The Effect of Aided Language Stimulation on the Acquisition of Receptive Vocabulary in Children with Complex Communication Needs and Severe Intellectual Disability: A Comparison of Two Dosages

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Abstract

Aided language stimulation is an augmented input strategy that facilitates the expressive and receptive language skills of persons who require augmentative and alternative communication (AAC). The aim of this study was to determine and compare the acquisition of receptive vocabulary items during implementation of aided language stimulation with dosages of 40% and 70%, respectively. An adapted alternating treatment design was replicated across six participants with complex communication needs and severe intellectual disability. All participants demonstrated receptive vocabulary acquisition when aided language stimulation was provided with a dosage of 70%, and two participants demonstrated acquisition when a dosage of 40% was provided. Receptive vocabulary acquisition was maintained following a 6-day withdrawal period. The dosage of augmented input may impact receptive vocabulary acquisition for children with complex communication needs and severe intellectual disability, with higher dosages being more effective for some participants. The findings indicate that clinicians should be aware that dosage is an important consideration when providing aided language stimulation to facilitate receptive vocabulary acquisition in children with complex communication needs and severe intellectual disability.

Keywords: Adapted alternating treatment design; Aided language stimulation; Augmented input; Complex communication needs; Dosage; Intellectual disability; Receptive vocabulary acquisition

Children who use AAC systems are provided with most of their language input in the auditory modality, using spoken language; however, they are often required to develop and use an expressive language system that uses a visual modality, such as graphic symbols or manual signs (Romski et al., 2010, Smith & Grove, 2003;). This input-output asymmetry places additional burdens on persons requiring AAC because they are required to code switch between a verbally symbolic language system and a visually symbolic language system. This switch may lead to a breakdown in understanding and use of symbolic communication (Dodd & Gorey, 2014). It is for this reason that AAC interventions are required to connect language exposure, communication opportunities, and intervention outcomes (Dodd & Gorey, 2014).

Augmented input specifically aims to reduce input-output asymmetry (Sennott et al., 2016). The term was described by Goossens' in 1989, as "pointing to key symbols on the learner's communication display in conjunction with all ongoing verbal language stimulation being directed toward that (learner)" (Goossens' et al., 1989 p. 11). Augmented input refers to a variety of strategies, such as the System for Augmenting Language (Romski et al., 2009), Natural Aided Language (Cafiero, 2001), aided language modeling (Drager et al., 2006), aided-AAC modeling (Binger & Light, 2007), and aided language stimulation (Goossens', 1989). These strategies have two commonalities: augmenting input (which focuses on comprehension) and providing a vocabulary expansion model (which focuses on expression) (Drager et al., 2006).

Common features of augmented input are that the communicative partner draws attention to the child's AAC system and models the expressive use of the system in a naturalistic communication interaction within the learner's everyday interactions (Sennott et al., 2016). The core principle is that, just as children learning a new language should be immersed in an environment that uses that language, persons who require AAC should be immersed in an environment that uses AAC (Sennott et al., 2016). Augmented input strategies differ with respect to whether the visual input is paired with high-tech voice output communication aids or low-tech communication aids that use verbal output of the facilitator during communication exchanges (Drager et al., 2006). Despite the complexities of language acquisition in relation to language exposure and/or asymmetry in communication, children with developmental disabilities who have little to no functional speech have been shown to develop receptive and expressive language skills using an aided-AAC system (Binger & Light, 2007; Geytenbeek et al., 2015; Romski & Sevcik, 1996) during modelling-based interventions (Allen et al., 2017; Biggs et al., 2018; Sennott et al., 2016). A variety of reviews have explored the effect of augmented input strategies on language development in children with disabilities (Allen et al., 2017; Biggs et al., 2018; Dada et al., 2020; O'Neill et al., 2018; Sennott et al., 2016). Two of these studies (Allen et al., 2017; Sennott et al., 2016) considered participants between 2- and 12- years-old; two studies considered older participants (Biggs et al., 2018; O'Neill et al. 2018), and four studies considered components of the intervention and dosage (Allen et al., 2017; Biggs et al., 2018; Dada et al., 2020; O'Neill et al., 2018).

Sennott et al. (2016) conducted a systematic review on the effects of augmented input on the language acquisition of persons with complex communication needs. A data set of 31 participants between the ages of 2-and 12-years old with a variety of disabilities was identified. The independent variable required that the AAC modelling-based intervention should include modelling of aided-AAC; the dependent variables included increased communicative turns, vocabulary knowledge, multi-syllable utterances, and knowledge of early morphological forms. The authors concluded that AAC modelling resulted in gains in pragmatics, receptive and expressive semantics, syntax, and morphology development for young/beginning communicators. However, as the intervention included AAC modelling-based amongst other interventions it is challenging to solely attribute gains to augmented input (Biggs et al., 2018). Minimal information regarding the components of the intervention was extracted in this review.

Allen et al. (2017) conducted a review to determine the effect of augmented input on persons with developmental disability and childhood apraxia of speech who used aided- AAC. Participants ranged from 2- to 12-years-old with moderate to severe intellectual disability. Augmented input was the independent variable; studies in which augmented input was provided in conjunction with other interventions were excluded, thereby making it less challenging to attribute gains solely to augmented input. The dependent variables were receptive vocabulary, expressive vocabulary, receptive syntax, expressive syntax and pragmatics. Allen et al. (2017) also reported gains in single-word vocabulary skills and expression of multi-symbol utterances but did not explore comprehension beyond the single-word level. A valuable aspect of this review is that it considered how frequently augmented input was provided. Of the 17 studies in Allen et al. 10 reported on dosage, which ranged from every opportunity (Drager et al., 2006) to 30 models per 15-min session (Binger & Light, 2007).

A review conducted by Biggs et al. (2018) examined experimental studies involving aided-AAC modelling to facilitate expressive communication of children and youth (birth to 21 years) with complex communication needs. The independent variable was aided-AAC modelling. The dependent variables were expressive pragmatics, morphology, syntax, and semantics. It was concluded that although procedures varied, interventions had a positive effect on expressive communication. Of the 48 studies reviewed, 11 reported on duration, frequency, and session length. The dependent variable focused exclusively on expressive communication area and limited the extent of overall communication performance.

O’Neill et al. (2018) conducted a meta-analysis to investigate the effects of AAC interventions (such as aided-AAC input) on the communication outcomes of individuals with developmental disabilities who required AAC. Participants ranged from 3- to 59-years-old with diagnoses of autism spectrum disorder, cerebral palsy, Down syndrome, intellectual or developmental disabilities, Prader-Willi syndrome, or childhood apraxia of speech. The independent variable was AAC interventions, including aided-AAC input. O’Neill et al. reported that dependent variables in the studies were related to outcomes for both expressive and receptive language; however, expressive outcomes were reported more frequently than receptive outcomes, and pragmatic outcomes were reported more frequently than semantics or morphosyntax and a limited number of studies included information regarding frequency of intervention sessions and the rate of aided-AAC input. The authors referred to rate as the number of aided inputs provided by length of session in minutes and suggested that a higher rate of input would obtain more positive results; however, this was based on a limited number of studies for which this data was available. Furthermore, when rate was mentioned, it was generally low – about two inputs per minute.

