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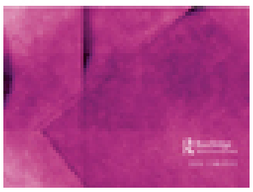

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Critically Appraised Topic

Impact of aided AAC interventions on speech comprehension of children with neurodevelopmental disabilities: A critically appraised topic

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Abstract
A critically appraised topic (CAT) is one form of rapid review that can be particularly useful for informing practice. The purpose of this CAT was twofold: to determine (a) the impact of aided augmentative and alternative communication interventions on speech and graphic symbol comprehension in children, aged birth-18 years with neurodevelopmental disabilities and (b) whether there are any potential learner characteristics that serve as moderators or mediators regarding intervention outcomes. In addition to the methodology, the authors present and discuss the findings of this CAT. The authors propose an update to this CAT in January 2022.

KEYWORDS: *Augmentative and alternative communication; comprehension; aided language stimulation.*

CLINICAL BOTTOM LINE

This critically appraised topic (CAT) identified four articles with the strongest available evidence examining the impact of aided augmentative and alternative communication (AAC) interventions on the collateral acquisition (unintended gains that are associated with an intervention implemented to teach a different skill) of speech comprehension among children with neurodevelopmental disabilities. Results provide evidence that technology aided-AAC interventions teaching symbol production can increase speech comprehension and graphic symbol comprehension (even though it may not be an intervention target) associated with productive use of AAC strategies. Three of the four included articles (Dada & Alant, 2009; Drager et al., 2006; Harris & Reichle, 2004) used aided language stimulation (ALS) procedures; while Brady et al. (2015) implemented a multimodal intervention consisting of speech sound practice and AAC. Given the limited number of studies addressing the current CAT's research questions, conclusions drawn are limited. However, in each of the included studies, all participants made comprehension gains. Other findings included that some participants responded better than others to treatment, suggesting that there may be learner characteristics that moderate or mediate intervention outcomes. We defined moderators as variables that can affect the direction and strength of the relationship between an independent variable and a dependent variable, and mediators as variables that can help account for the relationship between an independent and dependent variable (Baron & Kenny, 1986). Potential moderators may include the participant's ability to "fast map" (Drager et al., 2006; Harris & Reichle, 2004), and the participant's

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speech comprehension abilities (Dada & Alant, 2009).

LIMITATIONS OF THIS CAT

This CAT does not represent a comprehensive review of the literature; instead, its purpose is to provide a snapshot of the best available evidence on the effects of aided AAC interventions on the collateral acquisition of speech and/or graphic symbol comprehension as a function of aided AAC production interventions in children with neurodevelopmental disabilities. Only studies that employed at least a quasi-experimental design (e.g. non-randomized group designs), were published in English, and appeared in peer-reviewed journals were included. Further, this CAT did not consider unaided AAC applications, as unaided AAC applications are not always applicable to those with the most complex communication needs. For example, individuals with significant upper extremity physical disabilities may struggle to utilize unaided AAC and as a result, aided communication may be more viable in providing a more effective means to access symbols. Additionally, for those who are blind or deaf and blind and who experience complex communicative needs, the same may be true (although there are unaided systems that are designed to produce signs in the learner's hand; relatively few communicative partners are acquainted with these systems). Lastly, unaided AAC interventions may involve different mediators and moderators that influence success and are beyond the scope of this CAT. Additionally, there are limitations associated with the search strategies used in the current study. First, the number of databases searched may have potentially limited the number of eligible studies; however, the databases selected are consistent with other AAC reviews (e.g. Simacek, Pennington, Reichle, & Parker-McGowan, 2018). The search was limited to studies published before 31 December 2017, as a result, potential eligible studies published between then and May 2018, were not included. The search terms used may have also limited the number of potentially eligible studies. Last, only peer-reviewed studies were included and as a result, we cannot rule out publication bias.

CLINICAL SCENARIO/BACKGROUND

The role of speech comprehension in learning to produce early spoken words and graphic symbols has been addressed by several authors (e.g. Brady et al., 2015; Drager et al., 2006; Harris & Reichle, 2004; Pickering & Garrod, 2013; Romski & Sevcik, 1993). However, the reciprocal relationship between symbol production and speech comprehension with respect to collateral gains resulting from aided communication interventions remains relatively unexplored (Johnston, Reichle, Feeley, & Jones, 2012). If gains in speech comprehension do result from aided AAC intervention, this relationship would be beneficial in closing the vocabulary gap between speech comprehension and symbol production for many children with neurodevelopmental disabilities and their typically developing counterparts (Johnston et al., 2012). Additionally, as mentioned previously, there may be learner characteristics such as fast mapping, that may moderate the effectiveness of the AAC intervention on speech comprehension and symbol production. By better understanding these potential moderators, interventions can be tailored to specific learner characteristics and as a result, improve communication outcomes. The purpose of the current CAT is twofold. First, we explored the potential impact of aided AAC interventions on comprehensions skills and second, we explored if there are any potential mediators or moderators on intervention outcomes.

