = 4). Settings included classroom (N =5), clinic (N = 3), and home (N = 8) with activities including play (N =13), snack (N =3), and story book reading (N =6). AAC systems were available during all observational sessions.

Number of Different Words. Language sample analysis was used to report the number of different words during both semi-structured (N = 4) and unstructured (N =11) observational sessions to reflect the child's semantic knowledge. This method involved observing and transcribing the verbal words only (N = 2), AAC symbols only (N = 2), both AAC and verbal (N =2), or multiple modalities including verbal, AAC, gestures, and signs (N = 8) used by the child during observations, and then coding the transcripts for the number of unique semantic meanings. In terms of verbal words, few studies reported whether imitated verbal words were counted towards number of different words. Only one study (Yoder & Stone, 2006a) reported that imitated words were assigned a separate code. Another study reported only independent child utterance was counted, but it is unknown if "independent" was defined as non-imitative (Barker et al., 2013).

APPL. APPL (Assessment of Phase of Preschool Language; Flanagan et al., 2019) is a recently developed measure using a combination of information sources, including direct tests, parent interview, and direct observations of child language skills. The APPL assessment rates children's domain specific and overall language skills on a 5-point scale representing five language developmental phases from pre-verbal to complex language phases. In the APPL semantic subscale, direct observation is used to determine which 'phase' of expressive language a child is in based on the number of different words and number of utterances the child produces. For example, the phase 2 criteria indicate the child uses at least 5 different words and says at least 20 utterances. The recommended observation length is 20 minutes.

Indirect Measures

Vocabulary Checklist. One vocabulary checklist was identified to measure receptive and expressive vocabulary of children with CCN. As reported earlier, the M-CDI is a norm-referenced vocabulary checklist in which caregivers and teachers can check vocabulary words the child can speak.

Measurements of Morphology and Syntax Skills

Syntax refers to grammatical and sentence structures of language; morphology refers to the rules that govern word formation (Bernstein & Tiegerman-Farber, 2009). Knowledge of syntax and morphology are collectively referred to as grammatical knowledge, and therefore, commonly measured together and discussed together in this section. This review shows an increasing number of studies targeting syntax and morphology. Figure 3.5 and 3.6 presents morphology and syntax skills being measured and types of measures that measured these skills.

Expressive Morphology and Syntax Structures

Expressive skills of syntax and morphology were measured using tests, observational measures, and indirect measures.

Testing Stimuli

Two commonly used testing procedures included: (a) picture/action/video description tasks, and (b) imitation tasks.

Picture/action/video Description Tasks. During most direct tests or semi-structured observations of grammatical knowledge, the examiner shows a picture, action, or video, or manipulates objects, and provides the child verbal stimulus such as, “What’s happening?” The child’s verbal or AAC response is then evaluated for morphology and syntactic structures. Description tasks were often also used as testing items from global language measures, such as TELD (N =2), SICD (N = 9), LAP (N = 3), and BDI (N =7). Given the verbal response requirements, these tests were mostly used to report age equivalent or percentile scores to inform child demographic information. Only four studies reported the use of overall scores to inform study results, with the BDI (N =3) and SICD (N =1). Tests were often administered by researchers or trained SLPs, and took 15-30 minutes to complete.

Figure 3.5 Measures for Receptive and Expressive Syntax Measures

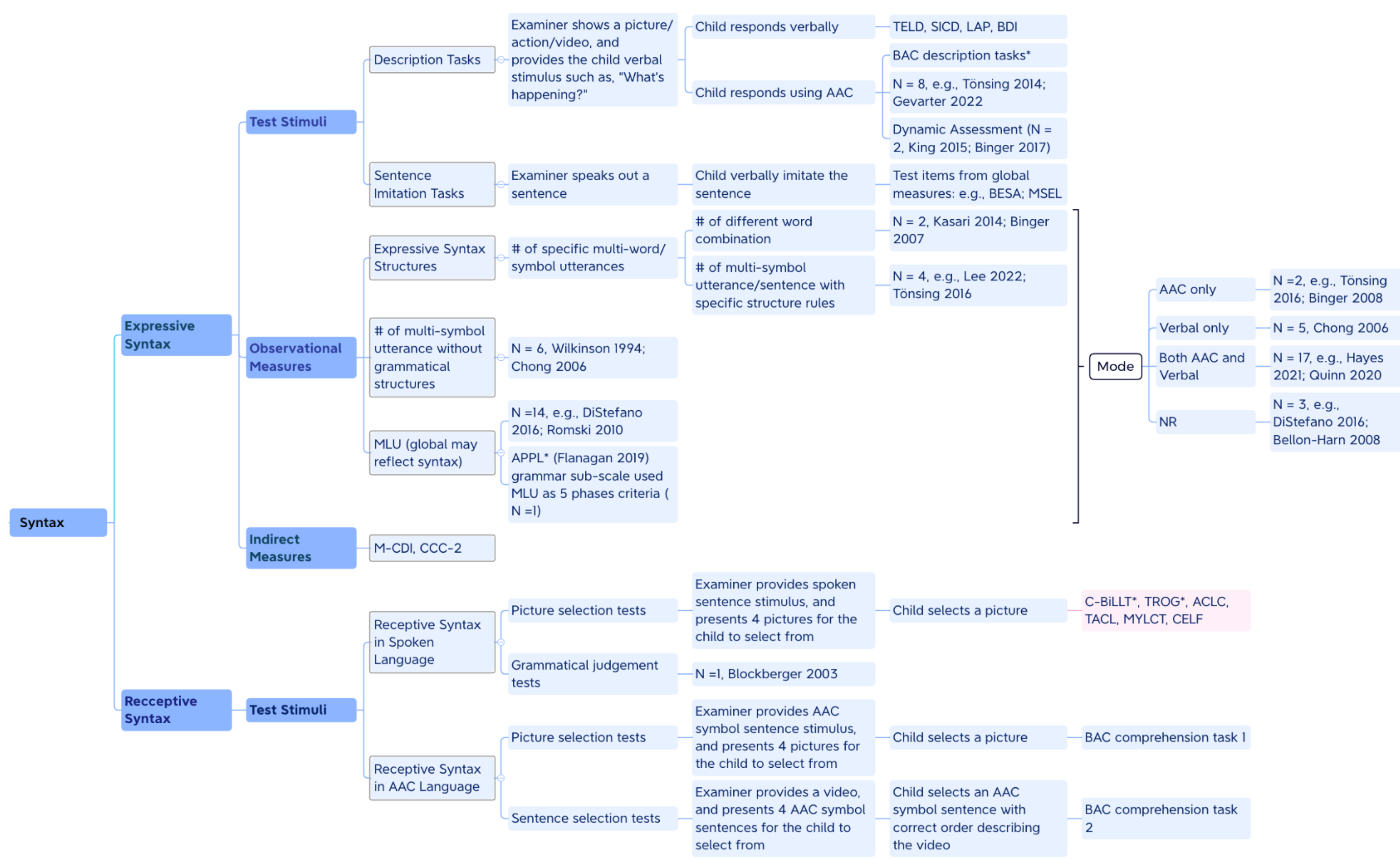
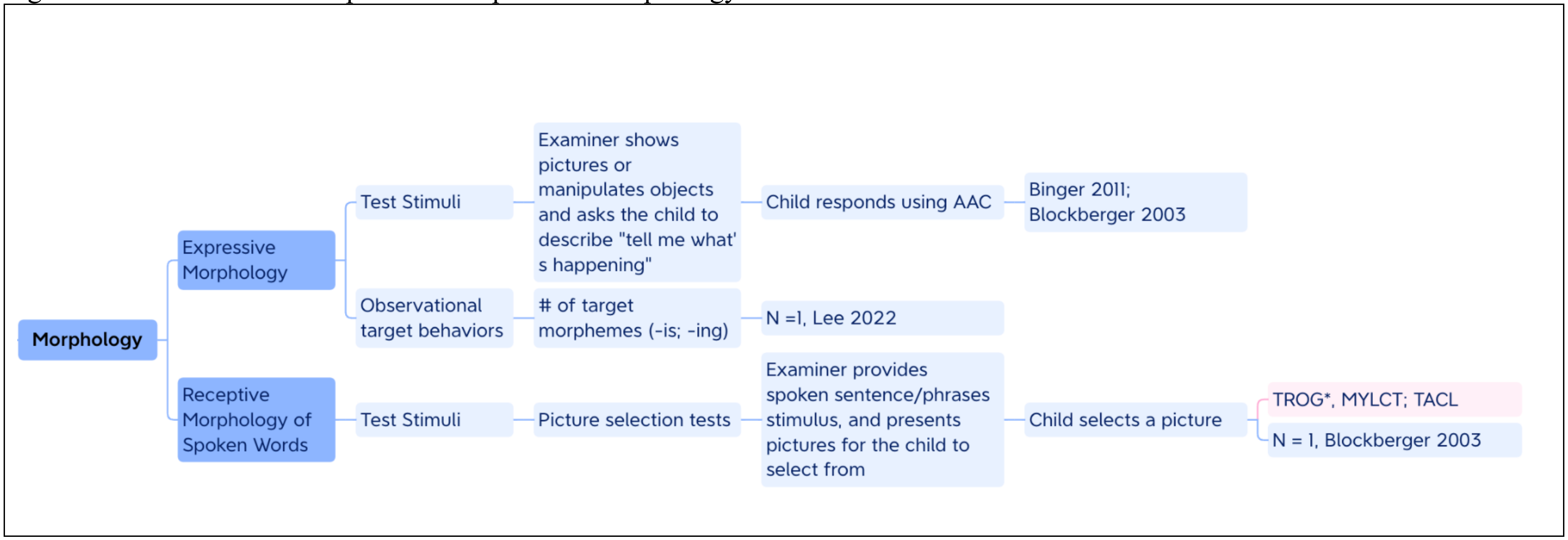


Figure 3.6 Measures for Receptive and Expressive Morphology Skills



Other tests allowed for AAC responses from the child. These tests included BAC, a self-developed pool of 50 items used in two studies (N = 2; Batorowicz et al., 2018; Stadskleiv et al., 2022). A few self-developed probe tests (Tönsing et al., 2014; Tönsing, 2016; Kent-Walsh et al., 2015; Lorah, Crouser, et al., 2014; Binger et al., 2017a; 2017b) and semi-structured observational measures also embedded stimuli in this format. The tests varied in number of items from 10 to 30. The tests were primarily conducted by researchers in clinical settings (N =3) or a quiet space in the classroom or home (N =2). All studies reported these tests informing study results. The most frequently targeted syntax structures included agent-action-object (e.g., "Pig chase cow"), entity-attribute (e.g., "Pig is happy"), entity-locative (e.g., "Pig under trash"), and possessor-entity (e.g., "Pig plate").

Following similar procedures with the direct tests mentioned above, semi-structured observational measures also embedded similar stimulus trials within intervention sessions, but differed by including prompts, error correction, and/or teaching. For example, in Tönsing (2016), during a shared book reading intervention activity, following verbal stimuli, the child used AAC to produce semantic-syntactic symbols describing the pictures. Feedback and interactive teaching trials were embedded throughout the test. In these measures, the child response was either reported as correct/incorrect or transcribed and evaluated on whether it contained the target sentence structures. The score was reported as the number or percentage of correct response (N = 4; Harris et al., 1996; Iacono et al., 1993; Lee et al., 2022; Tönsing, 2016). Some studies also reported error type as an outcome variable (Hochstein et al., 2004). Recently, a few studies have reported the development and use of dynamic assessment, in which the level of support was reported for each item response (King et al., 2015; Binger et al., 2017). Level of support was rated from 0 to 4, where 0 represents the child failed to make a correct response, 1 represents maximal support (i.e., both spoken and aided modeling support) and 4 represents minimum support (i.e., cueing or no support).

Imitation Tasks. A number of published tests also used items that require the child to imitate sentences spoken by the test examiner. These tests were included as part of language or developmental tests: BESA (N =1); MSEL (imitating sentence items, N = 16); TOLD (imitation sub-tasks, N =1); CELF (recalling sentences subtest, N =1).