Finally, Dada et al. (2020) conducted a scoping review to map and synthesise the effects of aided and unaided-AAC intervention on the receptive language of children with developmental disabilities. In contrast to Allen et al. (2017), Biggs et al. (2018), O’Neill et al., 2018; and Sennott et al. (2016), Dada et al. had an independent variable that, for the first time, included *both* aided and unaided intervention. The dependent variable -- receptive language -- included comprehension of words, morphology, discourse and understanding of symbols.

Expressive language was excluded. Dada et al. reported positive associations between aided and unaided-AAC, vocabulary acquisition and symbol comprehension. Gaps identified were (a) a lack of comparison studies on various interventions used for augmented input; (b) a lack of comparison studies for aided and unaided interventions; (c) little clarity on augmented input; (d) a focus on single word and single symbol vocabulary acquisition; (e) limited studies on the effects of AAC interventions on morphology, syntax, and discourse comprehension; (f) limited studies using randomized control trials or non-randomised group studies; and (g) a lack of evidence on the impact of AAC interventions on adolescents with developmental disabilities and different disability groups. The authors concluded that a lack of detail about and terms describing augmented input resulted in variations in instructional practices, which fractures the field and excludes augmented input as an evidence-based intervention. While there are high-quality studies that suggest aided augmented input may be linked to gains in receptive language development for children with developmental disabilities, the lack of clear descriptions and clarity regarding augmented input strategies, dosage, and frequency make use, replication, and generalizability challenging (Dada et al., 2020).

The previously discussed reviews differ with regard to independent and dependent variables, diagnosis, and chronological age of the participants – factors that should be considered in relation to outcomes. Although these studies vary in terms of recommendations for future research, the common element is the call for improving the evidence base and thereby making replication easier, although this will require explicit detail regarding the augmented input strategy. In terms of intervention, the studies highlight the need for future research to provide clarity regarding (a) dosage level (Biggs et al., 2018; Dada et al., 2020; O'Neill et al., 2018; Sennott et al., 2016); (b) frequency of augmented input (Allen et al., 2017; Dada et al., 2020;

O'Neill et al., 2018); (c) AAC systems and stimuli used (Allen et al., 2017; Biggs et al., 2018; Dada et al., 2020); (d) aspects of participant profiles (Allen et al., 2017; Biggs et al., 2018; Sennott et al., 2016); (e) maintenance (O'Neill et al., 2018); and (f) generalization (O'Neill et al., 2018). They also identify the need for varied populations, disabilities, and age groups to be represented in future studies (Allen et al., 2017; Biggs et al., 2018; Sennott et al., 2016).

The significance of aided language stimulation as an augmented input strategy that facilitates the expressive and receptive language skills of persons who require AAC cannot be overstated. The Goossens' (1989) study highlighted the interactive nature of aided language stimulation as the interventionist pointed to a symbol on the child's communication display while providing verbal output stimuli. Dada and Alant (2009) provided aided language stimulation to four participants with little to no functional speech. Participants demonstrated receptive language acquisition when aided language stimulation was used 70% of the time, with a statement-question ratio of 80:20 (for every 80 statements made there were 20 questions). The researcher conducted arts and craft, food preparation, and story time activities using a facilitator board with picture communication symbols (PCS) containing target vocabulary and core vocabulary.

While there is no accepted definition of treatment intensity in language and communication intervention studies, Warren et al. (2007) propose five terms that highlight the components of intervention intensity: dose, dose form, dose frequency, total intervention duration and cumulative intervention intensity. *Dose* refers to the number of accurately provided teaching episodes during a single intervention (Warren et al., 2007). During aided language stimulation, dose does refer to the number of times verbal output stimuli was paired with visual stimuli (i.e., the number of times the target vocabulary was spoken and the PCS symbol on the facilitator board pointed to. *Dose form* refers to the task or activity in which the teaching episode is delivered anddose frequency refers to the number of times a dose of intervention is provided per day (Warren et al., 2007). *Total intervention duration* refers to the time period in which a specified intervention was presented, with *cumulative intervention intensity* the product of dose x dose frequency x total intervention duration, which is a good general indicator of overall intensity (Warren et al., 2007). With respect to augmented input, the important components are (a) dosage of aided-AAC models (e.g., number of models provided); (b) dose form, which is the type of activity and communication techniques used; (c) dose frequency, which is the number of sessions per day or week; (d) time per session; and (d) intervention duration, which is the number of weeks or months (Brock & Allen, 2017).

By investigating treatment intensity, the door to a different type of knowledge is opened. Specifically, it highlights if an intervention is more or less effective at certain intensity levels, if changes in intensity variables may have different treatment effects for different population groups, and if side effects could occur when individuals or families are exposed to higher level of treatment intensity. Finally, it showcases the role of cumulative intensity on child development (Warren et al., 2007).

Schmitt et al. (2017) conducted a study that indicated more intensive language treatment, measured as time, did not necessarily result in greater gain. Higher dosage may not always result in greater gains and it is therefore important to consider high and low dosage in order to fully understand the economic and developmental costs treatment intensity may have on children and the communities that serve them (Schmitt et al., 2017). Treatment intensity should be provided in a manner that affords the best possible outcomes; thus, decisions about treatment intensity should be as precise as possible and consider empirical models of the relationship between treatment intensity and outcomes (Justice et al., 2017).

The purpose of the current study was to determine and compare the acquisition of receptive vocabulary items during implementation of aided language stimulation with dosages of 40% and 70%, respectively, in children with complex communication needs and severe intellectual disability. Key goals were to provide information pertaining to dosages of augmented input, specifically aided language stimulation, as well as detailed descriptions of participant profiles and interventions provided.

Method

Participants

Purposeful sampling was used to select participants from a school for learners with special educational needs in Gauteng, South Africa. Teachers at the school identified 12 possible participants, the parents of whom were sent consent forms and information about the study. Of 12 potential participants, six met the following inclusion criteria: (a) had complex communication needs determined by less than 50% intelligible speech in the sematic context – unfamiliar listener condition on the Index of Augmented Speech Comprehensibility for Children (I-ASCC; Dowden, 1997); (b) had a receptive single-word vocabulary age equivalent score of at least 2 years using the Peabody Picture Vocabulary Test – Fourth Edition (PPVT-4; Dunn & Dunn, 2007); (c) had attended school with English as a language of learning and teaching for at least 1.5 years; (d) were able to identify line drawings with a frequency of 90% using the Ability to Identify Line Drawings Test (Dada, 2004); (e) were able to concentrate for 15 min on an activity, based on teacher report; (f) had no reported visual and hearing impairments; (g) had severe intellectual ability as determined by the Kaufman Brief Intelligence Test (Kaufman &

Kaufman, 2004); and (h) had 0% correct responses on probe measures assessing receptive identification of the target vocabulary used in the study. They were aged between 8.8 and 13.7 (years;months) and had been diagnosed with Down syndrome and severe intellectual disability. The six participants were randomly assigned to Group 1 and Group 2. Group 1 consisted of Participants 1, 3, and 5; Group 2 comprised Participants 2, 4, and 6.

Participant 1 did not make use of aided-AAC systems and was receiving school-based speech therapy that did not focus on AAC intervention. Participants 2, 3, and 6 had been using low-tech aided-AAC for 3 years prior to the study, in the form of communication files containing picture communication symbols from Boardmaker Plus v6.1.6 (Mayer Johnson, 2011). They received weekly AAC intervention from the school-based speech therapist. Participants 4 and 5 had been using unaided-AAC in the form of key word sign and gesture for approximately 2 years and were not receiving speech therapy or AAC intervention. Participants 1, 4, and 5 did not have access to aided-AAC due to limited resources, staff shortages, and contextual factors unrelated to their performance or functioning, and were not receiving speech therapy. Parents provided consent in writing; assent was obtained from the participants. Table 1 provides a description of participant demographics.