FOCUSED CLINICAL QUESTION

(a) *What impact do aided AAC interventions have on speech and graphic symbol comprehension in children, aged birth-18 years, with neurodevelopmental disabilities?* (b) *Are there any potential learner characteristics that serve as moderators or mediators regarding intervention outcomes?* See Table 1 for clinical question in PICO format.

INCLUSION AND EXCLUSION CRITERIA

Articles were included if they met the following inclusion criteria: (a) full text publications available in English language from peer-reviewed outlets (not including dissertations or thesis papers, book chapters), (b) at least one participant was a child (between the ages of birth to 17 years, 11 months old) diagnosed with neurodevelopmental disability, (c) the independent variable included aided AAC, (d) one dependent variable of the study addressed speech or graphic symbol comprehension, and (e) the study design was either quasi or experimental single-case or group design.

In addition to not satisfying the inclusion criteria, studies were excluded if children experienced (a) only acquired disabilities (e.g. traumatic brain injury, in the absence of developmental disability) or only

Table 1. PICO elements derived from the focused clinical question.

P (Patient/Client Group)	Children aged birth through 18 years, with neurodevelopmental disabilities
I (Intervention)	Communication intervention using aided AAC that measured speech comprehension and/or graphic symbol comprehension
C (Context)	Potential learner characteristics
O (Outcomes)	Speech and graphic symbol comprehension

SEARCH STRATEGY

Search terms were developed to capture articles that would answer the PICO question (see Table 1). The search took place in May 2018. For a list of databases searched and search terms used see Table 2. Databases were chosen with the consultation of university library resources. The last three authors executed the initial search.

Table 2. Initial search terms for each database.

Databases searched	Search terms	Limits used
Google Scholar; Education Resources Information Center (ERIC); Linguistics and Language Behavior Abstracts (LLBA); PsychInfo; Academic Search Premier	"AAC AND Comprehension," "Aided Language Stimulation AND AAC," "Aided Language Stimulation AND Comprehension,	Peer-reviewed journal, English Language, ending 2017
ASHA Evidence Maps	"Augmentative & Alternative communication" Map	Peer-reviewed journal, English Language, ending 2017

sensory disorders (e.g. vision or hearing impairment, and/or blind or deafness, in the absence of other developmental disability) or a developmental disability with typical, age-appropriate communication skills, (b) interventions focused on facilitating literacy, mathematics, or other academic skills, or (c) only unaided forms of AAC modes (in the absence of aided AAC), (d) the study was a literature review or meta-analysis, and (e) the full text of the article could not be located.

RESULTS OF THE SEARCH

We followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (see Figure 1 with the