Observational Measure Behavioral Targets

Expressive syntax and morphology skills was often measured through direct observation by analyzing spoken or AAC utterances with sentence or target morphologies. In defining the sentences, studies differed in whether they counted only multi-symbol utterances if they followed specific syntax structures (N =6) or all multi-word or sentence utterances without specifying the sentence structures (N = 6). Language samples of these sentence utterances were then transcribed and the length of utterances or mean length of utterances was reported (N =14). One study was identified in which the number of target morphemes (-is, -ing; Lee et al., 2022) was counted. As a result, target behaviors that reflect morphology and syntax skills included: (a) number of multi-symbol utterances following specific syntax structures, (b) number of sentences, (c) number of different word combinations, (d) utterance length, and (e) number of target morphemes. These behaviors were observed in both semi-structured (N = 7) and unstructured observations (N = 15). Child response modes included verbal only (N = 5), AAC only (N = 2), both AAC and verbal responses (N =17), and not specified (N = 3). In defining what accounts for one utterance, only one study used a time-based segmenting rule: child utterances of verbal, AAC, and signs should occur with no more than a 1s pause to count as one utterance (Quinn et al., 2020). Observation length ranged from 5 min (Quinn et al., 2020) to 45 min (Harris et al., 1996), with the majority ranging from 10-25 min per session. Observations took place during play activities (N = 14), book reading activities (N = 6), teaching activities (N = 2), routines (N =1), and group activities (N = 1).

Indirect Measures

Checklist/Parent Interview. A few checklists and screening tools were developed that include items reflecting the child's grammatical skills, including M-CDI (N = 5) and CCC-2 (N =1).

Receptive Morphology and Syntax Structures

Direct Tests: Picture Selection Tasks

To measure receptive syntax and morphology knowledge with direct tests, measures generally used a common procedure: children were provided a spoken sentence stimulus, and were asked to select a picture from a field of 4 that represented the spoken information. Six published tests were identified using picture selection test items: ACLC (N =1), C-BiLLT (N =4), TACL (N = 15), MYLCT (N = 2, both morphology and syntax), TROG (N =8, both morphology and syntax), and CELF (N =1). Similar procedures were employed in a subtest from the BAC (N =1), where the examiner provided an AAC sentence with different symbol combinations to test the child's understanding of AAC multi-symbol input. Only one study (Blockberger & Johnston, 2003) reported the use of a self-developed test measuring spoken language morphology and syntax with tailored targets. Compared to expressive picture tests, receptive picture selection tasks do not require verbal response, and therefore were more frequently reported to inform study results for children who use AAC (N = 12). These tests varied in length and took 10-30 min to complete.

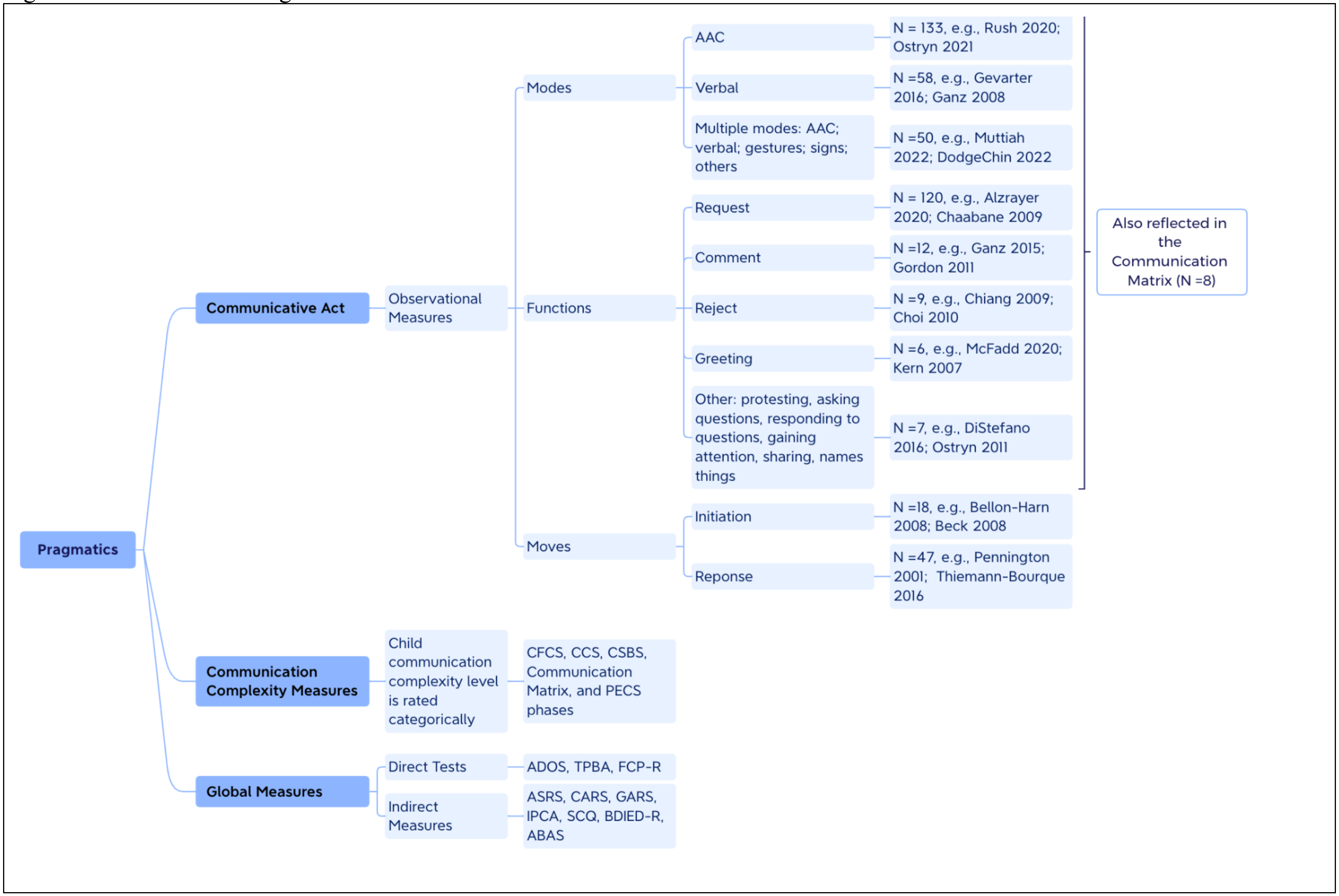
Direct Tests: Grammatical Judgement Tasks

One study (Blockberger & Johnston, 2003) used a grammatical yes/no judgement tasks. In this self-developed test, the examiner provides a list of stimuli of spoken sentence structures and asks the child to provide a yes/no response to determine whether the spoken sentence is correct or not. This study included children with cerebral palsy from age 5 to 17 years old.

Other Testing Methods

Unknown Formats: **Syntactic Understanding.** The TOLD (Hammill & Newcomer, 2008) has a sentence understanding sub-test which measures a child's ability to comprehend the meaning of sentences. The test was only reported in one study and the procedure was not identified in the study (Hill 2014).

Figure 3.7 Measures for Pragmatic Skills



Measurements of Pragmatics Skills

Pragmatics are conceptualized as communication skills, referring to rules that govern the use of language and non-linguistic behaviors in social contexts for the purpose of communication (Iacono, 2003; Roberts et al., 2007).

Counting the Number of Communicative Acts

Communicative acts, that is, the act of initiating or responding to a communication, are the most frequently used direct observational measures related to pragmatic skills (N = 183). Communicative acts were measured in a number of settings, including home settings, schools, and clinics. Communication partners included parents, teachers, researchers, SLPs, and peers. Each communicative act may be further coded as reflecting different modes, functions (i.e., reasons to communicate), and moves (i.e., conversational nature of communication).

Communicative Acts and Modes

Communicative acts were defined primarily based on the mode of communication and whether there was communicative intention. Frequently reported modes of communication include verbal (N = 58), AAC (N =133), or multiple modes (i.e., combining all AAC, verbal, gestures, signs without reporting a specific number for each mode; N =50). Among studies that included verbal communication modes, word approximations were often considered as verbal communication as long as they were intelligible to observers. Despite the fact that imitations are an important consideration in defining communicative intent, only 33 studies reported that imitation was differentiated from independent verbal utterances. All studies included AAC mode in counting communicative acts and children’s AAC systems varied greatly, including basic picture exchange systems and complex digitized systems.

Communicative Moves

Some studies specified the communicative moves, that is, whether the communication act was a child initiation or a child response. Only a few studies measured child communication initiations (N = 18); most studies focused on communication responses (N = 47).

Communicative Functions

Communicative acts can be further categorized based on their functions. The vast majority of studies reported requesting skills (N = 120); some studies also included rejecting (N = 9), greeting (N =6), and commenting (N =12). Other communicative functions noted in existing studies included: protesting, asking questions, responding to questions, gaining attention, and sharing.

Global Measures with Communication Subscale or Items

Since social communication difficulties are a key characteristic of children with ASD, ASD diagnostic measures through direct tests and indirect rating skills often contain a communication subscale. Other global measures of language and communication skills may also have communication subscales.

Direct Tests

Direct tests included ADOS (N =7), TPBA (N=1), and FCP-R (N =1). In these tests, the examiner provides communication opportunities during interactive play activities using standardized toys. Test items are used to address social communication skills by observing the child's reaction to the examiner's questions or instructions.

Indirect Rating Through Questionnaires

Indirect measures included parent and teacher questionnaires with items describing the child's daily social communication behaviors. A number of indirect rating scales were identified to inform children's demographic information, including: ASRS (N = 5), CARS (N =1), GARS (N =1), IPCA (N =2), SCQ (N=1), BDIED-R (N =1), ABAS (N = 2).

Communicative Complexity Measures

Tests, Observation, and Indirect Measures

Another way to measure pragmatic communication skills is to rate the child's communication complexity based on one or more of the following sources: direct observation, direct tests, and/or parent rating. Child communication complexity may range from single word utterances to multi-symbol communication. Measures that used this method include CFCS (N = 8), CCS (N = 1), CSBS (N = 7), Communication Matrix (N =8), and PECS (N = 11). For example, there are 6 phases defined in PECS that indicate the child's communication complexity level from using single AAC symbols to make picture exchange to using multiple symbols to make comments; these phases are often reported in studies to indicate the child's pragmatic communication skills.

Measurement of AAC Use Related Skills

According to the theoretical framework proposed by Light and McNaughton (2014), in addition to linguistic and pragmatic skills, children require operational skills and strategic skills in order to demonstrate effective communication. This review conceptualizes these skills as AAC use related skills that are different from linguistic (i.e., language form and content) and pragmatic skills (i.e., language use). This review identified two AAC use related skills other than linguistic and pragmatic skills: AAC symbol recognition and AAC operation skills.

AAC Symbol Recognition

AAC symbol recognition measures a child's ability to recognize symbols due to the representativeness of the graphic design of the symbol rather than the child's semantic knowledge. Direct tests were often used to test whether the child could recognize the symbols of familiar items (e.g., pre-test for C-BiLLT, Geytenbeek, Vermeulen, et al., 2015) to determine if the child could perform the vocabulary test that was the focus of the study, or used to test whether the child understood how an object (rather than a word) is represented by a symbol (e.g., Hartley & Allen, 2015a; McCarthy et al., 2018; Sevcik et al., 2018; Wainwright et al., 2020;).

AAC Operational Skills

Direct tests of AAC operational skills were specifically measured in two group design studies (McDougall et al., 2012; Schlosser et al., 2013), where the examiner presented a verbal stimulus of a word and asked the child to find the word in their AAC systems in a digitized device containing multiple pages and/or a picture symbol book containing multiple pages. The test required the child to navigate from a main page to a target page and identify the target symbol from a number of other symbols. The number of symbols was controlled (McDougall 2012) or varied across participants (Schlosser et al., 2013). This skill is different from AAC symbol recognition skills since the goal of operational skills is to properly operate the AAC system and find a known symbol from it. Although other studies did not report operational skills specifically, some observational measures in SCD studies defined their target requesting skills including the AAC operational behavioral chain, a concept that includes operational skills (e.g., Carnett et al., 2019; Gevarter et al., 2018; Genc-Tosun & Kurt, 2017). For example, Genc-Tosun & Kurt (2017) defined a correct request as the child completing the following behaviors: pressing on the home button of their digitized AAC to unlock the screen, selecting the category of their preferred items, scrolling the page to identify the target symbol, touching the symbol, and taking the requested object. Completing this procedure required AAC operational skills, although it was not measured as a separate skill from communication.

Reliability and Validity Evidence of Identified Measures

Reliability Evidence

Self-Developed Observational Measures and Probe Tests

The majority of studies that reported the use of observational measures and self-developed probe tests to inform study results reported reliability evidence. Inter-observer agreement (IOA) was reported for most studies by reporting percentage of agreement among coders. Other reliability evidence included Cohen's kappa coefficient, intra-rater agreement, and intra-class correlational analysis. Sessions selected for reliability coding ranged from 10% to 100%, with the majority of studies reporting a minimum of 20% of observational sessions for IOA coding. The results below summarize percentage agreement for language and communication skills.