Table 1

Participant Descriptions

#	Age [a]/Sex	Diagnosis	I-ASCC	PPVT-4	AILDT	KBIT-2	TACL-4			AAC system
							Vocabulary	Grammatical morphemes	Elaborated phrases and sentences	
1	8;5/F	DS	0%	<2yrs	95%	Lower extreme	<3yrs	< 3yrs	< 3yrs	None
2	9;10/M	DS	0%	<2yrs	95%	Lower extreme	<3yrs	<3yrs	<3yrs	Low-tech aided
3	10;2 /F	DS	0%	2yrs	90%	Lower extreme	<3yrs	<3yrs	<3yrs	Low-tech aided
4	10;2 /F	DS, MG	0%	2yrs	90%	No Basal	<3yrs	<3yrs	<3yrs	Unaided
5	12;2 /M	DS	26%	3.2 yrs	95%	Lower extreme	3.6 [a]	3yrs	3.6 [a]	Unaided
6	13;7 M	DS	3%	2.1yrs	95%	Lower extreme	[a]<3yrs	[a]<3yrs	[a]<3yrs	Low-tech aided

Note. F = female; M=male; DS = Down syndrome; MG = myasthenia gravis; I-ASCC= Index of Augmented Speech Comprehensibility for children (Dowden, 1997); PPVT-4 = Peabody Picture Vocabulary Test – Fourth Edition (Dunn & Dunn, 2007); AILDT= Ability to Identify Line Drawing test (Dada, 2004); KBIT-2= Kaufman Brief Intelligence Test Second Edition (Kaufman & Kaufman, 2004); TACL-4= Test of Auditory Comprehension of Language – 4th Edition (Carrow-Woolfolk 2014).
[a] years;months

Setting

The intervention and probe sessions were implemented in a small room at the participants' school. The room was controlled for visual and auditory distractions, and the intervention was provided to three participants simultaneously in a group format. The participants were seated in a small table in a semi-circle, in front of the low-tech facilitator boards developed for the study. The researcher was seated to the side of the communication board. A video camera was placed behind participants during intervention sessions. A video camera mounted on a tripod was used to capture pre-assessment, intervention sessions and probes, and was placed behind the participants.

Materials

Tests

The Index of Augmented Speech Comprehensibility for Children (I-ASCC: Dowden, 1997) was used to assess intelligibility. Participants who produced fewer than 15 intelligible words were included in the study. The Peabody Picture Vocabulary Test – Fourth Edition (PPVT-4: Dunn & Dunn, 2007). The PPVT-4 was used to determine the English receptive vocabulary skills of participants. The Ability to Identify Line Drawings Test (AILDT: Dada, 2004) was used to assess the ability to identify black and white PCS symbols (7.5 cm x 9 cm; 2.9 inches x 3.5 inches) against a yellow background. The Kaufman Brief Intelligence Test – Second Edition (KBIT 2: Kaufman & Kaufman, 2004) was used to measure the verbal and nonverbal intelligence of participants. The Test of Auditory Comprehension of Language – Fourth Edition (TACL-4: Carrow-Woolfolk, 2014) was used in conjunction with the PPVT (Dunn & Dunn, 2007) to assess receptive vocabulary, grammatical morphemes, and elaborated phrases and sentences in English because the intervention was provided using sentences. The Test of Aided-

Communication Symbol Performance (TASP: Bruno, 2010) was used to assess participants performance in relation to symbol size and number, grammatical encoding, categorization skills, and syntactic performance. Information obtained from this test was used to ensure that participants were able to engage with the facilitator board. The Manual Ability Classification System (MACS: Eliasson et al., 2006) classifies how children with cerebral palsy use their hands when handling or manipulating objects. This test was used to determine if participants has the motor ability to participate in the activity during intervention.