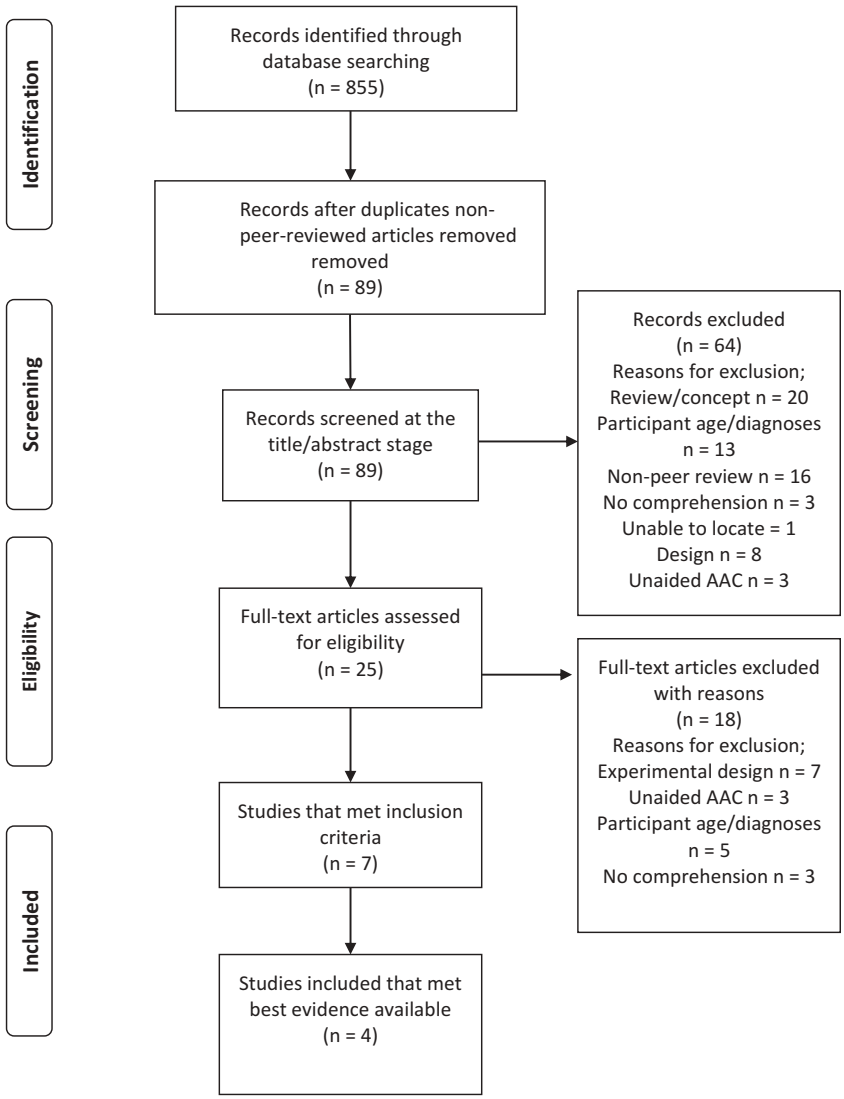

Figure 1. PRISMA flow chart detailing systematic review process.

results of each level of review). The search identified a total of 855 studies, seven meeting inclusion criteria. The first two authors independently coded across steps of the CAT review to determine Inter-Rater Agreement (IRA). IRA was calculated by adding all agreements and dividing by agreements and disagreements and then multiplying by 100%. For the title/abstract IRA 30% of the articles were randomly selected and IRA was 84%. Another 30% randomly selected articles were selected for full-text IRA which was 100%. Next, the two authors also completed IRA by independently coding for the quality indicator codes on four articles (63% of the total sample/100% of the articles included in the quantitative review). IRA of the primary study quality indicators (measured by agreement on each sub-code, each code contained 3 to 5 sub-codes) was 88% (range, 80% to 95%). IRA in applying secondary study indicators (measured by overall indicators, as only one indicator contained sub-codes) was 89.8% (range, 83% to 100%). In addition to the above IRA values, the two authors independently scrutinized the same four articles across the 12 narrative coding areas (e.g. population). Following the coding, the authors compared narrative results and resolved any discrepancies by reaching consensus. An example consensus was determining whether certain dependent measure probes reported in one of the studies constituted speech versus graphic comprehension.

EVALUATION

Evidence quality for each of the seven identified studies was evaluated by the two coders described previously. Following CAT methodology (White, Raghavendra, & McAllister, 2017), included articles matching the PICO were assessed on study design quality (see Table 3). Articles marked with an asterisk were included in the review and were selected because they received adequate evidence ratings and matched the PICO. We used quality indicators adapted from the *Evaluative Method for Determining Evidence-Based Practices (EBP) in Autism* developed by Reichow, Volkmar, and Cicchetti (2008). This tool was developed to help researchers and practitioners in identifying EBPs for children with autism, by providing a standardized method to evaluate empirical intervention studies. This tool was

Table 3. Identified articles matching PICO with assigned levels of evidence, evaluated with "evaluative method for determining EBP in autism."

Study – Author, Year	Study design/methodology	Level of evidence
Brady (2000)	SCD: multiple baseline design across two activities	Weak
Brady et al. (2015)*	SCD: Multiple probe design across word sets	Adequate
Drager et al. (2006) *	SCD: multiple baseline design across 3 vocabulary sets.	Adequate
Dada and Alant (2009)*	SCD: Multiple probe design across three activities design	Adequate
Emms and Gardner (2010)	Group: Cross over design between two interventions	Weak
Ganz, Hong, Goodwyn, Kite, and Gilliland (2015)	SCD: Multiple baseline design across target words	Weak
Harris and Reichle (2004)*	SCD: Multiple probe design across symbol sets/ activities	Adequate

Note. Study Quality indicators were adapted from Reichow et al. (2008). See Appendix A for full coding description, definitions and sub-code scores. SCD: single case design. *indicates article that met the strongest evidence available.

selected because it provided criteria specific to single case experimental designs as well as group designs.

CRITICAL APPRAISAL OF CURRENT BEST AVAILABLE EVIDENCE

Methodological rigor was assessed by quality indicators adapted from Reichow et al. (2008). Although all identified articles (see Table 3) matched the PICO, only four were selected after critical appraisal of study design. Common strengths among the included articles were in the descriptions of participant characteristics, dependent variable(s), and independent variable(s). Weaknesses included instability in the dependent variable during baseline and predictable trend during intervention phases based on visual analysis.

DATA EXTRACTION AND CHARACTERISTICS OF INCLUDED STUDIES

Data regarding study findings and characteristics were extracted from the four included articles (see Table 4). The four included articles represent the best available evidence examining the impact of aided AAC interventions on speech and graphic comprehension.