The mean IOA and range of IOA across sessions are summarized in Table 3.6. In terms of structure of measures, mean IOA was higher when measured with structured tests; semi-structured observational measures and unstructured observational measures had more variability in their IOA. Regarding linguistic skills, mean IOA for semantics and syntax related skills were all above 80%, showing good reliability evidence; none of the five studies that measured morphology information reported reliability evidence. Also as indicated in table 3.6, IOA varied across functions and modes.

Reliability Evidence for Published Measures

Only 20 studies reported reliability evidence for 18 published measures, including self-reported reliability evidence and reliability evidence cited from other studies. Table 3.7 presents the measures and studies that reported self-reported reliability evidence within children with CCN.

Table 3.6 Reliability Evidence of Observational Measures

Categories		Mean IOA range (%)		Session IOA range (%)	
		min	max	min	max
Structure of test					
	Probe test	90	100	60	100
	Semi-structured observation	44.7 (1 session <80%)	100	21	100
	Unstructured observation	63 (3 sessions < 80%)	100	36	100
Linguistic skills					
	Semantics	85	100	79	100
	Syntax	81	100	63	100
	Morphology	NR	NR	NR	NR
Language use (Pragmatics)		44.7	100	21	100
	Function-request	44.7 (63)	100	Unknown	100
	Function-comment	82	100	67	100
	Function-reject	95	98	Unknown	100
	Moves	80	100	67	100
	Mode-Verbal	44.7	100	21	100
	Mode-AAC	63	100	60	100

Table 3.7 Reliability Evidence for Published Measures

Measure	First author/ year	Reliability evidence
BAC	Stadskleiv 2022	intra-rater reliability intra-class correlation (ICC) = of 0.94, p < .001.
BDIED-R	Stahmer 2004	Average reliability ranged from 80% to 86% for functional communication skills, functional social interaction skills, and 82% for functional play skills. The range for each was 50% to 100%.
C-BiLLT	Geytenbeek 2014	[1] Intra-observer (n=32) and intra-observer reliability (n=35) were ICCs of 0.97 (95%CI=0.95–0.99) and 0.97 (95%CI=0.95–0.98), respectively. [2] SEM for intra- and inter-observer reliability for this group was 3.40 and 3.00, respectively. [3] Cronbach's alpha and Guttman's lambda[2] calculated with 75 items (see structural validity) in the group of children with cerebral palsy are 0.91 and 0.94.
C-BiLLT	Geytenbeek 2010	Sections 1–3 showed a high agreement with their respective parallel versions (Cronbach's alpha = 0.97 for Section 1 and Section 2; 0.93 for Section 3). Inter- and intra-observer agreement was evaluated for the children with CP (Cohen's Kappa 1=0.8 and an ICC =0.92 for inter- and intra-observer agreement, respectively

Table 3.7 (cont'd)

Measure	First author/ year	Reliability evidence
CFCS	Hidecker 2018	[1] inter-rater reliability among professionals are good (weighted kappa = .66) to excellent (weighted kappa = .98) [2] correlation between professionals and parents ranged from moderate (weighted kappa = .49) to excellent (weighted kappa = .91) [3] test- retest reliability (weighted kappa = 0.82)
Commu nication Matrix	Quinn 2017	Studies of construct validity, interrater reliability between parents and professionals, interrater reliability between professionals, test–retest reliability, sensitivity to change, and consumer satisfaction are reported in Rowland (2012). Briefly, four studies of reliability have produced interobserver agreement scores ranging from 83% to 93%; and a study of test–retest reliability resulted in an average 89% agreement (Rowland, 2011).
IPCA	Braddock 2016	IOA: 100%
MY	Osguthorpe 1988	internal consistency, Cronbach's Alpha = .93
RDLS-Dutch	vanderSchuit 2010	Cronbach's alpha = .90
STLP	vanderSchuit 2010	[1] sentence development or expressive syntax (Cronbach's alpha = .85), [2] and word development or expressive vocabulary (Cronbach's alpha = .87).
TASP	McDougall 2012	[1] different form correlation: The correlation of the participants performance on the subtest on the traditional compared to the computerized presentation method was rs = .86, p = .05. [2] Kuder-Richardson Formula 20 (KR-20) values for the traditional and computerized presentations of the test were .97 and .95, respectively. These results suggested that the internal reliability of the measure was maintained in the computerized presentation of the subtest. [3] IOA: All scores were compared and inter-rater reliability was found to be 100%.
VABS	Noens 2006	The reliability and validity of the American version of the Vineland Adaptive Behavior Scales were studied and described extensively. With respect to the Dutch Vineland Screener 0-6, all coefficients of inter-rater reliability, test–retest reliability and internal consistency are 0.89 or higher.

Validity Evidence

According to the Standards for Educational and Psychological Testing (Standards), validity refers to the degree to which evidence and theory support the interpretation of measurement scores for the proposed use of tests within a particular population (AERA/APA/NCME, 2014). Therefore, providing validity evidence of measures within the population of children who use AAC is important. This review identified a total of four studies (Brady et al., 2018; Flanagan et al., 2019; Geytenbeek et al., 2010; 2014) that provided preliminary validity evidence specifically for children with CCN who use AAC systems, and an additional three studies that did not clearly claim validity evidence, but the goals of the studies could potentially be interpreted to provide validity evidence for children with CCN (Batorowicz et al., 2018; DeVeney et al., 2012; Ross & Cress, 2006). The measures included in these seven studies included: APPL (which used number of different words, number of total words, and mean length of utterances as items), BAC (i.e., naming tasks, BAC vocabulary comprehension tasks, BAC other comprehension tasks), C-BiLLT (Dutch), CCS, BDI receptive language, dynamic assessment (i.e., expressive syntax skill tasks using AAC), M-CDI (i.e., overall & expressive language), CSBS communicative acts, and SICD receptive language. The correlations within the seven validity evidence studies also provided preliminary convergent validity evidence (i.e., relation to other measures) for the following tests: PPVT/BPVS, TROG, CFCS, VABS expressive communication, Communication Matrix, and RDLS. Table 4.8 presents each test, its validity evidence, and information about participants for whom the validity evidence was collected. The written result below is organized based on language and communication skills and testing format of these measures.

Table 3.8 Validity evidence for published measures in children with CCN

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
APPL*	Flanagan 2019	Children at higher overall APPL language phases had greater mean age-equivalent scores on the expressive language subdomain of the VABS-II (83% of the participants; one-way ANOVA, F (3, 75) = 54.68, p<.001).	95	56 (49-69)	NR	ASD
BAC*	Batorowicz 2018	Authors explored the relation between BAC scores and other standardized tests of language. [1] BAC vocabulary comprehension task significantly correlated with PPVT/BPVS (r=0.41, p<.01), TROG (r = 0.42, p<.01), Spelling (-0.47, p<.01), and CFCS (-0.47, N =p<.01). [2] sum of BAC comprehension of sentence & syntax tasks significantly correlated with TROG (r = 0.62, p<.05), Spelling (-0.47, p<.01), and CFCS (-0.47, N =p<.01). However, it did not correlate with PPVT/BPVS. [3] BAC naming tasks correlate with PPVT/BPVS (r=0.49, p<.01), TROG (r = 0.64, p<.01), and CFCS (-0.66, N =p<.01). Did not correlate with spelling (-0.47, p<.01). [4] BAC description tasks correlate with spelling (-.058, r <.01), did not correlate with PPVT/BPVS, TROG, CFCS.	96	130 (60-180)	Multiple	CP
C-BiLLT*	Geytenbeek 2010	C-BiLLT total score correlates significantly with the RDLS total score (r = 0.84, p < .001). C-BiLLT scores showed significant difference between children with different types of cerebral palsy (X^2(df 3, n=18)=5.54, p< .1).	18	19-75	NR	CP

Note. * measures with direct validity evidence. NR = not reported. ASD = Autism spectrum disorders. CP = cerebral palsy.

Table 3.8 (cont'd)

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
C-BiLLT*	Geytenbeek 2014	EFA yielded a one factor solution, which explained 76% variance and factor loadings ranged from 0.43 to 0.99. C-BiLLT significantly correlate with PPVT-3 in children with cerebral palsy (r = 0.87, p value unknown).	87	36.38 (12-144)	NR	CP
CCS*	Brady 2018 study 1	CCS optimal scores significantly correlate with VABS expressive language skills (r= 0.42, p < .01) and the Communication Matrix (r = 0.28, p <.01), indicating good concurrent validity evidence.	239	3–66 years including 2-6 yr old children	NR	ID, < 20 functional words
CCS*	Brady 2018 study 2	CCS optimal scores significantly correlated with rate of initiation of joint-attention per minute (r = .334, p < .01) and rate of initiation of behavioral regulation per minute (r = .340, p < .01) from ESCS (Mundy et al., 2003), showing good concurrent validity evidence.	110	3-9 years	NR	ASD
Communication Matrix*	Quinn 2017	"The Communication Matrix has demonstrated content validity for addressing the expressive communication skills of individuals with CCN (Rowland & Fried-Oken, 2010)"	NR	NR	NR	NR
Communication Matrix	Brady 2018 study 1	CCS optimal scores significantly correlate with VABS expressive language skills (r= 0.42, p < .01) and the Communication Matrix (r = 0.28, p <.01), indicating good concurrent validity evidence.	239	3–66 years including 2-6 yr old children	NR	ID, < 20 functional words

Note. * measures with direct validity evidence. NR = not reported. CP = cerebral palsy. ID = intellectual disabilities.

Table 3.8 (cont'd)

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
BDI receptive*	Ross 2006	Results indicates that Battelle receptive language skills significantly correlate with M-CDI during 3 data collection sessions (r range from 0.69 to 0.87, $p < 0.05$). Indicating good convergent validity evidence.	41	18.2 (9-27)	At risk for using AAC	CP 18; TBI 9; other 14
BDI receptive*	DeVeney 2012	[1] BDI receptive language skills, BDI expressive language skills, CDI-receptive vocabulary, SICD receptive language, and communicative act rated from CSBS significantly correlate with each other (r range from 0.40-0.93, $p < .01$). [2] A two-factor confirmatory factor confirmed that BDI receptive language skills, CSBS communicative act, SICD receptive language, CDI receptive language loaded on the same factor, indicating they are measuring the same underlying construct.	42	18.2 (9-27)	At risk for using AAC	Physical or neurological
DA*	King 2015	Correlation between dynamic assessment scores DA (i.e., average support level scores) and a self-developed syntax test (picture/video description test using AAC to respond, reporting # correct responses) were reported to support predictive validity evidence of the dynamic assessment. Three out of four participants demonstrate moderate correlation, r^2 range from 0.25-0.44. One participant demonstrated a trivial correlation, r^2=0.0.	4	60-70	SGD	CP 1; TBI 1; speech disorder 2

Note. * measures with direct validity evidence. DA = dynamic assessment. CP = cerebral palsy. TBI = traumatic brain injury.

Table 3.8 (cont'd)

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
M-CDI*	Ross 2006	Results indicates that Battelle receptive language skills significantly correlate with M-CDI during 3 data collection sessions (r range from 0.69 to 0.87, $p < 0.05$). Indicating good convergent validity evidence.	41	18.2 (9-27)		CP 18; TBI 9; other 14
M-CDI*	DeVeney 2012	[1] BDI receptive language skills, BDI expressive language skills, CDI-receptive vocabulary, SICD receptive language, and communicative act rated from CSBS significantly correlate with each other (r range from 0.40-0.93, $p < .01$). [2] A two-factor confirmatory factor confirmed that BDI receptive language skills, CSBS communicative act, SICD receptive language, CDI receptive language loaded on the same factor, indicating they are measuring the same underlying construct.	42	18.2 (9-27)	At risk for using AAC	Physical or neurologic al
Commu nicative act from CSBS*	DeVeney 2012	[1] BDI receptive language skills, BDI expressive language skills, CDI-receptive vocabulary, SICD receptive language, and communicative act rated from CSBS significantly correlate with each other (r range from 0.40-0.93, $p < .01$). [2] A two-factor confirmatory factor confirmed that BDI receptive language skills, CSBS communicative act, SICD receptive language, CDI receptive language loaded on the same factor, indicating they are measuring the same underlying construct.	42	18.2 (9-27)	At risk for using AAC	Physical or neurologic al

Note. * measures with direct validity evidence. DA = dynamic assessment. CP = cerebral palsy. TBI = traumatic brain injury.