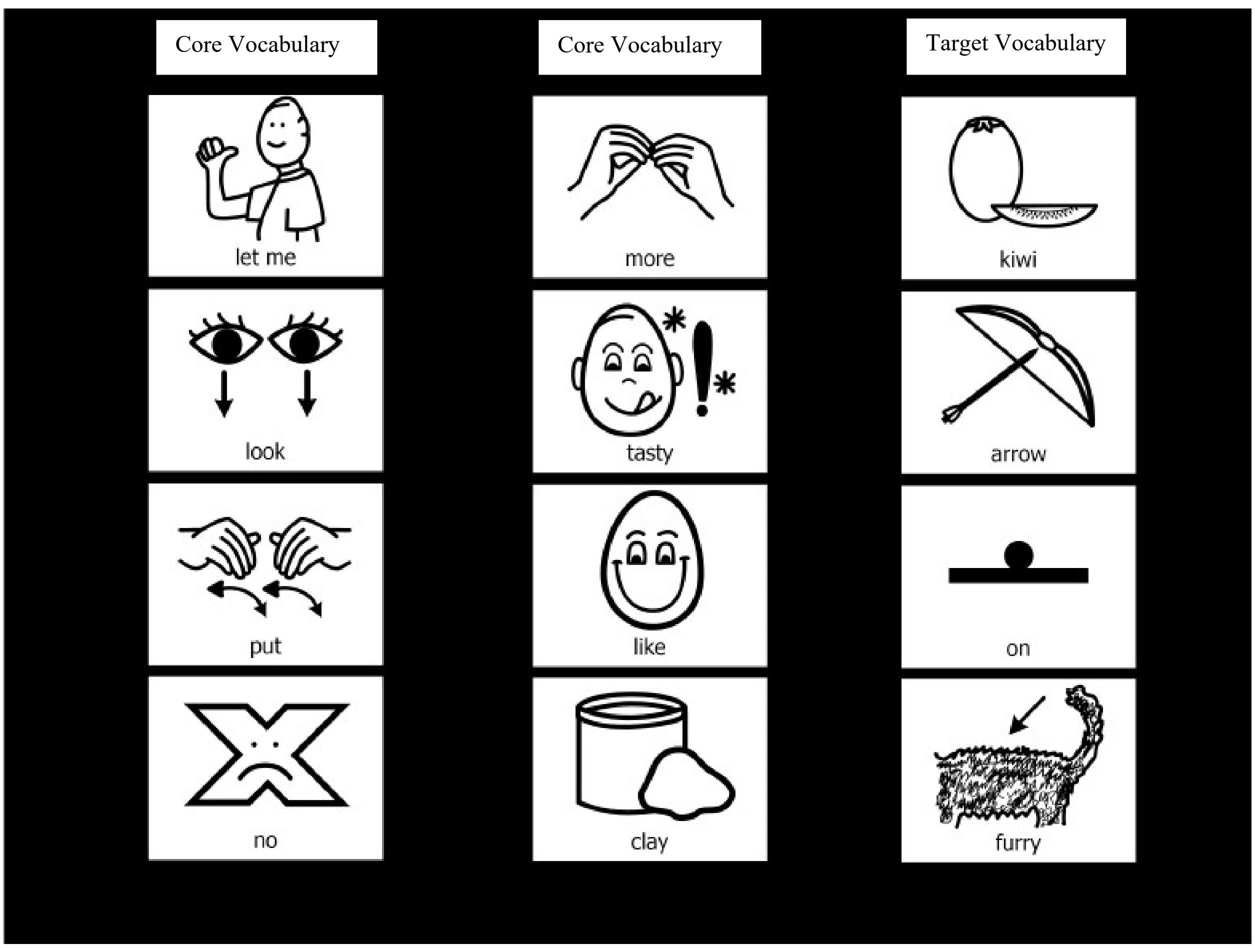
Facilitator Boards

Two matte black facilitator boards - one for the 40% and one for the 70% aided-language stimulation dosages - were developed using Boardmaker Plus v6.1.6 software (Mayer Johnson, 2011). The boards were 19.6 inches x 27.5 inches/ 50 cm x 70 cm in dimension, and were based on principles outlined by Goossens' et al. (1992) and Dada and Alant (2009). For example, a grid layout was used with each board and contained 12 PCS symbols: four target vocabulary symbols and eight core symbols. Size, number, arrangement, use of colour, and organization of symbols play a role in the cognitive processing and ultimately the learning and use of symbols (Wilkinson & Jagaroo, 2004). The PCS were 10 cm by 10 cm (3.937 x 3.937 inches) in dimension and laminated. Each symbol had a corresponding written gloss above the picture in Junior ABC font in font size of 18 point was used.

Results from the Test of Aided-Communication Symbol Performance (Bruno, 2010) were used to determine the size and number of PCS symbols, which should be large enough for participants to see clearly (Thistle & Wilkinson, 2020). As suggested by Goossens' et al. (1992), the PCS were black and white with a colored background, depending on the category of the words. Core vocabulary symbols remained fixed on the facilitator boards while the target vocabulary symbols were attached behind the board and then placed on the board during aided language stimulation (Goossens' et al, 1992). Target vocabulary items were placed in the same column to draw participants attention to the them; this also improved the researcher's access to the items.

As noted by Thistle and Wilkinson, factors that facilitate augmented input include clustering symbols into small quadrants rather than row-column grids, grouping symbols according to shared internal color, and arranging symbols by grammatical category. Figure 1 depicts one of the facilitator boards, including fixed core vocabulary and removable target vocabulary that were removable, used for the 40% aided language stimulation activity.

Figure 1
Facilitator Board Used for the 40% Aided Language Stimulation Activity



Target Receptive Language Items

Three sets of target receptive vocabulary items were selected for this study. One set for the 40% dosage and one for the 70% dosage respectively, while the third set acted as a control to detect history and maturation effects and was not linked to an intervention. In keeping with adapted alternating treatment design principles (Wolery et al., 2014), all vocabulary sets were equally difficult, and three methods were used to ensure this was the case: First, vocabulary was selected from vocabulary lists for which norms exist (e.g., core vocabulary lists and developmental checklists). Second, postgraduate students were consulted to rate the difficulty of potential target vocabulary. Third, logical analysis of the target vocabulary was conducted by ensuring each set consisted of two nouns, a preposition, an adjective, and words with the same number of syllables. The target vocabulary associated with aided language stimulation with a dosage of 40% was “kiwi”, “arrow”, “furry” and “on.” The target vocabulary associated with aided language stimulation with a dosage of 70% was “cactus”, “violin”, “tall” and “under.” Vocabulary items in the control set were “squirrel”, “wedge”, “tall” and “under.” Items used during intervention were clay, a plastic bow and arrow, fur, sand, seeds, water, and a toy violin.

Probe Test

The probe test was used to determine the degree of acquisition of the target receptive vocabulary items. The test was used during baseline testing, before intervention on alternating days, and during the maintenance probe. Three consecutive baseline scores were established prior to intervention to assess participants’ acquisition of the target receptive vocabulary items during the intervention and maintenance phases. The probe test was comprised of four objects: one target vocabulary item and three foil items. Each target receptive vocabulary item from the intervention and control sets, respectively, were presented in the following manner: The researcher said, *Show me the cactus*, and the participant was required to select one object using direct selection.

Probe and Intervention Scripts

A script for the probes was used to ensure procedural integrity. Results were marked on a probe answer sheet. Two intervention scripts were created for providing aided language stimulation: one with a dosage of 40% and one with a dosage of 70%. Each target vocabulary word was predetermined to appear 20 times and was scripted with a statement-question ratio of 80:20 (Goossens', 1989). The scripts used the same sentence structures, number of words per sentence, and number of syllables per word. The script for the dosage of 40%, involving a kiwi fruit, ensured that stimulation occurred for the core vocabulary words only 40% of the time it was spoken by the researcher. The stimulation was provided for each target word 8 times in each activity. The script for the 70% dosage, which involved planting a seed, ensured that stimulation occurred for the target words only 70% of the time it was spoken by the researcher. The stimulation was provided for each core vocabulary word 14 times. Table 2 illustrates a part of the intervention script with 40% and 70% dosages.

Table 2
Portion of the Intervention Scripts for Dosages of 40% and 70% Aided Language Stimulation

40% aided language stimulation	70% aided language stimulation
Look at the KIWI ON the plate	*Look the seed is UNDER the sand*
Let me cut it so you can see how it looks inside	*Who wants to press the seed UNDER the sand?*
Look it is green inside	*Press the seed UNDER the sand*
With a FURRY brown peel	*Look the seed is UNDER the sand*
Look this is what we need to make it	*Who wants to press the seed UNDER the sand?*
We need green clay	*Press the seed UNDER the sand*
We need brown clay	*Look the seed is UNDER the sand*
It feels FURRY	*Who wants to press the seed UNDER the sand?*
This is what we need to make it FURRY	*Press the seed UNDER the sand*
We are going to make it FURRY by putting fur ON it	*Look the seed is UNDER the sand*

Note. Naturally spoken elements are italicized. Words capitalized and italicized received aided language stimulation.

Research Design

An adapted alternating treatment design was replicated across the six participants and used to determine the relative effectiveness of the two augmented input dosage conditions on participants' acquisition of target receptive language items (Wolery et al., 2014). This design allowed for each participant to be exposed to each condition and for the efficiency of each strategy to be compared in each participant. The two augmented input dosage conditions (40%

and 70%) were provided simultaneously to the two groups of randomly assigned participants in a systematically alternating fashion. A break of at least 1 hr between sessions was provided to minimize multi-treatment effects (Wolery et al., 2014). If Group 1 received the intervention with a dosage of 40% first on a particular day, then Group 2 received the intervention with a dosage of 40% first on the following day. Intervention probes were conducted before each intervention session on every alternate day, in accordance with the baseline probes. Table 3 illustrates the systematic alternation of the intervention sessions.

Table 3

Implementation of Intervention (40% and 70% Aided Language Stimulation)

Group	Day	Intervention received first	Intervention received second
Group 1	Day 1	Dosage of 40%	Dosage of 70%
Group 2	Day 2	Dosage of 70%	Dosage of 40%
Group 1	Day 3	Dosage of 40%	Dosage of 70%
Group 2	Day 4	Dosage of 70%	Dosage of 40%

A total of four target vocabulary items were taught in each dosage condition, with the control set of four vocabulary items probed each time the target vocabulary was probed. In accordance with the simultaneous replication design, assessments, baseline measurements, and probes of each participant were done individually.