CAT FINDINGS

Individual studies

Brady et al. (2015) conducted a multiple probe single case design across word sets replicated across 10 participants. Participants received a multimodal intervention targeting both speech and aided AAC symbol production, which included elements of ALS during play routines, practice with speech sounds, and shared reading. Speech production was the primary dependent variable and aided AAC word production, speech, and graphic comprehension was measured as collateral skills. Although spoken word production was assessed, the study's aims addressed our PICO. Results from the study show that half of the participants ("high responders") met mastery criterion for spoken word production. Brady et al. (2015) noted that at baseline the "high responders" scored higher on both speech comprehension performance on the PPVT and verbal imitation scores compared to the "low responders", but that both groups had similar scores on the VABS, consonant scores, and on the speech comprehension probes at baseline. Interestingly, despite similar scores at baseline, the "high responders" also improved in speech comprehension probes following intervention, however, these results should be interpreted with caution, as speech comprehension probes were not measured experimentally.

Brady et al. (2015) was rated as *adequate* quality on the quality indicators for the primary DV (i.e. expressive probes). Four secondary indicator items could be improved including using Kappa scores, using blind raters, collecting fidelity data for a minimum of 30% of sessions, and including social validity measures. Including kappa scores provides a more robust measure of interobserver agreement, as it considers the possibility of observers agreeing by chance, which increases the reliability and validity of study findings. Additionally, by including blind raters, it can reduce potential rater bias.

Drager et al. (2006) conducted a multiple baseline single case design across vocabulary sets, replicated across two participants. The study matched our PICO by examining the effect of ALS on both symbol production and comprehension using aided AAC and demonstrated experimental control. Results showed that ALS increased both symbol production and symbol comprehension in both participants. During intervention, for one participant symbol comprehension was higher than symbol production for all word sets and for the second participant this occurred for two of three-word sets,

Table 4. Summary of extracted data from included studies.

	Brady et al. (2015)	**Drager et al. (2006)**	**Dada and Alant (2009)**	**Harris and Reichle (2004)** [c]
Population	Ten participants (one female), aged 6.5–10.11 years, all diagnosed with ASD.	Two female participants, aged 4–4; 5 years diagnosed with ASD.	Four participants (three female), aged 8.5–12.1 years, three diagnosed with CP, 1 with DS.	Two participants (one female), aged 3.10–5.4 years, both diagnosed with DS.
Sample	*Receptive Language* • PPVT-4[a]: 3(20) 24(20). *Expressive language* • Consonants[b]: 10–16. • CCS: 6.33 –10.33. *Other* • VABS-C[a]: 14(28)-30(28). • VABS-M[a]: 18–37. • Imitation-V: 0–8. Normal hearing.	*Receptive Language* • PPVT-III: Both participants unable to achieve basal score. • MCDI: approximately 20–57 words comprehended, primarily nouns. *Expressive Language* • MCDI: approximately 10–20 single words produced and several 2–-3-word combinations. *Other* Normal hearing.	*Receptive Language* • RDLS-RS[a]: 31–40. • PPVT[a]: 10–20. *Expressive language* • RDLS-ES[a]: 9–15. *Other* • Normal hearing.	*Receptive Language* • PPVT: <1.9 years age equivalency. • MCDI: 87–143 *Expressive Language* • MCDI: 3–11. *Other* • VABS: 55–61 composite score. • Identify matching task: 100%. • Fast mapping task[d]: 75%. Normal hearing.
Study Design	Multiple probe across word sets.	Multiple baseline across vocabulary sets.	Multiple probe across activities.	Multiple probe across symbol sets.
Study Aim	Purpose was to pilot a multimodal intervention to increase expressive word learning in school-aged children with autism.	Purpose was to assess the effectiveness of ALS on improving symbol comprehension and expression in two preschoolers with ASD.	Purpose was to develop, implement an ALS program, and describe its effect on vocabulary acquisition of children with LNFS.	Purpose was to determine if an ALS intervention program increased a) symbol comprehension and b) symbol production.
Setting	Not described	Day-care	Schol.	School, home, or day-care.

(*Continued*)

Table 4. (Continued).