Table 3.8 (cont'd)

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
SICD*	DeVeney 2012	[1] BDI receptive language skills, BDI expressive language skills, CDI-receptive vocabulary, SICD receptive language, and communicative act rated from CSBS significantly correlate with each other (r range from 0.40-0.93, p < .01). [2] A two-factor confirmatory factor confirmed that BDI receptive language skills, CSBS communicative act, SICD receptive language, CDI receptive language loaded on the same factor, indicating they are measuring the same underlying construct.	42	18.2 (9-27)	At risk for using AAC	physical and/or neurological
TROG	Batorowicz 2018	In the aided group, TROG cor with BPVS/PPVT r= 0.6** (n=37) p<.001; with Raven 0.45** (38); with spelling -0.50** (37);with CFCS -0.39* (37); Percent correct Vocabulary Comprehension 0.42** (41); with Percent correct Sum of other Comprehension tasks 0.62** (25); with Percent correct BAC Naming 0.64** (34)	96	130.3 (60-180)	Multiple	CP 85; other 8
VABS (Vineland)	Flanagan 2019	Children at higher overall APPL language phases had greater mean age-equivalent scores on the expressive language subdomain of the VABS-II (83% of the participants; one-way ANOVA, F (3, 75) = 54.68, p<.001).	95	56 (49-69)	NR	ASD
PPVT	Geytenbeek 2014	Correlation with others: PPVT-3 correlates with C-BiLLT, r = 0.87, p < .05	87	12-144	Not reported	CP

Note. * measures with direct validity evidence. DA = dynamic assessment. CP = cerebral palsy. ASD = Autism spectrum disorders.

Table 3.8 (cont'd)

Name	First Author/Year	Validity Evidence	# of participants	Age (month)	AAC Systems	Diagnosis
PPVT/BPVS	Batorowicz 2018	Correlation with others: BPVS-2/PPVT-3&4 significantly correlated with TROG ($r = 0.6$, $p < .01$), CFCS level (i.e., higher score represents lower communication ability, $r = -0.27$, $p < .05$), BAC Vocabulary Comprehension tasks (percentage correct, $r = 0.41$, $p < .01$), and BAC Naming tasks (percentage correct, $r = 0.49$, $p < .01$); BPVS-2/PPVT-3&4 did not correlate with spelling ability.	96	130.3 (60-180)	Multiple	CP 85; other 8
CFCS	Batorowicz 2018	Authors explored the relation between BAC scores and other standardized tests of language. CFCS significantly correlated with BAC vocabulary comprehension task (-0.47, N =p<.01); BAC comprehension of sentence & syntax tasks (-0.47, N =p<.01). **Did not correlate with BAC naming tasks.**	96	130 (60-180)	Multiple	CP
RDLS	Geytenbeek 2010	C-BiLLT total score correlates significantly with the RDLS total score ($r = 0.84$, $p < .001$).	18	19-75	NR	CP

Note. DA = dynamic assessment. CP = cerebral palsy.

Receptive Semantic Knowledge Measures with Validity Evidence

Picture Vocabulary Tests. Two spoken vocabulary measures and one AAC symbol vocabulary measure using a picture vocabulary test format showed preliminary validity evidence within children with CCN. These tests are: PPVT/BPVS (Dunn & Dunn, 1997; 2007), C-BiLLT (Geytenbeek et al., 2010; Geytenbeek et al. 2014), and the BAC vocabulary comprehension tasks (Batorowicz et al., 2018).

PPVT and BPVS (i.e., the British version of PPVT) versions included PPVT-R (Dunn & Dunn, 1981), PPVT-3 (Dunn & Dunn, 1997), PPVT-4 (Dunn & Dunn, 2007); BPVS-2 (Dunn et al., 1997), and BPVS-3 (Dunn & Dunn, 2009). PPVT-3, PPVT-4, and BPVS-2 showed validity evidence of relation with other variables in children with cerebral palsy in two studies (Table 3.5). C-BillT is a computer assisted picture vocabulary test (Geytenbeek et al., 2010; 2014) with validity evidence in the following areas: relation with other measures (i.e., RDLS, PPVT) and construct validity (i.e., test scores are significantly different across different types of cerebral palsy and exploratory factor analysis supported a one factor solution). For the BAC Vocabulary Comprehension Task, convergent validity evidence was supported for the BAC vocabulary comprehension test, since it had significant correlations with other language measures (i.e., PPVT/BPVS, TROG, Spelling, CFCS; see Table 3.5).

Expressive Semantic Knowledge Measures with Validity Evidence

Picture Naming Tasks. Among measures that assessed expressive semantic knowledge, the only measure that had validity evidence is the ***BAC naming test*** (measured in Deliberato et al., 2018), showing correlations with PPVT/BPVS, TROG, and CFCS. It did not correlate with spelling.

Observational Measure: Number of Different Words & Number of Total Words. Though there was no direct validity evidence for number of different words and number of total words utterances, the semantic subtest of APPL included both as phase rating criteria. For example, the phase 2 criteria for semantic development indicate that children need to demonstrate at least 5 different words and 20 utterances during a 20 minutes' observation. The APPL total phase score was supported with convergent validity, indicating the potential for using both number of different words and number of total words as valid methods of measuring semantic knowledge.

Grammatical Measures with Validity Evidence

Receptive Grammatical Measures: Picture Selection Tests. Three measures that used picture selection tests provided validity evidence, including TROG (i.e., correlate with PPVT, BAC, CFCS, and spelling), RDLS (i.e., correlate with C-BiLLT), and C-BiLLT (i.e., evidence of correlation with others and construct validity). All validity evidence was with children who have cerebral palsy.

Expressive Syntax Measures: Picture Description Task Using Dynamic Assessment. Mixed validity evidence was found for a dynamic assessment using picture description task to measure syntax skills (King et al., 2015). As mentioned earlier, dynamic assessment is a semi-structured observational measure with prompts given to the child during the measurement procedure. Instead of providing count coding for a target behavior, dynamic assessment code levels of support for each child response to testing stimuli. Predictive validity evidence was demonstrated only in three of four participants using the dynamic assessment in predicting performance on a self-developed picture description test. Given that both tests were in early development, further sources of validity evidence with additional participants is needed before conclusions about validity can be made.

Observational Measure: Mean Length of Utterance. There was no direct validity evidence for mean length of utterance, although mean length of utterance was included as a phase criterion in the APPL measure, which demonstrated preliminary convergent validity evidence.

Measures of Pragmatic Skills

Observational Measure: Communicative Act. The number of communicative acts collected during the CSBS measure was shown to correlate with other measures (i.e., BDI, M-CDI receptive vocabulary, SICD receptive language), and evidence suggested that it measured the same construct as BDI receptive vocabulary, M-CDI receptive vocabulary and SICD receptive language (DeVeney et al., 2012). Additionally, one study (Quinn et al., 2020) measured the rate of symbolic communication acts as a dependent variable, and reported this measure as a valid measure of expressive communication growth (Greenwood et al., 2013).

Global Communication Measure: Communication Matrix. Communication matrix was supported with content validity evidence (Rowland & Fried-Oken, 2010; Quinn & Rowland, 2017) and preliminary evidence showing a correlation with CCS (Brady et al., 2018).

Communication Complexity Level Rating. Three measures were identified using this categorical rating scale representing children’s communicative complexity or developmental stages: CFCS, APPL, and CCS.

CFCS. The CFCS yields a 5-level score, with Level I indicating the best communication and Level V, the most severely affected. CFCS correlates with PPVT/BPVS, and TROG in children with cerebral palsy (Batorowicz et al., 2018).

APPL. Flanagan (2019) provided preliminary validity evidence that children at higher overall APPL language phases had greater mean age-equivalent scores on the expressive language subdomain of the VABS-II.

CCS. CCS showed concurrent validity evidence as it correlated with VABS expressive language skills, communicative matrix, and social-communication acts measured by ESCS (Table 3.5). However, participants included a substantially large age range in people with cerebral palsy who have limited verbal skills (Brady et al., 2018). Additionally, in a second Brady (2018) study, language skills and AAC systems were not reported for participants who had ASD, so their linguistic needs were unknown. Future studies should further test validity evidence in young children who use aided AAC to communicate.

Global Measures

Measures that Used Multiple Methods of Testing. Two measures were identified that have test items using a combination of different testing formats to measure language and communication skills: BDI Receptive and Expressive Subscales and VABS Communication Subscale.

BDI Receptive and Expressive Subscales**.** Both BDI receptive and expressive language scales were shown to be correlated with other language measures and assess the same construct as other receptive and communication measures (i.e., M-CDI receptive vocabulary, SICD receptive language, and communicative act; DeVeney et al., 2012). However, a confirmatory factor analysis of the five language and communication scores and other domains from BDI yielded a two-factor solution. Results showed that the measures of expressive communication (CSBS communicative act), BDI receptive language, SICD receptive language, and CDI receptive language loaded on one factor, while BDI expressive language and other BDI domains (i.e., cognitive, motor, adaptive, social) loaded on another factor. This result indicates that the BDI expressive subscale may not measure the same construct as other language tests. It also indicates that providing only evidence of correlation with other measures may not be sufficient validity evidence.

VABS Communication Subscale. VABS was supported with convergent validity evidence as it correlated with APPL language phases scores.

Narrative Skills: BAC Description Tasks. BAC Description tasks only correlated with Spelling, and did not correlate with other measures (i.e., PPVT/BPVS, TROG, CFCS; Batorowicz et al., 2018). Future studies should explore how to measure global linguistic skills.

Other Observational Measures

Despite the fact that validity is an important psychometric property of observational measures, almost no studies reported validity evidence for observational measures. One study was identified that evaluated content validity for reliability evidence of 13 linguistic variables (Lee et al., 2022). This study presented a full list of coding manual, definition, examples and non-examples for language and communication observational measure variables. The authors mentioned that the coding manual was developed through 9 months across two separate research sites. Data from a related but separate ongoing randomized controlled trial involving different participants was used to develop the definitions and coding schemes, with modifications made for this study as needed. Thus, this study showed preliminary theoretically driven content validity evidence. However, external expert review was not reported, a standard approach for content validity evidence.

CHAPTER 4: DISCUSSION

What Skills were Measured and What Should be Measured?

This review found previous empirical studies measured a broad range of language and communication skills, including pragmatic skills (i.e., language use in social situations) and linguistic skills (i.e., semantics, syntax, and morphology), as well as global language and communication skills for 2-6 years old children who use aided AAC. In addition, this study identified two AAC use related skills that are important and measurable factors that may influence communication performance, but are also different from linguistic and pragmatic skills: AAC symbol recognition and AAC navigational skills. However, major research gaps exist in the following three areas. First, previous studies have had a primary focus on pragmatic skills and semantic knowledge, with only a few studies measuring syntax, morphology, and AAC related skills. Second, within communication skills, most studies focused on requests or communicative acts, with only a few global measures that targeted comprehensive communicative function or communication skills (e.g., ADOS) and only a few studies that reported other communicative functions such as making comments, descriptions, greetings, and rejection. Third, both expressive and receptive skills were measured when describing children's demographic information; however, there was a lack of receptive measures informing study results.

Grammatical Knowledge: Syntax and Morphology Skills

Consistent with previous study findings (Gevarter et al., 2022), current research primarily focused on one-word communicative acts and single-word meaning, with only a few addressing multi-symbol utterances that include syntax and morphology features. In typically developing children, syntax and morphology skills start developing from around 18 months of age when the child begins to use two-word utterances (Fahey et al., 2019). Being able to understand rules that connect words is an important skill for children to build complex language (Binger & Light, 2008), which is in turn important for their later literacy development and to participate in meaningful academic and social activities (Kent-Walsh & Light, 2003). In this scoping review, among studies that measured syntax and morphology skills, a large proportion of these studies were originally designed to include a broader age range, such as primary school students and older students. In fact, studies have shown that children with CCN were able to build sentence-like multi-symbol utterances around 3-5 years of age (Binger et al., 2010; 2017). However, little is known about how children develop early grammatical skills using AAC and how to support early grammatical development in children with CCN. Future studies should explore how to effectively measure young children's grammatical skills and how to support sentence building in young children with CCN.

Pragmatic Skills: Communication Functions Beyond Request

Pragmatic skills are the most frequently measured language and communication skills in existing literature. Pragmatic skills measured in previous studies covered several broad subdomains including forms, functions, and moves (Toppelberg & Shapiro, 2000; Bernstein & Tiegerman-Farber, 2009; Bloom & Lahey, 1978; Landa 2005). However, the vast majority of measures only reported either communicative acts or requests, a narrow representation of pragmatic skills. Few studies reported other functions, including comments, rejections, greetings, asking questions, gaining attention, and expressing feelings (e.g., Schlosser et al., 2020), all of which are important functions to fulfil children's needs. Given the fact that the vast majority of included studies examined interventions using a SCD or group experimental design (76.24%), these results indicate requests and communicative acts were the primary intervention targets.