Both teaching and learning criteria were set. A learning criterion of 100% correct identification of target vocabulary in the probe conditions over two consecutive probes was set (Schlosser, 2003). A teaching criterion of 10 days (excluding weekends) was set because it allowed the termination of teaching if the learning criterion was not achieved (Schlosser, 2003).

Additionally, the teaching criterion was designed to prevent boredom, fatigue, and decreased participation and attention due to repeated exposure to the same activity. In keeping with the school curriculum, teaching, and learning activities were not repeated for more than 10 lessons. The teaching criterion also ensured that participants would not lose teaching and learning time in the classroom. A withdrawal period of 6 days followed, where no aided language stimulation was provided. Thereafter maintenance probes were conducted for three sets of vocabulary items once a week for 3 weeks.

Approval for this study was obtained from the ethics committee of the University of Pretoria, South Africa. Written permission was obtained from the relevant South African provincial department of education, as well as the principal, educators, and governing body of the students' school.

Procedures

Baseline Phase

Prior to the commencement of the interventions, three consecutive baseline measures were completed for all the target vocabulary items, including those in the control set, using the probe test for each participant. Baseline probes were conducted until a stable baseline of 0/8 correct responses was obtained over three consecutive tests.

Intervention Phase

Group 1 and Group 2 participants received the aided language stimulation interventions with dosages of 40% and 70% daily, in a systematically alternating fashion as described in Table 2. Each intervention session was 20 minutes in duration with a break of one hour between sessions to minimize multi-treatment effects (Wolery et al., 2014). The dose frequency of this study was once a day, participants received the intervention with a dosage of 40% and 70% once a day. The same scripts were used during each intervention session. The total duration of this study was 10 days, in accordance with the set teaching criterion. Participant data was excluded if they missed an intervention session due to absenteeism.

The dose form was aided language stimulation delivered during two activities. Target words were spoken a total of 20 times in both the 40% and 70% aided language stimulation interventions. During the 40% dosage intervention, each participant had an opportunity to assist in making a kiwi fruit out of clay and shooting it with a foam bow and arrow. The first author provided spoken language input paired with simultaneously pointing to the PCS symbol (2 *s*) on the facilitator board (core vocabulary), 8 times, thereby providing 40% aided language stimulation. For example, when the first author said, *Look the Kiwi is on the table,* she pointed to the PCS symbols on the facilitator board: *Look + KIWI + ON*. During the intervention with a dosage of 70%, participants assisted in planting a cactus seed and helping it to "grow" by playing music from a violin. The facilitator used verbal output paired with pointing to the PCS symbol on the facilitator board (core vocabulary) 14 times, thereby providing 70% aided language stimulation. The participants took turns interacting with the materials.

Activities for this study were custom developed. All featured the same number of steps to completion and allowed participants to take the same number of individual turns to interact with materials. The first author was responsible for conducting baseline, intervention and maintenance probes and providing intervention to both groups of participants.

Maintenance Phase

Maintenance probes were conducted, after withdrawal of intervention, for three sets of vocabulary items once a week for 3 weeks.

Data Analysis

A comparison of the number of correct responses obtained for the dosages of 40% and 70% was conducted both visually and statistically for effect (Kratochwill et al., 2010). In an adapted alternating treatment design, each participant serves as their own control; hence, the results from the probes were analyzed for individual participants in terms of level, immediacy of effect, trend, variability, relative change, and overlap within and between phases. This data was used to determine if there was an effect that could infer a causal relationship between the dependent and independent variables (Kratochwill et al., 2013).

Level. A change in level between phases provides evidence of the effect of the independent variable. A change in level of 1 is considered evidence of an effect (where results are percentages, a change in level of 20% is suggested). For this study, 1 represented 25% (Ayres & Gast, 2010).

Immediacy of Effect. This provides an indication of how quickly a change in levels occurred on introduction of the independent variable. For this study, a difference of +/-1 was considered sufficient to indicate immediacy (Kratochwill et al., 2013).

Trend. The trend for each phase of the study was determined. A positive slope indicated that results improved from one probe to the next, while a negative slope shows that results deteriorated from one probe to the next.

Variability. To determine if changes in the outcome measure were following the trend, a stability envelope of +/- 0.5 (12.5%) from the trend line was used (results were not represented as a percentage) (Gast & Spriggs, 2010). A stable trend is indicated when 80% of the data falls within the stability envelope. A variable trend is reflected when more than 20% of the data falls outside of the stability envelope (Horner et al., 2012).

Relative Change (trend). A change in trend between phases provides evidence of the effect of the independent variable (Gast & Spriggs, 2010). For this study, a change in level of 1 was considered evidence of an effect (Ayres & Gast, 2010).

Overlap. Due to the widespread application of the Percentage of Non-overlapping Data (PND) in single-subject research (Scruggs & Mastropieri, 2013), PND was selected (in addition to IRD) as a measure of effect to allow its comparison to existing studies (see below). PND was calculated as follows:

$$\text{PND} = \frac{\text{number of data points in treatment phase higher than the highest in baseline phase}}{\text{total number of data points for treatment phase}}$$

PND scores above 90% indicate very effective intervention, scores between 70% and 90% indicate effective intervention, scores between 50% and 70% indicate questionable intervention, and scores below 50% indicate ineffective intervention (Scruggs & Mastropieri, 2013).

Statistical Analysis

The effect size of the treatment was calculated using Improvement Rate Difference (IRD). IRD provides an indication of the percentage of improvement in performance between baseline intervention phases and is considered a robust measure of improvement rate, equal to Cohen's Kappa and Cramer's V (Parker et al., 2009). IRD is more sensitive than PND, particularly in overlap data situations. It has strong inter-scorer reliability, correlates with para-metric and non-parametric effect sizes, and meets APA 6 publication standards of providing the Confidence Interval (CI) (Parker et al., 2009). In the current study, IRD was calculated in two steps: The first involved calculating the improvement rate within each baseline and treatment phase and the second involved calculating the IRD by determining the difference between the improvement rate (IR) of treatment and baseline phases. The improvement rate within each baseline and treatment phase is calculated using:

$$\text{IR} = \frac{\text{number of improved data points}}{\text{total number of data points in that phase}}$$

In the baseline phase, an improved data point is equal to or greater than any data point in the treatment phase. In the treatment phase, an improved data point is greater than all data points in the baseline phase. For the current study, an improved data point was higher than a previous data point, as the aim of the intervention was to increase receptive vocabulary.

The IRD was calculated by determining the difference between the IR of treatment and baseline phases: IR_T - IR_B = IRD. IRD values of 0.7 and higher show large effects, while values between 0.5 and 0.7 show moderate effects, and values of 0.5 and below show small or questionable effects (Parker et al., 2009). Positive IRDs indicate that intervention phase responses are equal to or higher than points in the baseline, while negative IRDs indicate higher values in the baseline rather than the intervention phase (Parker et al., 2009). For this study, IRD was calculated using the online statistical calculator available at www.singlecaseresearch.org (Vannest et al., 2016); CIs were calculated using IBM SPSS statistics software (version 26) using a two-tailed parametric *t*-test (Michiels et al., 2017)

Reliability/Integrity

The stimulation provided was scripted for each activity to ensure procedural integrity. Reliability was determined through adherence to the intervention script, probe script, and scoring of the probe test. An independent speech therapist served as an inter-rater. She randomly selected and observed 40% of the video recordings and completed the procedural checklists. She also calculated integrity of adherence to the intervention scripts using a procedural integrity checklist. Each step was scored as “done” or “omitted” and converted to a percentage, after which procedural integrity was calculated using the formula of Kuoch and Mirenda (2003, p. 222).