	Brady et al. (2015)	**Drager et al. (2006)**	**Dada and Alant (2009)**	**Harris and Reichle (2004)** [c]
Intervention	*Interventionist* • SLP. *Aided AAC mode* • High-tech; Proloquo2Go. *Intervention targets* • Single words based on phonetic repertoire. *Procedures* • Multimodal intervention; models, physical prompts, corrective, and positive feedback were used during speech sound practice. During joint book reading and interactive routines the interventionist provided models and on subsequent trials, paused to allow the child to initiate response. *Dosage* Sessions contained five trials for speech sound practice and ≥5 trials for interactive routines. No information was provided for joint book reading. 15–16 sessions across participants.	*Interventionist* • Researcher or SLP. *Aided AAC mode* • Low-tech; object references and graphic symbols. *Intervention targets* • Single words with the majority being nouns. *Procedures* • Aided language stimulation; during play activity, interventionist pointed to a target object and within 2s pointed to graphic symbol and concurrently spoke the word. *Dosage* Sessions contained four trials per target word, during two sessions per week, with a total of 37 sessions over 5 months.	*Interventionist* • SLP. *Aided AAC mode* • Low-tech; graphic symbols. *Intervention targets* • Single words, with the majority being nouns. *Procedures* • Aided language stimulation; during each activity the interventionist provided a verbal label and pointed to the symbol on the communication board within 1s of the spoken word. *Dosage* Sessions lasted 15–25 min, containing 3–5 trials per target word, and each activity was implemented for a week or five consecutive days over the course of 3 weeks.	*Interventionist* • Experimenter. *Aided AAC mode* • Low-tech; graphic symbols. *Intervention targets* • one-two words, all nouns. *Procedures* • Aided language stimulation; during each activity the experimenter pointed to the target stimuli referent within the environment and within 2s pointed to the graphic symbol and concurrently spoke the word. *Dosage* Sessions contained 4 trials per target word. 5–31 across participants and vocab sets.

Baseline (Comparison)	Expressive (speech) and receptive speech comprehension probes were administered for each word set.	Researcher's engaged participants in same joint play activities as intervention sessions. A communication board present and target words were referred to with personal and demonstrative pronouns.	Receptive speech probes were administered for each target word.	The experimenter engaged participants in same activities as intervention. A communication board was present, but not referred to. All target words were referred to with personal and demonstrative pronouns.
Dependent (Outcome) Measures	*Primary DV* • Expressive probes defined as verbally producing at least the first consonant and vowel of target word. *Secondary DV* • Speech comprehension probes, defined as matching a spoken word to graphic symbol on a computer.	*Primary DV* • Number of target items correctly identified when responding to graphic and verbal stimuli. *Secondary DVs* • Number of target items correctly identified when responding to graphic stimuli only. • Number of target items correctly identified when responding to verbal stimuli only. Number of referents correctly labelled using graphic symbols (i.e. symbol production).	*Primary DV* Speech comprehension probes defined as matching spoken word to object.	*Primary DV* • Receptive symbol comprehension probes defined as "symbol to object task". *Secondary DV* • Production probes defined as "object to symbol task". Receptive speech comprehension probes assessing graphic vs. spoken stimuli comprehension.

(*Continued*)

Table 4. (Continued).

	Brady et al. (2015)	Drager et al. (2006)	Dada and Alant (2009)	Harris and Reichle (2004) [c]
Methodology	*Pre-assessment* • The following measures were obtained; VABS, PPVT-4, CCS, and the early steps imitative sequences. *Baseline* • All DVs were measured during baseline with a range of 1–7 sessions. *Phase changes* • Mastery criterion of at least 70% correct word approximations over three consecutive expressive probes, and a stable baseline trend for next word set. *Intervention sessions* • Expressive and receptive probes were measured every session. Range of 15–66 sessions. *Maintenance/generalization* Maintenance was assessed for expressive probes and occurred between 2 and 40 sessions after intervention had ended.	*Pre-assessment* • Participants were assessed on their ability to fast map. *Baseline* • All DVs were measured during baseline with a range of 4–19 sessions. *Phase changes* • Performance criterion of 75% accuracy over three consecutive sessions for primary DV. *Intervention sessions* • Comprehension of graphic and verbal stimuli and symbol production were measured every session. Range of 10–13 sessions. *Maintenance/generalization* Maintenance was assessed for 2/3 activities. Probes were conducted at random and assessed comprehension of graphic and verbal stimuli and symbol production was assessed.	*Pre-assessment* • The following measures were obtained; RDLS and PPVT. *Baseline* • Receptive vocabulary acquisition was measured for three consecutive sessions. *Phase changes* • After five consecutive sessions. *Intervention sessions* • Receptive vocabulary acquisition probes were assessed three times a week, directly after intervention sessions (five sessions per week). *Maintenance/generalization* • Collected "post intervention" data for first two activities, for 1–2 weeks after intervention.	*Pre-assessment* • Participants were assessed on their ability to fast map and identity match. *Baseline sessions* • All DVs were measured during baseline, with a range of 4–17 sessions. *Phase changes* • Mastery criterion of 75% accuracy across 5 consecutive sessions for comprehension. *Intervention sessions* • Comprehension probes were conducted for every session, production probes occurred every 2–4 sessions. Range of 4–31 sessions. *Maintenance/generalization* Maintenance was assessed for both DVs.