This might be because requesting skills is an important early emerging communication skill and relatively easy for children to acquire compared to other functions (Schlosser et al., 2020). Existing research suggests that children with CCN can fulfill a wide range of communication functions (Smith, 2015). A recent study that observed communicative functions of children with CCN during a six-month period found that requesting and rejecting together accounted for around 40-60% of their communication, discussion (comment) about object/activities accounted for 20-40% of their communication, and other functions accounted for 10-20% (DiStefano et al., 2016). This result indicates preschool children with CCN have the need to go beyond just requesting and be able to communicate with different functions. Future studies should further explore measuring other communicative functions.

Receptive Language Skills

This review found that few studies measured receptive language skills compared to expressive language skills. There are a number of well-developed receptive language tests that were originally developed for typically developing children. Given the fact that these receptive measures do not require verbal responses, group design studies included in this review often reported receptive language scores to inform study results. However, in SCD studies where standardized tests were only used for informing demographic information, the majority of self-developed observational measures and probe tests targeted expressive language skills. However, the measurement of linguistic competence may not be accurately reflected by expressive tasks alone. As mentioned in the results, a study showed that the Battelle expressive language subscale along with other domains that required verbal responses were not measuring the same construct as the Battelle receptive language subscale and other receptive measures (DeVeney et al., 2012). Receptive language measures may provide a more accurate representation of children's linguistic competence (Light, 2003). Future studies should consider including receptive language measures for children with CCN.

AAC Related Skills

This study identified AAC operational (i.e., navigational skills) and symbol recognition skills (i.e., whether children can recognize the symbol with already known words) as important skills uniquely related to communication for children who use AAC. AAC operational skills include the ability to activate AAC systems, identify symbols from their AAC systems, navigate pages or categories in their AAC systems, build symbols into a sentence, and activate their voice output (Light & McNaughton, 2014). This is an important skill that influences child communicative competence in addition to linguistic and pragmatics skills in the AAC competence model proposed by Light & McNaughton (2014). AAC operational skills were measured in only two studies (McDougall et al., 2012; Robillard et al., 2018;). There were a substantial number of studies which, although measurement of linguistic or pragmatic skills occurred, did not control for AAC operational skills and therefore the conclusions may have been influenced by AAC operational skills rather than the targeted skill. For example, in studies that measured Phase 4 PECS requesting skills, children needed to take out multiple symbols, put these symbols on a sentence strip, and hand symbols to their communication partners (e.g., Genc-Tosun & Kurt, 2017). Incomplete or incorrect procedures were not counted towards the final correct response count. As a result, child language and communication skills may have been underestimated because, without knowing the child's operational skills on the AAC systems on which they were being tested, it is hard to know whether an incorrect child response was because of a lack of linguistic skills or a lack of AAC operational skills despite adequate linguistic skills.

Therefore, future measures should consider measuring AAC operational skills and supporting these skills in general and when measuring other linguistic skills.

A second AAC related skill identified in this review is AAC symbol recognition, conceptualized as the ability to recognize the link between symbols and their referent in known vocabulary words. AAC symbol recognition skills were not clearly defined in existing studies and did not have a clear boundary from semantic knowledge of symbols as a linguistic skill. Nonetheless, symbol recognition is an important skill different from linguistic skills as children may learn a word in one AAC system, but not recognize the symbol representing the word in another AAC system. Some studies compared AAC symbol recognition with different AAC systems with the goal of identifying which AAC was more suitable for supporting child learning and communication (e.g., Tönsing, 2016). Additionally, child experience and familiarity with AAC symbols may influence their communicative competence (Light & McNaughton, 2014). There are also a few studies (e.g., Geytenbeek et al., 2010; 2014) providing a pre-test of symbol recognition skills in known words before they start formal symbol comprehension vocabulary tests in order to rule out the influence of unfamiliar symbols on the results. Future studies should further explore how to define AAC symbol recognition skills and consider providing symbol recognition tests before formal language measures.

Who were Targeted and Who should be Targeted?

Overall, this review found that existing studies included children with CCN who have a variety of underlying etiologies, including ASD, Down Syndrome, Cerebral Palsy, speech language impairment, developmental delay, and other disabilities. This result is consistent with previous studies that children with CCN are a heterogenous group including many different etiologies (Lund et al., 2017). However, the distribution of diagnoses differed between SCD studies and group design studies. The three most prevalent diagnoses reported by SCD studies included ASD (51%), uncategorized other or multiple disabilities (14%), and developmental disabilities or delay (11%); down syndrome, intellectual disabilities, speech language impairment, apraxia of speech, and cerebral palsy were less represented, accounting for 3% to 7%. On the contrary, the vast majority of participants from group design studies were diagnosed with cerebral palsy (62%) or ASD (23%), with only a few with other diagnoses. This result indicates that children who have cerebral palsy were underrepresented in SCD studies, while children who have other types of disabilities were underrepresented in group design studies in language and communication measures. Future studies should consider including children with cerebral palsy in SCD intervention studies supporting early language and communication learning, and consider including children with other etiologies in group design studies.

Despite the variety of diagnoses for child participants in the reviewed studies, the vast majority of measures that have validity evidence for children who use AAC collected that validity evidence with children who have cerebral palsy (11 out of 13 studies with validity evidence: BAC, C-BiLLT, BDI receptive, Dynamic Assessment, M-CDI; Communicative act from CSBS, SICD, TROG; PPVT; CFCS; RDLS), with only a few measures having validity evidence for children with ASD (APPL; VABS) and intellectual disabilities (CCS; Communication Matrix). Children who have different disabilities may have varied performance on the same test. For example, children with cerebral palsy may find it difficult to perform tests that require physically manipulating objects or using point selection (Cooper et al., 2021). Children with ASD may have difficulties in completing tests that have many visual distractors (Trembath et al., 2015). Therefore, measures with validity evidence in one group may not provide an accurate estimation of language skills in another group of children. Future studies should consider testing validity evidence in children with different etiologies.

In terms of AAC systems, more than half of child participants were provided with digitized grid display AAC systems. Children may have operational challenges in identifying symbols from multiple digitized pages and from grids with multiple distracting symbols. Additionally, different types of AAC systems with multiple symbols may also make measures challenging since the symbolic levels are different across AAC systems. Therefore, as mentioned earlier, future measures should take AAC operational skills and AAC symbol recognition skills into account while measuring linguistic and pragmatic skills. On the other hand, many of these digitized AAC systems are able to include more AAC symbols, allowing for more complex sentences with more complicated syntax and morphology structures compared to paper-based communication boards. Future studies should explore methods of measuring and supporting language skills that allow children to demonstrate more complex language while accounting for the children's AAC use.

What Measures were Used and What Measures Should be Developed?

It is commonly agreed that there is a lack of valid measurement of language and communication for children who use AAC (Flanagan 2019). This study identified 64 published measures, within which most measures (N =51) do not have validity evidence for 2-6 year old children who use AAC. As reported in Chapter 3, language and communication measures without validity evidence were frequently used to inform participant information, but were also used in group design studies to inform study results. The most frequently used measures without validity evidence in informing study results included: PLS (Zimmerman et al., 1992; Zimmerman et al., 2002; Zimmerman et al., 2011), MSEL (Mullen, 1995), CFCS (Hidecker et al., 2011), and ADOS communication subscale (Lord et al. 1997; Lord et al. 1999; Lord et al. 2000). Using these measures could be problematic (Ross & Cress, 2006) since many of these tests require verbal responses and test items may include language targets that are less frequently used by children with CCN; using these tests may not yield accurate estimation of the language and communication skills of children with CCN. As a result, conclusions from these studies may not be accurate. Future studies should provide reliability and validity evidence of these tests before using them to inform study outcomes.

This study identified a total of 14 published measures with preliminary validity evidence in 2-6 years old children with CCN. These included measures that were originally developed for typically developing children (e.g., BDI receptive language, M-CDI overall & expressive language, SICD receptive language, PPVT/BPVS, TROG, CSBS communicative acts, RDLS, VABS expressive communication) and measures developed specifically for children with CCN (i.e., APPL; BAC; C-BiLLT; CCS; dynamic assessment of expressive syntax; Communication Matrix; CFCS). Among these measures, only PPVT/BPVS, VABS, and TROG were frequently used to inform study results; measures recently developed for children with CCN were only used in a small portion of studies. This study recommends using measures with validity evidence in future studies. Additionally, self-developed tests using similar procedures could also be used and tested for reliability and validity evidence. Detailed recommendations for each of these measures are discussed in the section below.

In addition to published measures, self-developed tests and observational measures were widely used to inform study results. Compared to highly structured tests, observational measures using either semi-structured or unstructured observation are more motivating, and thus could lead to potentially maximal child communicative performance (Yoder et al., 2018). Despite the fact that validity evidence for measurements is recommended to ensure accuracy of results of observational measures in single case design studies (Ledford & Gast, 2014; Yoder et al., 2018), these measures were only reported with reliability evidence without validity evidence.

How to Measure?

How to Measure Receptive Semantic Knowledge?

This study identified two frequently used testing methods measuring semantic knowledge: picture vocabulary tasks (e.g., PPVT; ROWPVT), symbol mapping tests (e.g., BAC vocabulary comprehension task, Batorowicz et al., 2018), and following direction tasks (e.g., test items from PLS; Schlosser 2013).

Picture Vocabulary Tests for Spoken Language

This study identified three picture vocabulary tests showing preliminary validity evidence in measuring semantic knowledge in spoken language: PPVT/BPVS (Dunn et al., 1997; Dunn & Dunn, 2006) and C-BiLLT (Geytenbeek et al., 2010). In picture vocabulary tests, the examiner presents a verbal stimulus, asks the child to select a picture from four selections that match with the verbal word. Within studies included in this review, these tests measured the child's ability to map verbal words to their referent (i.e., item shown on picture). Both measures were shown to have convergent validity evidence in children with cerebral palsy (Batorowicz et al., 2018; Geytenbeek et al., 2010); C-BiLLT also included construct validity evidence (Geytenbeek et al., 2014). These results indicate the potential of using picture vocabulary test as a valid method of measuring receptive semantic knowledge measure in children with CCN.

Generalization of the results in this area should be done with care. First, validity evidence was only provided for children with cerebral palsy who use AAC systems. Whether picture vocabulary tests yield valid estimation of vocabulary knowledge in children with other etiologies is unknown. Second, in many studies, children were not able to demonstrate basal levels using the PPVT (e.g., Sevcik et al., 2018). Challenges of using the PPVT include requiring the child's physical movement (i.e., pointing to select pictures) which can be difficult for children with physical disabilities (e.g., cerebral palsy; Geytenbeek et al., 2014) to complete the test. Additionally, vocabulary items included in PPVT were selected for typically developing children, and therefore may not be as frequently used for children with CCN (Geytenbeek et al., 2014). Eye-tracking was provided in some studies and shown to be feasible for children with ASD (Brady et al., 2014) and cerebral palsy (Geytenbeek et al., 2015) as a way to deal with the challenges with physical abilities. Furthermore, the C-BiLLT (Geytenbeek et al., 2010) provides a computer-assisted eye-tracking picture vocabulary test in which selected vocabulary words were more frequently used by children with cerebral palsy. Future studies considering using picture vocabulary tests for children with CCN may need to adapt test items to core vocabulary used by children with CCN (van Tilborg & Deckers, 2016) and test validity evidence in children with different etiologies, such as ASD, intellectual disabilities, and other speech language impairment.

Symbol Mapping Tests for AAC Symbol Comprehension

One primary goal of learning vocabulary with symbols is understanding that a symbol is not simply an object itself, but also serves as a representation for a referent (DeLoache,1991; Huist et al., 2020). To date, the only method measuring AAC symbol comprehension with preliminary validity evidence is the BAC vocabulary comprehension tasks. BAC vocabulary comprehension tasks (Deliberato 2018) use similar test procedures as picture vocabulary tests; the difference is that the test examiner presents an AAC symbol and asks the child to select a matched picture. This test measures the child's ability to map AAC symbols to their referents (i.e., item show on picture). A number of other self-developed probe tests and semi-structured observational measures use similar testing stimuli by asking the child to map AAC symbols to referents in pictures and objects. Within included studies, these self-developed tests were used in children with different etiologies but without validity evidence. Validity evidence for the BAC vocabulary comprehension tasks was only provided for children with cerebral palsy and only included convergent validity evidence. Given the fact that there are not yet gold standard measures in language and communication skills of children with CCN, providing evidence of relations with other measures may not be sufficient as validity evidence. Future studies should further explore other sources of validity evidence in AAC symbol vocabulary tests.