Procedural integrity scores were above 90% for both dosages, which exceeded the acceptable score of 80% (Ayres & Gast, 2010).

In order to determine reliability of data capture, all probe answer sheets were checked by the inter-rater to ensure that the first author had marked answers correctly on the answer sheet and that results were tallied correctly. Inter-rater reliability was calculated using the Tawney and Gast (1984) inter-rater reliability formula. There was 100% agreement on the scoring of the probe answer sheets.

Results

Data in the control set remained stable for all participants across baseline, intervention, and maintenance phases.

Baseline Phase

Participants 2 to 6 maintained a stable baseline of 0 (i.e., no knowledge of the target vocabulary). Participant 1 showed a small amount of variability in the baseline phase (33%); intervention was initiated because this participant did not show consistent receptive knowledge of a specific target vocabulary.

Intervention

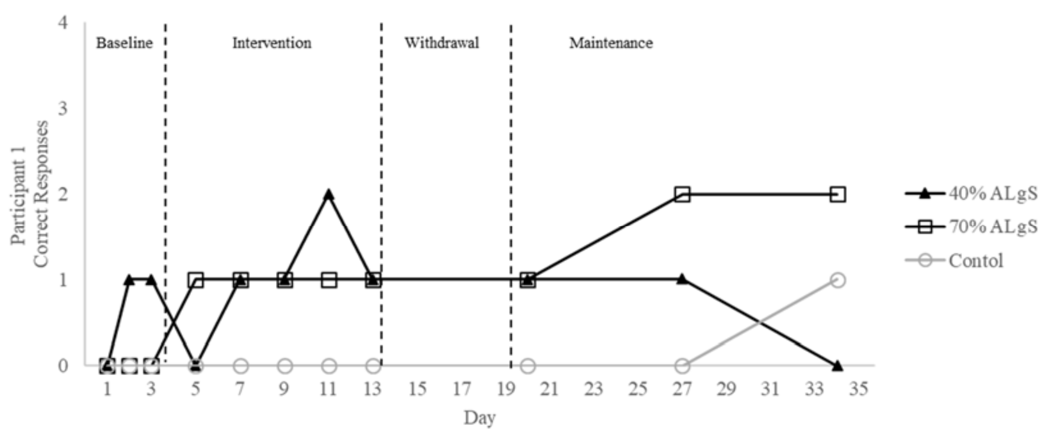
40% Dosage

For the 40% dosage intervention, Participants 3 and 4 demonstrated a large effect of the independent variable on the dependent variable for overlap (PND) and IRD of 100% and 1(1.000;1.000) and 100% and 1(1.1015; 2.984), respectively. Participants 2 and 5 had a PND of 60% (questionable effect) and an IRD of 0.60 CI (0.685; 2.815) (moderate effect). Participants 1 and 6 showed no effect of the intervention with PND (P1: 20% P6:0%) or IRD (P1: -0.8 and P6:0). For Participants 3 and 4, the relative change in level was immediate upon introduction of the intervention. Both participants presented positive trends in data; however, the data for Participant 3 was variable while the data for Participant 4 was stable to the trend (20% variability). Participants 1, 2, 5, and 6 did not record an immediate change upon introduction of the intervention. They showed a relative change in level of 0.33, 0.66, 0.60 and 0.00, respectively (no effect); and relative change in trend of -0.20, 0.66, 0.60 and 0.00, respectively (no effect).

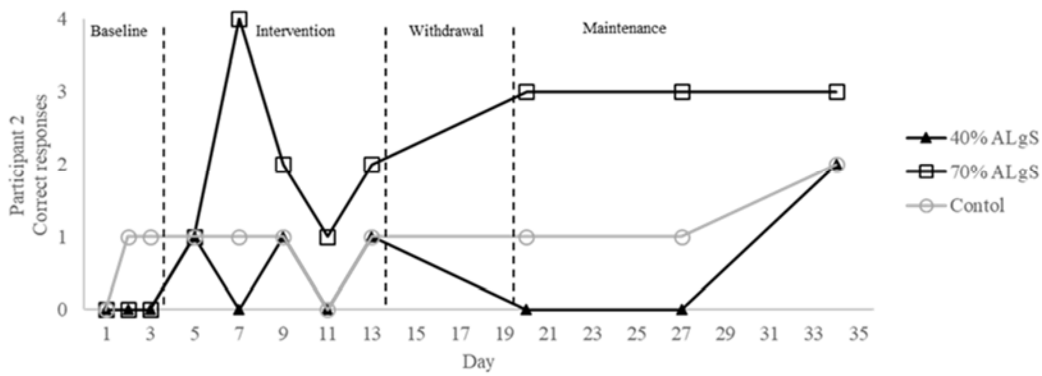
70% Dosage

In the 70% dosage intervention, all participants demonstrated an improved effect of the independent variable on the dependent variable for level, immediacy, overlap (PND), and IRD. The relative change in level for participants was immediate: 1.00, 2.00, 1.60, 1.40, 2.00, and 3.00 for Participants 1 to 6, respectively. All had PNDs of 100% (no overlap, very effective). Participants 1, 3, and 4 had data that was stable to the trend, while the data for Participants 2, 5, and 6 varied from the trend. Participants 1, 2, and 5 showed continued improvement during the maintenance phase while Participants 3, 4, and 6 maintained the gains from the intervention phase. Figure 2 (a-f) illustrates individual participant performance of probe data across conditions.

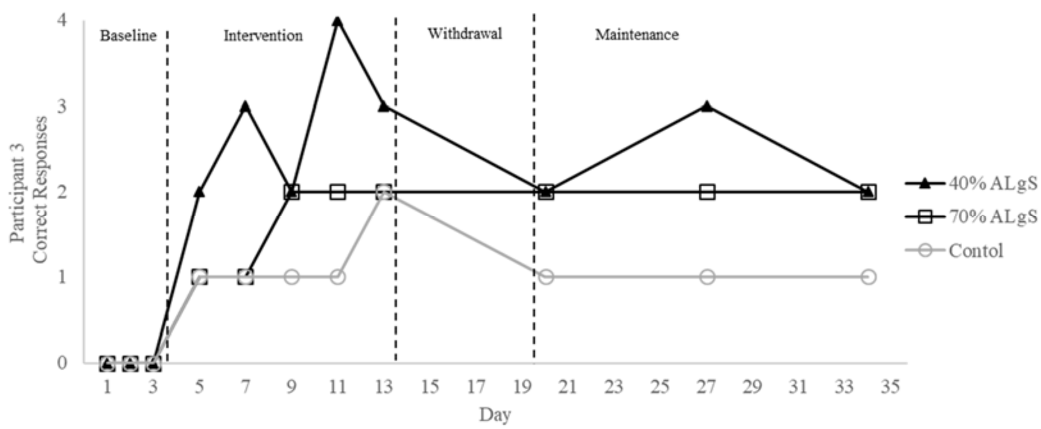
Figure 2 (a-f)
(a) *Individual Participant Performance of Probe Data Across Conditions for Participant 1*