Key Findings	Multimodal intervention resulted in 5 of the 10 ("high responders") participants meeting performance criterion with increasing verbalizations and these five participants also improved in receptive speech comprehension (identifying correct graphic symbol upon hearing the spoken speech model) identification trials. Word production was maintained post intervention. Of the remaining five participants, three showed some improvements in word production and two made no improvements from baseline.	Aided language stimulation was effective in increasing symbol comprehension and production for both participants and effects maintained post intervention. For one participant, symbol comprehension improvement was higher than symbol production improvement in all three contexts; For the 2nd participant, symbol comprehension was higher than symbol production in 2/3 contexts, and relatively equal in 1/3 contexts.	Aided language stimulation intervention resulted in an increase in acquisition of target vocabulary items across activities and participants and results were maintained or increased during post intervention for activity 1 and 2 (no maintenance data was collected for activity 3).	Aided language input intervention resulted in an increase in graphic symbol comprehension, speech comprehension and graphic symbol production for all participants. For two out of three participants, vocabulary acquisition occurred faster after the first symbol set/activity. During maintenance participants maintained mastery criterion apart from one participant (first two maintenance probes for symbol set 1).
Study limitations	Intervention setting was contrived, may limit generalizability to more natural settings.	Small heterogeneous sample limits ability to generalize findings to other individuals with autism. Personal history may have played a potential role in results.	Heterogeneous sample limits ability to generalize findings to other individuals with LNFS.	Heterogeneous sample limits ability to generalize findings to other individuals with developmental disabilities. Used black and white graphic symbols, different symbols e.g. pictures, may yield different results.

(*Continued*)

Table 4. (Continued).

	Brady et al. (2015)	Drager et al. (2006)	Dada and Alant (2009)	Harris and Reichle (2004) [c]
Authors conclusions	Pilot study provided some initial evidence that the current multimodal intervention led to an increase in spoken words and for some participants (high responders) and was also associated with increases in speech comprehension (for high responders). Further research is needed to identify variables that are associated with positive learning outcomes.	Results from the present study provide some preliminary evidence that ALM can increase symbol comprehension and production and potentially can be used as an intervention for young children with autism. The participant characteristic of the ability to "fast-map" may have influenced their performance as well.	Results from the study show that the aided language stimulation intervention promoted the acquisition of the target vocabulary items. Although all participants saw growth in vocabulary acquisition, there were individual differences, and these may be due comprehension abilities. Future research is needed to examine different aided language stimulation approaches, as well as dosage.	Results from the current study provide evidence to show that aided language input can facilitate symbol comprehension as well as symbol production, in children with moderate cognitive disabilities.

Note. Age reported in years; months. ASD: autism spectrum disorder; CP: Cerebral Palsy; DS: Down Syndrome; PPVT-III: Peabody Picture Vocabulary Test-III (Dunn & Dunn, 1997); PPVT-4: Peabody Picture Vocabulary Test-4 (Dunn & Dunn, 2007); MCDI: MacArthur Communicative Development Inventories (Fenson et al., 1993); CCS: Communication Complexity Scale; scored on 1–11 scale with 11 being the highest. (Brady et al., 2012). VABS-C: Vineland Adaptive Behavior Scales – communication domain (Sparrow, Cicchetti, Balla, & Doll, 2005); VABS-M: Vineland Adaptive Behavior Scales – Maladaptive Behavior Index (Sparrow et al., 2005); Imitation – V: Vocal/verbal/oral imitation tasks taken from Early Steps Imitative Sequences Assessment, scored 0–8 scale (Rogers, Hepburn, Stackhouse, & Wehner, 2003); RDLS-RS: Reynell ReceptiveScale; RDLS-ES: Reynell Expressive Scale; [a]Raw scores and standard score in parentheses, if available; [b]Number of consonants that participants produced as identified by LENA recording system, obtained over two 12-h recording periods; [c]Two out of three participants met review inclusion criteria. [d]Fast mapping task scored on four trials; ALs: Aided language stimulation; LNFS: little or no functional speech; DV: Dependent variable.

however, during maintenance, participants met criterion for symbol production as well. Prior to intervention and post-intervention, participants were assessed on comprehension of graphic and verbal stimuli separately, to assess preference. For one participant in the first two activities, she/he had a higher preference for verbal stimuli, whereas in the third activity there was an equal preference for graphic and verbal stimuli. The second participant showed a slight preference for graphic stimuli in activity 1, but this was reversed in activity 2 and during activity 3 showed equal preference for both verbal and graphic stimuli.