Symbol to Verbal Mapping Tests

A second frequently used testing method is AAC symbol to verbal mapping tests (e.g., Huist et al., 2020; Hochstein et al., 2004). In these tests, the examiner presents verbal stimuli and asks the child to select from 2-4 symbols (e.g., Hochstein et al., 2004), or asks the child to verbally name a symbol (McCarthy et al., 2018). Some studies use these tests to examine a child's understanding of novel symbols they just learned (e.g., Huist et al., 2020). However, interpretation of testing results should be made with caution. These tests require the child to know the words, so test results are not solely reflecting AAC symbol comprehension skills but also may be influenced by the child's receptive vocabulary knowledge. Additionally, the child being able to select the correct symbol that matches with the spoken word does not necessarily mean the child understands the symbol to referent link. There are a few studies using these tests with already known words (e.g., collect words the child already knows through parent completed vocabulary checklist) or with the goal of comparing children's ability to recognize symbols with different levels of graphic design representativeness. These studies conceptualized this as symbol recognition skills that are non-linguistic skills (e.g., Wainwright et al., 2020a). To date, there is no clear cut definition that distinguishes symbol recognition skills as non-linguistic skills from symbol comprehension skills. Future studies should further explore how different testing forms influence child performance and what underlying constructs are reflected by these tests.

Following Direction Tasks

Though following direction tasks are a frequently used testing format in many global language tests such as PLS, Battelle, and VABS, there were only a few studies using this format for self-developed tests (e.g., Schlosser et al., 2013). The use of directive following tasks for manipulating or performing an action could be an important approach to capture the child's understanding of certain verbal or AAC words. While following directions during a highly structured test may be difficult for children with CCN since some children may not be willing to stay in the test, giving directions to children during semi-structured or unstructured play activities could make it more motivating and help children cooperate. In addition, giving directions is a frequently occurring communication partner behavior (Douglas et al., 2023). Therefore, future studies could explore the potential of using direction following testing stimuli in observational measures.

How to Measure Expressive Semantic Knowledge?

Results from this study indicated that picture naming tasks using AAC symbols may be a potentially valid method for measuring expressive semantic knowledge. Traditional picture naming tests require children to make verbal responses (e.g., EVT). No study provided validity evidence for these measures for children with CCN. One picture naming test using AAC symbols was identified showing convergent validity evidence in children with cerebral palsy (BAC naming task, Deliberato et al., 2018). The BAC naming task follows a standardized testing procedure; however, children were able to use their own AAC systems to respond. How the variation in AAC design influenced testing results is unknown. Future studies should explore the potential of measuring expressive semantic knowledge using picture naming tasks by using standardized AAC systems as well as variability due to differences in AAC systems.

Two variables from observational measures were identified to be potentially appropriate for indicating child's expressive semantic knowledge: number of different words and number of total words. Theoretically, both are valid representations of children's expressive language skills in both children who are typically developing and children with disabilities (Condouris et al., 2003; Gilkerson et al., 2017; Heilmann et al., 2010; Leadholm & Miller, 1994; Stockman, 1996). Additionally, number of different words and number of total words were used as cutoff scores to categorize children's language development into 5 phases in the APPL measure, which has convergent validity evidence for children with ASD (Flanagan et al., 2019). These results provide preliminary evidence that number of different words and number of total words could be valid measures in children with CCN. However, the validity evidence is indirect. Additionally, the data collection environment (e.g., activities, materials, etc.) and length of observation may influence the results. In the APPL measure, Flanagan (2019) suggested that at least 20 minutes of observation is sufficient data collection time. However, no empirical evidence was identified examining how the length or specific timing of data collection influences the accuracy and reliability or representativeness of the measurement results. Future studies should provide validity evidence of these two measures and explore how different data collection environments and lengths of observation may influence measurement results.

How to Measure Grammatical Knowledge?

This review identified four measures with preliminary validity evidence for the use of picture selection tasks, indicating picture selection tests could be a potentially valid method for measuring grammatical knowledge for children with CCN. These measures included TROG (Bishop, 2003), RDLS (Reynell & Huntley, 1987), C-BiLLT (Geytenbeek et al. 2014), and BAC comprehension tasks (not vocabulary subset, Deliberato et al., 2018). Each of these four measures showed convergent validity evidence in children with cerebral palsy. These tests were slightly different from each other. In TROG and RDLS, an examiner presents verbal stimuli and asks the child to select pictures use finger pointing. In C-BiLLT, test stimuli are presented through a computer and eye-tracking is provided as an accommodation for children with motor impairments. In BAC, the testing procedure includes (a) providing the child with AAC symbol sentences and asking the child to select the picture that matches, or (b) providing the child with pictures and asking the child to select the AAC symbol sentence with the correct order. While all measures had convergent validity evidence, C-BiLLT was the only one with construct validity evidence. Additionally, mixed findings were presented for the BAC comprehension tasks, as it only correlated with TROG and did not correlate with PPVT/BPVS (Batorowicz et al., 2018). TROG, however, significantly correlated with PPVT (Batorowicz et al., 2018). This result may indicate that AAC syntax comprehension tasks measure a similar construct as verbal syntax comprehension tasks (TROG); however, verbal vocabulary knowledge may not influence a child's AAC symbol syntax comprehension. Future studies should further examine correlations among linguistic tests and identify other sources of validity evidence in children with different etiologies.

Picture/Action Description Tasks for Expressive Grammatical Knowledge

Expressive grammatical knowledge could be measured through providing picture/action description tasks. In picture/action description tasks, the examiner presents the child a picture or performs an action, then asks the child to describe what happened using their AAC system. This form of testing stimuli was used in self-developed tests and semi-structured observation measures. However, studies differed in how they reported test scores. In most measures, the number of correct responses or percentage of correct responses was reported. More recent studies used a new form of this measure, dynamic assessment, which is a semi-structured observational measure that allows the examiner to provide assistance and feedback throughout the testing procedure (Binger et al., 2017). Instead of counting independent and correct responses, dynamic assessments count the level of support for each testing item. Results from this review identified one study providing mixed predictive validity evidence of using dynamic assessment to measure syntax structures. Future studies should explore how introducing examiner support during the measurement procedure influences results compared to traditional testing procedures.

Observational Measure: Mean Length of Utterances and Number of Multi-symbol Utterances

Observational measures reflecting children's syntax and morphology knowledge included (1) mean length of utterance, (2) number of sentence utterances, (3) number of target syntax structures, and (4) number of target morphemes. None of these measures included validity evidence for children with CCN and validity should therefore be examined in future studies. Among these measures, mean length of utterance and number of non-specified sentence utterances do not directly reflect syntax knowledge; however, they show children's ability to combine multiple words to form sentences (Binger & Light, 2008). There is not yet validity evidence on mean length of utterance when including both verbal and AAC responses.

Additionally, one important consideration when counting multi-symbol utterances is what counts as the boundary between one utterance and the next, separate utterance. This is especially important for AAC users who may take a longer pause time before finding the next symbol in a sentence. As reported in the results of this review, only one study defined that a 1s pause time is allowed between symbols in order to be counted as one single utterance (Quinn et al., 2020). A 1s pause time may not be sufficient for children to identify symbols especially when the AAC system requires navigation from page to page. It is unknown how other studies addressed pause time.

Another consideration when measuring grammatical knowledge using observation measures is the support level provided during the measure. Similar to dynamic assessment, observation of sentence utterances may also occur during natural observation sessions where different levels of prompts are provided to the child. A lack of reporting was found on independent and imitated utterances. Clear definitions for independent communication and imitation are important in future studies. In sum, future studies are needed to provide further validity evidence of these observational measures and to determine how variation in definitions of key concepts influence their validity evidence.

How to Measure Pragmatic Skills?

While studies may use standardized tests or indirect measures of pragmatic skills as demographic information, observational measures of pragmatic skills were predominately used to inform study results.

Communication Complexity Level

In representing children's overall pragmatic skills as demographic information, several measures that provided ratings of a child's communication complexity level were shown to have evidence of validity. These measures included: Communication Matrix (Rowland, 2004; 2013), CFCS (Hidecker et al., 2011), CCS (Brady, et al., 2011), and APPL (Flanagan & Smith, 2019). Complexity levels were reported as ordinal levels. The number of complexity levels differed across measures, but they generally follow the developmental phases of communication (Tager-Flusberg et al., 2009), from pre-intentional to intentional communication, from single word utterances to multi-word utterances, and from use of requesting communication functions to adult-like complex language serving more communicative functions. Table 4.1 presents communication phases from the above mentioned measures. Additionally, PECS describes children's skills with a set of phases which are similar to the complexity levels described above. These PECS phases were widely used to describe the child's ability to use single or multiple symbols to make requests or make more advanced communication functions. However, there is no validity evidence yet for the PECS phases. Future studies should further examine validity evidence of these measures and explore what range of communication complexity levels should be measured for children with CCN with different etiologies.

Table 4.1 Communication Complexity Level Scales

Measure Name	Phases
CFCS, Hidecker et al., 2011	CFCS is a measure of everyday communicative functioning that included 5 levels indicating an individual's frequency and effectiveness of their communication: Level 1: independently and effectively alternates between being a sender and receiver of information with most people in most environments. Level 2. independently alternates between being a sender and receiver with most people in most environments but the conversation may be slower. Level 3. usually communicates effectively with familiar communication partners, but not unfamiliar partners, in most environments. Level 4. not always consistent at communicating with familiar communication partners. Level 5. seldom able to communicate effectively even with familiar people.

Table 4.1 (cont'd)

Measure Name	Phases
Communication Matrix, Rowland, 2004	The Matrix categorizes communication skills in 7 stages of communication development that typically occur between birth and 2 years of age: Phase 1: pre-intentional communicative behavior (body movement; early sounds..) Phase 2: intentional communicative behavior (body movement; early sounds, visual behavior…) Phase 3: unconventional communication (…gestures) Phase 4: conventional communication (conventional gestures, vocalization) Phase 5: concrete symbols (object symbol, picture symbol, mimic sounds) phase 6: abstract symbols (spoken words, signs, written words) phase 7: language (combination of 2 or more words)
CCS, Brady et al., 2012	CCS measures the development of pre-intentional and intentional expressive communication in individuals with developmental disabilities and minimal verbal skills Level 1: Pre-intentional (no response, scanning, reaching, vocalization) Level 2: Intentional non-symbolic (eye gaze; gesture; vocalization) Level 3: Intentional symbolic (1 word utterance; multi-word utterances)
APPL, Flanagan et al., 2019	APPL provides 5 phases of in overall language development and in the following domains: phonology, vocabulary, grammar, and pragmatics. Phase 1: pre-verbal communication phase 2: first words phase 3: word combinations phase 4: sentences phase 5: complex language

Table 4.1 (cont'd)

Measure Name	Phases
PECS phases, Frost & Bondy, 2002	PECS have 6 phases of learning from single picture exchange for requesting function to more complex language and communication functions. The learning phases were also used to indicate the child's abilities of using PECS. Phase 1: know how to communicate (single picture exchange) Phase 2: Distance and Persistence (single picture exchange with distance across settings and communication partners) Phase 3: Picture Discrimination (single picture exchange from an array of several selections) Phase 4: Sentence structure (multi-symbol exchange for requesting function) Phase 5: Answering questions (use PECS for answering question function) Phase 6: Commenting (use PECS for comment function)

Observational Measure: Child Communicative Act

Child communicative acts were the most frequently reported communication measure. Counting of communicative acts from the CSBS has preliminary convergent validity evidence with other receptive linguistic language measures. This indicates communicative acts as a potential valid measure of communication skills for children with CCN. However, a communicative act is a behavior that is heavily influenced by a communication partner's behavior (Douglas et al., 2023). The number of communication opportunities provided may influence the number of communication acts observed. One way of accounting for variability in communication partner's influence is reporting a percentage score based on how many communication opportunities were provided. There is not yet empirical evidence showing how different approaches influence the validity evidence of communicative acts as a measure of pragmatic skills. Future studies should systematically examine this issue.

Communicative Functions

Although there are few studies reporting communicative functions other than requesting, several studies provided operational definitions to communicative functions that included comments, rejects, greetings, and asking wh- questions. The Communication Matrix, which is supported by content (Rowland & Fried-Oken, 2010; Quinn & Rowland, 2017) and convergent validity evidence (Brady et al., 2018), defined four functions including to refuse, to request, to engage in social interactions, and to provide or seek information. Future studies that address communicative functions could refer to the definitions provided in Communication Matrix to develop an initial coding manual. In addition, more validity evidence is needed regarding direct counting of different functions: whether different types of communicative functions should be counted separately or combined into a single measure.