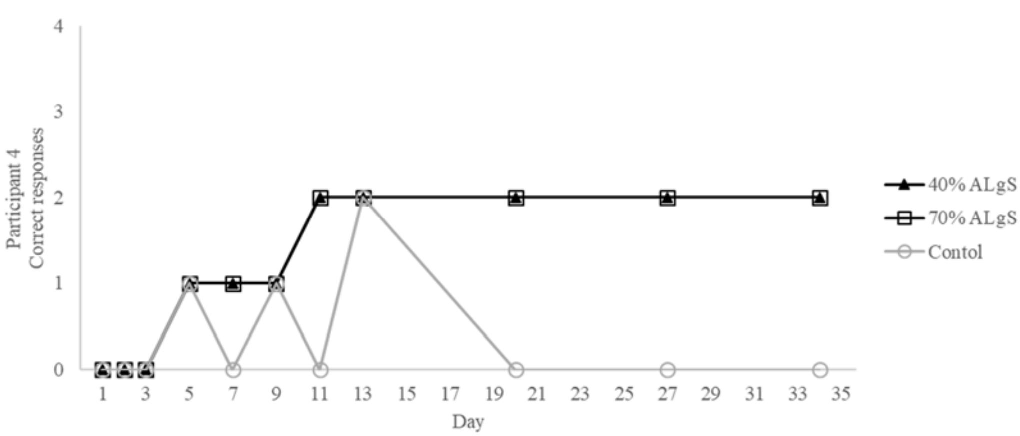
(b) *Individual Participant Performance of Probe Data Across Conditions for Participant 2*



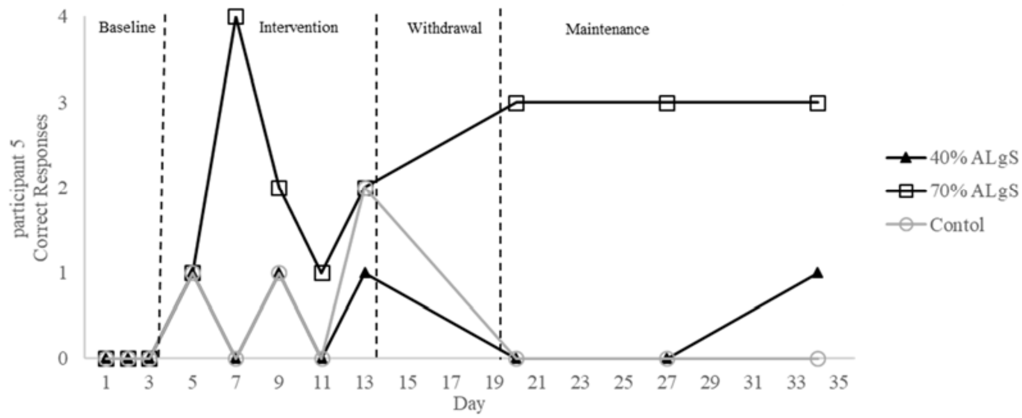
(c) *Individual Participant Performance of Probe Data Across Conditions for Participant 3*



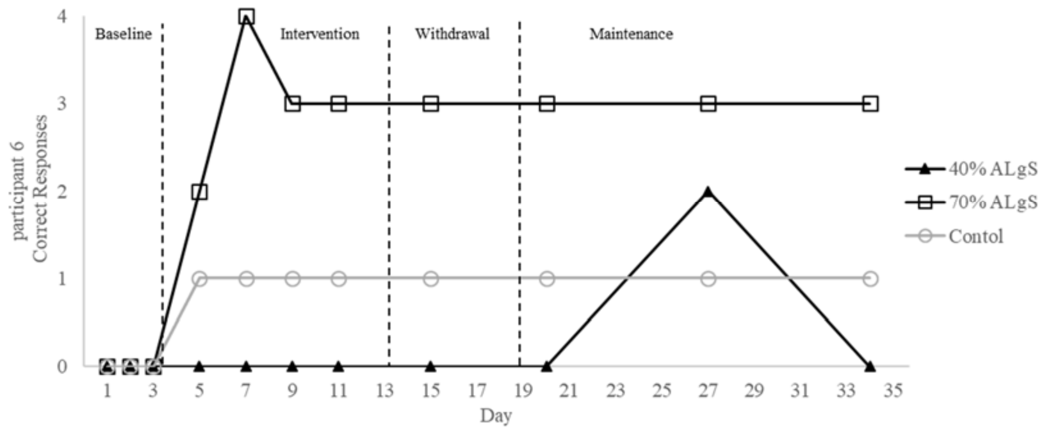
(d) *Individual Participant Performance of Probe Data Across Conditions for Participant 4*



(e) *Individual Participant Performance of Probe Data Across Conditions for Participant 5*



(f) *Individual Participant Performance of Probe Data Across Conditions for Participant 6*



Comparison of 40% and 70% Dosage Interventions

The 40% intervention was shown to be effective for two participants, while the 70% intervention was shown to be effective for all six participants across level, immediacy, PND, and IRD.

Table 4

Summary of the Comparison of Intervention with Dosages of 40% and 70% Aided Language Stimulation on the Receptive Vocabulary Acquisition of Participants (P)

Analysis		P 1		P 2		P 3		P 4		P 5		P 6	
		40%	70%	40%	70%	40%	70%	40%	70%	40%	70%	40%	70%
Level (mean)	Baseline	0.66	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]	0 [S]
	Intervention	1.00	1.00	0.66	2.00	2.80	1.60	1.40	1.40	0.60	2.00	0.00	3.00
	Maintenance	0.66	1.66	0.33	3.00	2.66	2.00	2.00	2.00	0.66	3.00	0.00	3.00
Immediacy of effect (baseline-intervention)		×	✓	×	✓	✓	✓	✓	✓	×	✓	×	✓
Relative change (level)	Baseline – Intervention	0.33	1.00 [e]	0.66	2.00 [e]	2.80 [e]	1.60 [e]	1.40 [e]	1.40 [e]	0.6	2.00 [e]	0	3.00 [e]
	Intervention - Maintenance	-0.33	0.66	-0.33	1.00 [e]	-0.14	0.40	0.60	0.60	0.06	1.00 [e]	0	0
Trend (slope)	Baseline	+0.50	0	0	0	0	0	0	0	0	0	0	0
	Intervention	+0.30	0	0	-0.10	+0.30	+0.30	+0.30	+0.30	0	-0.10	0	+0.10
	Maintenance	-0.50	+0.50	+1.00	0	0	0	0	0	+1.00	0	0	0
Trend variability (%)	Baseline	33.33%	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]	0% [S]
	Intervention	60%	0% [S]	40%	60%	40%	0% [S]	20% [S]	20% [S]	40%	60%	0% [S]	40%
	Maintenance	0% [S]	0% [S]	33.33%	0% [S]	33.33%	0% [S]	0% [S]	0% [S]	33.33%	0% [S]	0% [S]	0% [S]
Relative change (trend)	Baseline - Intervention	-0.20	0	0	-0.10	+0.30	+0.30	+0.30	+0.30	0	-0.10	0	+0.10
	Intervention - Maintenance	-0.80	+0.50	+1.00 [e]	+0.10	-0.30	-0.30	-0.30	-0.30	+1.00 [e]	+0.10	0	-0.10