Drager et al. (2006) rated as *adequate* quality on the quality indicators. One of the primary indicator items were scored as acceptable due to variability in one of the participant's data and the delay in change the manipulation of the IV. Several secondary indicator items could be improved by using Kappa scores, blind raters, and increasing measurement of fidelity to a minimum of 30% of sessions. Although Drager et al. (2006) did measure fidelity, they did not meet the minimum criteria (30%) set by Reichow et al. (2008). Procedural fidelity is both important for practice and research, as it provides an indicator of how well the intervention is being implemented as intended and can be used as a coaching tool to improve fidelity (Schlosser, 2002). Additionally, it provides evidence to support the internal validity of a study by providing evidence that the independent variable (e.g. AAC intervention) is producing the intended outcomes (e.g. AAC acquisition).

Dada and Alant (2009) conducted a multiple probe single case experimental design across activities, replicated across four participants. The study examined the effects of ALS on symbol comprehension acquisition and found that with the introduction of ALS there was an increase in comprehension across activities and participants and these results were maintained post-intervention. The study matched our PICO by investigating an ALS program on vocabulary acquisition and speech comprehension for children with little to no functional speech.

Dada and Alant (2009) was rated as adequate on the quality indicators. Several secondary indicator items could be improved including using Kappa scores, using blind coders, and including maintenance or generalization measures (the study included a post-intervention phase, but it remains unclear if this included maintenance data). Maintenance and generalization are important intervention outcomes that can demonstrate the interventions efficiency and effectiveness; it is cumbersome to teach new behaviors in every context rather than embedding generalization strategies into the intervention and assessing whether they worked. Additionally, if an intervention is not effective over time (maintenance), it will need to be continued to be implemented to full capacity, using up potential resources that could be allocated elsewhere.

Harris and Reichle (2004) conducted a multiple probe single case design across word sets, replicated across three participants, two of whom met our inclusion criteria. The study examined the effect of ALS on symbol and speech comprehension and symbol production and found that the intervention was effective in increasing both. For both participants, in two of the three-word sets, the acquisition of symbol and spoken comprehension was faster than for production and faster overall acquisition after the first word set was introduced. Participants were also assessed prior to intervention and post-intervention on comprehension of speech and graphic stimuli separately. For one participant, during the first activity, there was no difference in responding to graphic or spoken stimuli with respect to comprehension. During the second and third

activity, there was a slight bias towards responding to graphic only stimuli. For the second participant, there was no difference in preference for graphic only versus spoken stimuli during activity 2 and there was a slight preference for graphic stimuli in the first and third activity.

Harris and Reichle (2004) was rated as *adequate* on the quality indicators. Improvements that could be made for several secondary indicators included using Kappa values, using blind raters, including social validity measures, and contextual fit. For example, including measures of social validity provides information on whether stakeholders found the intervention to provide meaningful results. Contextual fit addresses whether the intervention conforms to the teaching style and belief system of those implementing the intervention. Some evidence suggests that when contextual fit is good, an intervention is more apt to be implemented and when it is implemented fidelity tends to be enhanced (Horner, Blitz, & Ross, 2014).

Synthesized findings

All four included studies examined interventions that contained at least some element of ALS. Results provide evidence that aided AAC in combination with ALS interventions (and intervention variations across the studies) increased speech comprehension (Brady et al., 2015; Dada & Alant, 2009; Drager et al., 2006; Harris & Reichle, 2004) and graphic comprehension (Drager et al., 2006; Harris & Reichle, 2004) in children with neurodevelopmental disabilities. It is important to note that evidence regarding speech comprehension in Brady et al. (2015) study is not causal; however, improvements in speech comprehension were associated with the multimodal intervention. Improvements in comprehension were seen regardless of AAC mode; three studies employed low-tech communication aids (Dada & Alant, 2009; Drager et al., 2006; Harris & Reichle, 2004), while Brady et al. (2015) utilized high-tech AAC.

The small sample in this analysis limits definitive conclusions that can be drawn; however, there were several patterns that emerged in relation to production and comprehension. Three of the studies included in the quantitative review (Brady et al., 2015; Dada & Alant, 2009; Harris & Reichle, 2004) measured both production and comprehension. For Brady et al. (2015) data for comprehension probes were only as baseline and treatment scores, making it impossible to determine the timing of these increases (e.g. whether both skills were learned simultaneously during the intervention or if there was a different learning rate). However, for the remaining two studies (Drager et al., 2006; Harris & Reichle, 2004) that measured both production and comprehension throughout the intervention, participants tended to increase in speech comprehension or graphic comprehension more rapidly than increasing in speech production or graphic production. Also, the overall levels of speech and/or graphic comprehension tended to be either equal to or higher than the overall levels of production at the end of intervention and in maintenance.

Some of the studies, included in the quantitative review also included participant characteristics that may have contributed to more favorable outcomes. These included participants with higher levels of baseline verbal imitation skills, and PPVT scores (for expressive outcomes; Brady et al., 2015), and fast mapping (for comprehension outcomes; Drager et al., 2006; Harris & Reichle, 2004). These point to some potential participant characteristics that may moderate or mediate language outcomes. These are all factors that have been hypothesized to play a role in language development and intervention outcomes (e.g. Bopp & Mirenda, 2011; Brady et al., 2015; Ganz et al., 2014; Harris & Reichle, 2004; Sievers,

Trembath, & Westerveld, 2018); however, further research is required to determine if and how they play a role in aided AAC interventions with respect to comprehension and production of speech and graphic symbols.