Other Considerations in Language and Communication Measures

Measuring Skills Related to AAC

As mentioned earlier, AAC symbol recognition and operational skills should be measured in future studies. They are important to consider in linguistic and pragmatic measures, as both skills can influence child performance. For both AAC symbol recognition and operational skills, measures should start with selecting vocabulary words the child already knows, which can be provided by caregivers. As measured by previous studies (e.g., Wainwright et al., 2020a), AAC symbol recognition tests could be conducted by presenting the child verbal stimuli of familiar words and asking the child to select matched symbols from an array of 2 to 4 selections. For AAC operational skills, test stimuli could be verbal prompts or AAC symbols that the child is familiar with, and the child can be asked to find the symbol on their AAC systems (McDougall et al., 2012). To date, there is no validity evidence for these two measures even though they are clearly important for understanding language and communication skills. Future studies should examine validity evidence, especially on how AAC related skills correspond to linguistic and pragmatic skills.

Wait Time for Child Response

For both tests and semi-structured observational measures with testing stimuli, it is important to consider how much time is allowed for the child to make a response before providing the next testing item. A total of 110 included studies reported how long the administrator waited for the child to respond. For the majority of studies reporting wait time to allow the child to make a response, between 3s and 30s was used. A recent study (Sun et al., 2023) found that the optimal response time for children with CCN varies across children, although 5-7s was sufficient in general. Therefore, studies that employed wait time under 5s may underestimate child's language skills since some children were not yet able to initiate a response. Future studies should further explore how different wait times influence testing results.

Sampling Methods

In observational measures, one important consideration is the sampling method. Sampling methods include continuous (i.e., observe continuously for the whole observational session) and discontinuous (i.e., only code parts of the observational session and estimate behavioral occurrence for the whole session). For language behaviors, event recording systems (i.e., counting occurrence of all behaviors during the observational session) as a continuous measurement are considered to best represent the true number of occurrences. Therefore, this approach is theoretically seen as the gold standard of measurement to detect all instances of language and communication behaviors (Cooper, 2020). The use of interval-based coding system (i.e., a discontinuous sampling method that separates an observational session into intervals and estimates the occurrence of behaviors based on what was coded in the intervals) may not accurately represent child behavior, given that language behaviors are often short in length and not necessarily captured well with discontinuous sampling. A total of 10 studies with 11 measures employed an interval sampling method. Observed behaviors included communicative acts verbally or using AAC (N = 10) and vocalizations (N = 1). All of them used a partial interval sampling method, meaning if a communicative act occurred once within an interval, the occurrence was counted for the whole interval. The percentage of intervals that had the target behavior were reported. Interval time ranges vary widely across studies, from 6 s intervals to an entire day. One study used 10 minutes intervals over a 5.5 hr observation period (McDonald et al., 2015); two studies used 6 s intervals across a total of 5 min of observation (Anderson et al., 2016; Schieltz et al., 2010); and seven studies used 10-60 s of intervals for a total of 3 to 35 min of observation (e.g., Liao et al., 2022; Durand, 1993). For behaviors that are short in length, using long intervals may overestimate the occurrence of the target behavior. However, this approach is more efficient for coding. Future studies should further explore using continuous sampling methods or using shorter intervals across wider time ranges and explore ways to correct estimation for discontinuity (Wattanawongwan et al., 2022).

A total of 30 studies reported the use of continuous sampling methods, including both event recording systems and timed event recording systems (i.e., reporting both occurrence and time of the behavior). Observed behaviors included communicative acts verbally or using AAC (N = 10) and vocalizations (N = 1). Although other studies did not specify which sampling method they used, the score of direct counting of behaviors they reported suggests the use of continuous sampling. Future studies should include this information in their reports.

Implications for Future Measures

This review identified a number of testing stimuli to measure receptive and expressive language and communication skills that reflect linguistic, pragmatic, and AAC related skills. Within this collection of tests, some had preliminary convergent validity evidence for children with cerebral palsy, ASD, and intellectual disabilities. Given the fact that there is not yet a gold standard measure for children with CCN, convergent validity evidence alone may not be sufficient. Future studies should provide further validity evidence in multiple forms for children with different etiologies.

Even in standardized tests with preliminary validity evidence (e.g., PPVT), studies reported that some children with CCN were not able to complete the measures. This result indicates the need to develop tests and observational measures that are specifically designed for children with CCN accommodating their need to use multiple modalities to respond, and the need to select test items that are relevant to their learning experience and daily needs. Future studies might explore building tests using the testing stimuli recommended in this study. As discussed earlier, compared to direct tests that are highly structured and lengthy, observational measures using either an unstructured format or semi-structured format could be more motivating and allow more flexibility in the use of communication partners supporting the child's performance. Therefore, developing comprehensive observational measures targeting different aspects of language and communication skills is an important next step.

Existing Observational Measures: Expressive Linguistic and Pragmatic Skills

This review identified observational measures that can be used to reflect linguistic and pragmatics skills: (1) using number of different words and number of total words with both verbal output and AAC symbols to reflect expressive vocabulary knowledge; (2) using mean length of utterance, number of multi-symbol productions, and number of words with morphemes to measure expressive syntax and morphological skills; (3) using measures of communicative acts with coding of functions including request, comment, reject, and greetings to reflect communication skills.

Observational Measures of Receptive Language Skills

To date, receptive language skills are not included in existing observational measures. Part of the reason is because child behaviors that reflect receptive understanding are difficult to define, and these behaviors are highly dependent on examiner or communication partner's behaviors. However, this review suggests it might be feasible to measure receptive linguistic skills through observation using either semi-structured procedures or unstructured procedures. In semi-structured observational measures, it is feasible to embed testing stimuli within interactive play, reading, or learning activities. Future studies should explore embedding testing stimuli identified from this review that might yield valid estimation of children's receptive linguistic skills in semi-structured observational measures. Testing items could be tailored to the child's learning targets.

In terms of unstructured observational measures, receptive linguistic skills could also be measured similar to how existing studies measured communicative functions. First, for receptive linguistics skills, future studies can code the communication partner/examiner's language behavior that may elicit a child response, and then define child behaviors that shows understanding of the language produced by the communication partner. An exhaustive list of the communication partner's behaviors could be generated from common testing procedures identified from this review. Then, the next step would be to define what child behavior (communicative and non-communicative) shows understanding of the communication partner's behavior. To account for the variability of stimuli provided during each observation, scores can be reported by using percentage counts, although other more sophisticated methods such as factor analysis and item response theory may be needed. Future studies should further explore the feasibility, reliability, and validity of using unstructured observational measures to estimate receptive linguistic skills of children with CCN.

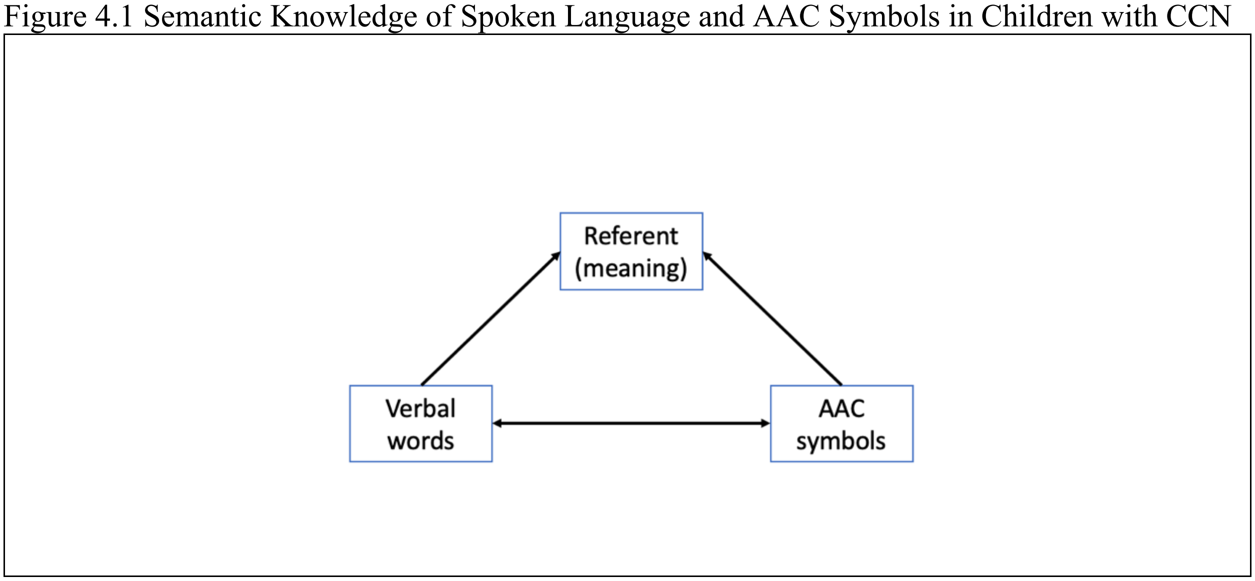
Implication to the Theory of Language and Communication Skills of Children with CCN

Both spoken language and AAC symbols are language forms that children with CCN use to communicate. In order to build language and communication skills and communicate effectively, children must develop linguistic skills (semantic knowledge: reception and comprehension of word and sentence meaning; syntax and morphology: build sentences and convey meaning), pragmatic skills (using language in social situations with different functions), and AAC use related skills.

Understanding Semantic Knowledge of Children with CCN

Results from this study provide some implications on understanding aspects of semantic knowledge in children who use AAC systems. Existing measures of semantic knowledge cover four skills related to semantic knowledge building using both verbal and AAC forms. Their relation is presented in figure 4.1.

Figure 4.1 Semantic Knowledge of Spoken Language and AAC Symbols in Children with CCN



First, traditional picture vocabulary tests measure the child's ability to understand the connection between verbal words and their referents. Receptive picture vocabulary tests (e.g., PPVY) requires the child to select pictures representing verbal stimuli and measure the child's ability to understand the meaning of a spoken word; picture naming tests (e.g., EVT) require the child to name a picture verbally and measure the child's expressive vocabulary knowledge. Since verbal language is the primary input for children with CCN, they develop understanding of verbal words before they are introduced with AAC systems.

Second, photo-to-object mapping tests measure the child's understanding of the representational feature of picture symbols. The ability to understand the dual representation feature of AAC symbols means understanding that AAC symbols are objects themselves but also represent their referents (Blockberger & Sutton, 2003). This is an important prerequisite skill for early AAC communicators to learn before they can map AAC symbols to referents. Research shows that children with ASD do not readily understand that AAC symbols represent referents. Therefore, even if a child builds the link between a verbal word and an AAC symbol, they may not be able to use the AAC symbol to communicate. This may partially explain why when children start learning to use AAC, they often use it as a toy and use it only when prompted by caregivers (Sun et al., 2023). This skill is an important aspect of PECS training, where a phase 1 training goal is to help children to understand that they can use AAC symbols to exchange a concrete referent (i.e., object).

Third, after children learn the dual-representational feature of AAC symbols, they are able to connect AAC symbols with referents and build vocabulary knowledge of AAC symbols from there. Receptive semantic knowledge of symbols was typically measured by presenting children object/pictures/actions and asking children to select AAC symbols that match with the referent (e.g., BAC vocabulary comprehension tasks); expressive semantic knowledge of symbols was typically measured by presenting the child a picture and asking the child to select matched AAC symbols to name it (e.g., BAC naming tasks). To support the growth of semantic knowledge of AAC symbols, aided AAC modeling (pointing to both the AAC symbols and their referents) is an important intervention strategy and can be used to build vocabulary knowledge of novel symbols (Biggs et al., 2018).

Fourth, since spoken language is the primary input form of children with CCN, previous studies also used symbol-to-verbal tasks measuring the ability to map AAC symbols to verbal words. As indicated earlier, results of these tests require careful interpretation. The child's correct response of selecting a symbol that matches with the verbal referent may not indicate the child understands that the AAC symbol could serve as the representation of a referent. Instead, it is possible that the child only understands the AAC symbol as an object which matches with the spoken word. On the contrary, an incorrect response in these tests also does not mean the child failed to comprehend the AAC symbol; instead, it is possible that the child knows the AAC symbol without knowing the verbal words. Therefore, in order to gain a full picture of children's semantic knowledge involving AAC symbols, measures of spoken vocabulary knowledge only and AAC symbol comprehension only may be more appropriate.