DISCUSSION

Evidence from this CAT suggests that gains in speech and graphic symbol comprehension can result from aided AAC interventions with persons who experience neurodevelopmental disabilities (e.g. Harris & Reichle, 2004). The extent to which this can be expected as an outcome has very limited verification given the small number of studies and participants. To address this question, future studies must more closely scrutinize comprehension in vocal and graphic modes that include dependent measures implemented during baseline, intervention, and post-acquisition probes. Additionally, the heterogeneous characteristics of the participants limited any definitive statements regarding learner characteristics or pre-intervention skills that may influence the acquisition of speech comprehension. Findings from the limited sample did not shed a substantial base of experimental support in addressing potential learner characteristics that may moderate or mediate comprehension acquisition. However, results provided limited evidence suggesting the need to continue to investigate the role that fast mapping have on speech comprehension outcomes. Additionally, more research is needed to examine the role of imitative skills and baseline language skills on both expressive and comprehension outcomes. Given that half of the included articles in this limited sample did not receive high study quality ratings, caution is needed when interpreting findings. Further research is needed to replicate the current findings before a conclusive decision can be made regarding the effectiveness of aided AAC interventions on improving speech comprehension even if it was not a direct target.

Fast mapping has been associated with a "vocabulary spurt" or the rapidly escalating number of different words that are acquired by children beginning around 14 months of age. It has been proposed as a pivotal milestone demonstrating an increased effectiveness of more indirect instructional strategies with the inference being that this may be associated with greater attendance to multicomponent stimuli associated with referents and communicative symbols (Johnston et al., 2012). Imitation is another possible learner characteristic that may influence intervention outcomes. Yoder and Layton (1988) previously found that the proficiency in verbal imitation was associated with the degree of speech production acquisition occurring during unaided (gestural) communication instruction. Some investigators have reported that receptive language skills at the onset of instruction are associated with more prolific gains during productive communication intervention for both persons learning to speak and persons learning to use aided AAC (e.g. Brady et al., 2015). More research is needed to pinpoint if these, or other, pre-existing skills influence the likelihood that people will benefit from ALS.

Recommendations for practice/policy

Results from the current CAT provide limited evidence that supports the use of aided AAC in combination with elements of ALS interventions to improve graphic and speech comprehension skills in children with neurodevelopmental disabilities. Given the quality of the included articles, the evidence is suggestive, as none of the studies met all primary quality indicators, and not all studies measured procedural reliability at adequate levels. Results described are specific to speech and graphic comprehension outcomes, and do not apply to expressive outcomes. Therefore,

speech-language pathologists, special educators and other professionals implementing interventions to teach aided AAC production skills with the target population should carefully monitor speech comprehension and graphic symbol comprehension skills along with graphic symbol production during baseline, intervention, and subsequent to mastery. Doing so will inform intervention decisions related to speech and symbol comprehension intervention targets.

Recommendations for research

Although AAC interventions relying on ALS have been found to be effective in improving expressive outcomes (e.g. Allen, Schlosser, Shane, & Brock, 2017; Lynch, McCleary, & Smith, 2018; Sennott, Light, & McNaughton, 2016) and comprehensions outcomes (e.g. Harris & Reichle, 2004), findings from this CAT highlight the need for extensive further high-quality research to determine what type of aided AAC interventions have the biggest impact on improving comprehension skills in children with neurodevelopmental disabilities. Given the limited evidence for ALS interventions improving speech and graphic comprehension and quality of the included studies, these results are suggestive.

Future research is needed to fully establish the evidence base on the use of ALS and other AAC interventions for improving speech and graphic comprehension across aided AAC system, either as direct or indirect intervention targets. While at the same time, researchers also should focus on identifying learner profiles for whom these interventions are most effective, through a combination of systematic reviews and meta-analyses and empirical studies that match learner characteristics with hypothesized AAC interventions (e.g. individuals with imitative skills being exposed to ALS procedures).

Last, since most of the studies reviewed employed single case design, there is a need for careful, direct and systematic replication before conclusions can be made. To increase the ability to make direct comparisons across studies and investigators, it would also be helpful to agree on a standard assessment protocol prior to beginning an investigation; this could include baseline learner characteristic measures (e.g. consistent receptive language, imitation, and fast mapping assessments), consistent outcome measure definitions (e.g. speech comprehension vs. graphic comprehension and speech production vs. graphic production) and intervention definitions (e.g. ALM vs. ALS).

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