AAC Symbol Recognition Skills VS. Semantic Knowledge

Among studies that measured the child's ability to map AAC symbols to verbal stimuli (i.e., the fourth method mentioned above), some conceptualized these skills as non-linguistic AAC symbol recognition skills. The focus of these measures was to understand child performance on symbols with different graphic designs. The graphic design of AAC symbols may have different levels of representativeness of their referent. For example, line drawings may be less directly representative compared to photographs of objects (Hartley & Allen, 2015). Another example is dynamic symbols (i.e., animated symbols on a digitized device), which may have better representation of verbs compared to static symbols (Hochstein et al., 2004). How well a child can map symbols to their referent depends on the child's semantic knowledge of the vocabulary, previous experience of using similar symbols, and representativeness of the graphic design (Blockberger & Sutton, 2003). Although the communicative competence model (Light & McNaughton, 2014) suggests representational competence as a linguistic skill that includes the child's ability to learn representational aspects of AAC symbols, results from the current review suggest that representation of graphic design is an extrinsic factor influencing the child's ability to comprehend a symbol rather than a language skill per se. This is different from the child's intrinsic ability to recognize the dual-representational feature of AAC symbols and the ability to gain semantic knowledge of the symbol. Therefore, the current review proposes AAC symbol recognition skills as a non-linguistic AAC use related skills when measured with familiar words and with the focus on level of graphic design representativeness.

Conclusion

This scoping review summarized existing literature on language and communication measures for 2-6 years old children with CCN who use AAC systems. Findings identified research gaps in language and communication measures that imply what should be measured and how to measure language and communication skills in future research.

First, this review found existing studies primarily measured expressive aspects of language and communication skills, semantic knowledge, and pragmatic skills (i.e., primarily communicative act and requesting), with only a few studies measuring receptive language and communication skills, syntax, morphology, and AAC related skills. This highlights a need for further research to develop comprehensive measures and explore how to measure receptive language skills, syntax and morphology skills, as well as use of AAC for more communication functions in young children with CCN. These skills will be essential for understanding how to support children building their linguistic complexity rather than just quantity.

Second, existing studies that measured language and communication skills of children with CCN heavily depended on self-developed measures and published measures that do not have any validity evidence within children with CCN. These measures may underestimate language and communication skills of children who use AAC systems. Although there is little consensus on how to measure language and communication skills, there were patterns found among commonly used measurement methods in each domain specific area. Results from this review provided a comprehensive synthesis on how existing measures measured language and communication skills. Measurement methods identified from this review can help to identify testing procedures that can be used in future studies. Future studies should further explore, develop, and validate measures for children who use AAC systems.

Third, this review identified 15 measures with preliminary validity evidence in children with CCN, indicating methods that can potentially be used to measure language and communication skills in future studies. However, current validity evidence was primarily provided within children with cerebral palsy and with convergent validity evidence. Future studies should further explore validity evidence from different sources and in children with different etiologies.

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APPENDIX A. ELIGIBILITY CRITERIA

Participant Disabilities. This review will include studies that recruited children with CCN who use aided AAC systems.

- In single case studies or case studies, the study must include at least one participant who has CCN.
- In other study designs, the study must include at least one group of participants who have CCN.
- The definition for children with CCN includes children who have disabilities and use aided AAC systems (either before or during the intervention study).
- Aided AAC systems include picture symbols, picture exchange communication systems, digitized AAC systems, bliss systems, etc. This distinguishes from unaided AAC systems, such as sign language or manual signs.

Participant Age. The purpose of this review is to identify measurement appropriate and capable of capturing language and skills of children in preschool or kindergarten age who are beginning communicators. That is 3-5 years of age. Given that children may have high variability in their language and communication skills across ages, to ensure comprehensiveness of this review, the age for inclusion will be expanded to 2-6 years old.

- In single case studies or case studies, the study must include at least one participant who was 2-6 years old at the start of the study;
- In group design studies, the mean age of children must 2-6 years old at the start of the study.

Measurement. This review will include studies that used quantitative measurement(s) evaluating language or communication skills of children with CCN. Location of the measurement can be listed in (a) demographic information, (b) independent variable, or (c) dependent variables (outcome measures). As guided by the 5-domain language skills and communication skills of children with CCN, below I present a list of possible language and communication skills. This is not exhaustive list, but rather serves as examples.

- ***Language content.*** Semantic knowledge; vocabulary knowledge; symbol knowledge.
- ***Language form.*** Morphology, syntax, single symbol production, multiple symbol production.
- ***Language use.*** Pragmatics (communication skills).
- ***Additional communication skills***. Operational competence, strategic competence.
- ***Exclusion criteria of measurement***. The following are not counted as language or communication skills: (a) vocalization alone, (b) quality of speech, (c) facilitated communication, and (d) literacy skills (e.g., phonological awareness, phonemic awareness, phoneme awareness, single-word reading, word reading, spelling, letter name, letter knowledge, & others).

Study Design. This review will not have specific restrictions on study design as long as the study reported a quantitative measurement of language or communication skills of children with CCN from 2-6 years old.

- Included study design: (a) single case design; (b) group experimental design (two data points or longitudinal); (c) correlational design (cross-sectional or longitudinal); (d) quantitative descriptive studies; (e) measurement development studies.
- The following will be excluded: (a) book chapter; (b) practitioner focused article; (c) review study; (d) qualitative study. Although review studies will not be included in this current review, an ancestral search will be performed for reviews relevant to this topic to locate additional relevant studies.

APPENDIX B. DATA EXTRACTION MANUAL

Table B.1 General Study, Participants, and Measurement Information for SCD Studies

Item	**Description**
Study In-text Citation	(First author, Publication Year)
Study Design	Code the following categories: [1] Group design, including group experimental design (with randomization), quasi-experimental design, one group pre-/post-test design [2] SCD, including AB design [3] Correlational study [4] Quantitative descriptive study [5] Measurement development or validation study [6] Others. Other quantitative design need further discussion

Table B.2 Participant Information and General Measurement Information for SCD studies

Coding Items	Definitions
P_Total #	Total number of participates. Write the number of participants within age 2 years 0 month to 6 years 11 month.
P_ID	Participant ID. Label participant ID with P(n). Each participate ID in a new row.
P_name	Participant Name. Write participant names/lables reported from the study. Each participant in a new row that matches with participant ID.
P_Age	Participant Age. Write each participant age in month. Each participant in a new row that matches with participant ID.
P_Gender	Participant Gender. Write participant gender as: F = Female M = Male Each participant in a new row that matches with participant ID.

Table B.2 (cont'd)

Coding Items	Definitions
P_Diagnos	Participant Diagnosis. [1] ASD [2] DS [3] SLI: Speech Language Impairment/delay (Apraxia) [4] Developmental delay [5] Physical disabilities (CP) [6] Other
P_ASD	Does the child have Autism Spectrum Disorder? 0 = No 1 = Yes
P_DS	Does the child have Down Syndrome? 0 = No 1 = Yes
P_LI/D	Does the child have language impairment or delay? 0 = No 1 = Yes
P_SI/D	Does the child have speech impairment or delay? 0 = No 1 = Yes
P_DD	Does the child have developmental delay or disorders? 0 = No 1 = Yes
P_PD(CP)	Does the child have physical disabilities or cerebral palsy? 0 = No 1 = Yes
P_Other	Write done the diagnoses.
P_AAC	[1] Paper based AAC Symbols/books [2] Digitized AAC without voice output [3] Digitized AAC with voice output (SGD) [4] Visual scene display (VSD) [5] grid display
P_Ethnicity	Participant Ethnicity. Report as: 1 = White 2 = African American 3 = Hispanic 4 = Asian 5 = Native American 6 = other/mix 7 = not reported

Table B.2 (cont'd)

Coding Items	Definitions
M_ID	Measurement ID Label measurement ID with S(n)M(n). Each participate ID in a new row.
M_Name	[1] name of test for existing measures or [2] name of the behavior being measured from observational measures
M_Subscale	Name of the subscale if available.
M_Citation	Intext citation for the measurement if has any.
M Type	Measurement type. 1 = observational measurement 2 = standardized test 3 = indirect measure
M_Use/location	Measurement use and location 1 = the measure is used as demographic information report 2 = the measure is used as a variable (either IV or DV) to inform the study outcome.
M_Page #	Page number of where to find the measurement information

Table B.3 Participant information and General Measurement Information for non-SCD studies

Coding Items	Definitions
P_Total #	Total number of participates with CCN. Write the number of participants within age 2 years 0 month to 8 years 11 month.
P_Age Range	Participant Age range in month.
P_Age_Mean	Participant mean age in month.
P_Gender_F	The number of child participants who are female.
P_Gender_M	The number of child participants who are male.
P_Diagnos	Participant Diagnosis. [1] ASD [2] DS [3] SLI: Speech Language Impairment/delay (Apraxia) [4] Developmental delay [5] Physical disabilities (CP) [6] Other
P_ASD	Number of participants who have ASD
P_DS	Number of participants who have DS
P_LI/D	Number of participants who have language impairment
P_SI/D	Number of participants who have speech impairment
P_DD	The number of child participants who have developmental delay

Table B.3 (cont'd)

Coding Items	Definitions
P_PD(CP)	The number of child participants who have physical disabilities including cerebral palsy.
P_Other	Number of participants who have other diagnosis.
P_AAC	[1] Paper based AAC Symbols/books [2] Digitized AAC without voice output [3] Digitized AAC with voice output (SGD) [4] Visual scene display (VSD) [5] grid display
Participant Primary Language	Participant language? Maybe not.
M_ID	Measurement ID Label measurement ID with S(n)M(n). Each participate ID in a new row.
M_Name	[1] name of test for existing measures or [2] name of the behavior being measured from observational measures
M_Subscale	Name of the subscale if available.
M_Citation	Intext citation for the measurement if has any.
M Type	Measurement type. 1 = observational measurement 2 = test 3 = indirect measure
M_Use/location	Measurement use and location 1 = the measure is used as demographic information report 2 = the measure is used as a variable (either IV or DV) to inform the study outcome.
M_Page #	Page number of where to find the measurement information

Table B.4 Measurement Information for Observational Measures

Coding Items	Definitions
M_ID	Measurement ID Label measurement ID with S(n)M(n). Each participate ID in a new row.
M_Target behavior	[2] name of the behavior being measured from observational measures. Same with the Measurememt Name item from the previous table.
M_Skill	Which language and communication skills reflected by this behavior?
Type of observational measures	[1] individual behavior [2] language sample analysis [3] dynamic assessment
Conceptual or Operational definition	Write down the definition of the behavior

Table B.4 (cont'd)

Coding Items	Definitions
Name of coding system	Write done the name of the coding system if available
M_Observational system developer	[1] self developed [2] adapted from others [3] Not report
Structure of measurement	[1] structured [2] unstructured natural conversation [3] Semi-structured
Child response mode	Note one of the following: [1] AAC [2] verbal [3] gesture [3] eye-gaze [4] sign language [5] object [6] other
Observational length	Observational length for each observational session. Note the length in minutes.
Start and stop coding rules	Write when the observation starts and ends.
Segmentation rules	[1] Event based [2] time based
Contexts	[1] school [2] home [3] clinic [4] Other
Administrator/communication partner	[1] Teacher [2] SLP [3] Parent [4] Peer [5] Other
AAC materials	Does the measurement procedure includes AAC materials? [0] no [1] yes.
Activities	[1] play [2] book reading [3] routine [4] other-specify
Child response mode	
Segmenting rules	[1] event based [2] time based
Sampling method	[1] interval; [2] continuous; [3] rating
Type of recording system	[1] event [2] timed event [3] interval XXX
Scoring system	[1] count [2] rate [3] percentage [4] style proportion [5] accuracy proportion [6] duration
Reliability	[1] yes [2] not reported
Reliability Evidence	Write done the reliability evidence as authors reported
Validity evidence	[1] yes [2] not reported
Validity evidence	Write done the reliability evidence as authors reported

Table B.5 Measurement Information for Standardized tests or Indirect Measures

Coding Items	Definitions
Name of measure and citation	Code the full name of the measure including information of (a) measure version and (b) intext citation of the measure
Sub scale of measure (if applicable)	Code the language and communication related sub-scale name of the measure
Language and communication skills being measured	Code what aspects of language and communication skills were measured
Accommodations	List any accommodations to the standardized direct measures specific to the need of children with CCN.
Administrator	Code who performed administration to the measure: [1] teacher; [2] clinicians; [3] researchers; [4] parents; [5] other
Procedures of measure and scoring	List key components of the procedures of administering the measures.
Item number	The number of items for this measure.
Test length	The length of testing in minutes.
Settings	[1] school [2] home [3] clinic [4] other
Child response mode	[1] AAC [2] verbal [3] gesture [3] eye-gaze [4] sign language [5] object [6] other
Reliability Evidence	describe any reliability evidence reported in this study
Validity Evidence	describe any validity evidence reported in this study
Definitions to language and communication skills	If this information is available, record the definitions to language and communication skills provided in the study.