PND (baseline-intervention) (%)	20%	100%*	60%	100%*	100%*	100%*	100%*	100%*	60%	100%*	0%	100%*
IRD (CI at 85%) (baseline-intervention)	-0.8	1* (1:000; 1:000)	0.6 (0.685; 2.815)	1* (1.061; 2.139)	1* (1:000; 1.000)	0.75* (0.778; 1.922)	1* (1.015; 2.984)	1* (1.015; 2.984)	0.6 (0.667)	1* (1.000; 1.000)	0	1* (2.304; 3.696)
Effect of intervention	×	✓	×	✓	✓	✓	✓	✓	×	✓	×	✓

Note. S=stable trend (<20% variability); e = effect determined through visual analysis (change of change of ≥1.00); PND=percentage of non-overlapping data (>90% - very effective, 70% - 90% effective, 50% - 70% questionable, <50% ineffective); IRD=improvement rate difference (>0.7 - large effect, 0.5 - 0.7 moderate effect <0.5 small or questionable effect)

*= large effect; ×= Absent effect; ✓ = present effect

Maintenance

In the maintenance phase, no changes in level were identified at the 40% dosage, but three participants (1, 2, and 5) showed continued improvement following the 70% dosage. Table 4 provides a comparison of the results.

Discussion

This study examined the effect of dosage on receptive vocabulary acquisition for children with complex communication needs and severe intellectual disability; the results provide evidence that using a low-tech AAC board for activities with a dosage of 70% can increase receptive vocabulary. The findings add to the body of evidence that supports the use of augmented input as a tool for the development of language skills (Allen et al., 2017; Biggs et al., 2018; Dada et al., 2004, 2020; Drager et al., 2006; Goossens', 1989; Harris & Reichle, 2004; O'Neill et al., 2018; Preis, 2006; (Sennott et al., 2016). This study also expands on the work of Dada and Alant (2009), who reported that aided language stimulation intervention with dosages of 76% to 93% facilitated the acquisition of target vocabulary.

O'Neill et al. (2018) refer to rate as the number of aided inputs provided by length of session in minutes and suggest a higher rate of input may obtain positive results; however, this was based on a limited number of studies for which data were available. In the current study, evidence suggests that a higher dosage results in greater gains. The effect of differences in dosage was evident, in that all six participants showed a positive effect from the intervention at the 70% dosage level, but only two (Participants 3 and 4) showed a positive effect at the 40% dosage level, suggesting that, for some children, a lower dosage of 40% may be sufficient; however, for the remainder of the participants, augmented input at 70% was required. Furthermore, the participants who benefitted at the 40% dosage level also benefited to the same extent at a dosage of 70%. Based on these preliminary findings it was unclear if different dosages yielded different outcomes for different children. While gains were evident at a dosage of 70%, it was interesting to note these gains translated to receptive vocabulary acquisition of two words per participant. Consideration should be given to participant characteristics, cumulative intervention intensity, and gains in receptive vocabulary. Treatment intensity should be provided in a manner that provides the best possible outcomes; as such, decisions about treatment intensity should be as precise as possible and consider empirical models of the relationship between treatment intensity and outcomes (Justice et al., 2017).

The effect of the different intervention dosages was also visible during the maintenance phase of the study. In this phase, two participants demonstrated a relative change of 1 within the intervention with a dosage of 70%, which indicated effect from intervention to maintenance. In the review by Biggs et al. (2018) a total of 32 studies assessed maintenance, 14 of which involved doing so for more than a month after the intervention. Altogether, 25 of the 32 studies reported that communication outcomes were maintained, eight had mixed maintenance effects, and four did not have a maintenance phase. Some participants showed a positive change in level from the intervention to the maintenance phases, while others maintained both level and trend. In the current study, no change in level was identified from the intervention to the maintenance phases for the 40% dosage intervention; however, two participants showed evidence of a change in level within the maintenance phase. This change in level (the last session was different for both participants) raises the question of whether extraneous factors may have resulted in this effect. As various reviews have highlighted, AAC modelling-based interventions aid vocabulary knowledge for small sets of target vocabulary, predominantly nouns. The current study adds to this evidence base, and expands on the effect of dosage of aided-AAC modelling (Allen et al., 2017; O'Neill, 2018; Sennott, 2016).

Clinical Implications

The main implication of this study is that is that children with severe intellectual disability and complex communication needs may be able to acquire target receptive vocabulary items when aided language stimulation is provided at a higher dosage. Gains were evident in the 40% aided language stimulation condition, indicating that low doses of aided language stimulation results in gains for some children. In addition, this intervention proved to be a time and cost-effective intervention because, although provided daily, it lasted only 10 to 15 min and participants were seen in groups. Furthermore, the value of clinical assessment of receptive vocabulary acquisition before, during, and after intervention has been demonstrated. Finally, the results were obtained using two low-tech AAC facilitator board per group, indicating that aided language stimulation using low-tech AAC resources may be an effective, cost effective, and accessible means for clinicians and others in low-income countries to explore or supplement current AAC systems used for the development of receptive language skills in children with intellectual disability and complex communication needs. Both higher and lower dosages should be considered during the provision of intervention in order to fully understand the costs treatment intensity may have on children and the communities that serve them (Schmitt et al., 2017).

Limitations and Future Directions

A limitation of the current study was that the dependent measure only determined the acquisition of one-word receptive vocabulary items without considering changes in receptive language abilities. Furthermore, the study did not consider syntactic, morphological, semantic, and pragmatic domains (Sennott et al., 2016). In addition, the study assessed the acquisition of identification of target vocabulary using probe tests in the short term; therefore, limiting generalizability of the findings regarding long-term effects.

A further limitation is that in the adapted alternating treatment design there was only one evaluation of the relative efficiency between the compared strategies. Although inter-subject replication of the strategies was performed, further research repeating the comparisons with new behaviour sets would further strengthen confidence in the results (Gast & Ledford, 2014). Future research is needed to expand our understanding of dosage and intervention, particularly related to the specific parts of speech that are targeted. This study included nouns, adjectives, and prepositions, but additional vocabulary classes should be considered. Furthermore, future research is required across semantic, syntactic, morphological, and pragmatic domains affected by augmented input (Sennott et al., 2016), as well as different population groups.

While the study provided insight into dosage of aided language stimulation, the duration of intervention (10 sessions of the 40% and 70% intervention per participant) can be considered limited. Given the language ability of participants, as well as the level of intellectual disability, future research should consider increased duration of intervention.

A premise of AAC modelling-based interventions is that they should occur in the context of naturalistic communication interactions (Sennott et al., 2016). Due to the need to ensure control regarding dosage, the intervention scripts were designed to provide exactly 40% and 70% of stimulation, which left no room for deviation or naturalistic communication interactions with participants, which should be a consideration of future research.

The current study used aided language stimulation principles highlighted by Goossens' (1989) and Dada (2004). All communication modalities require cognitive processing skills in attention and memory (Thistle et al., 2018); aided-AAC adds the component of dual processing model (Thistle & Wilkinson, 2013). Effective display designs reduce demands of learning and using aided-AAC (Wilkinson & Jagaroo, 2004), thereby making the systematic attention to the design of the aided-AAC system a crucial component of the intervention (McFadd & Wilkinson, 2010). Additionally, it is crucial that display designs support communication partner modelling (Thistle & Wilkinson, 2015). Future studies should consider variables such as physical and organizational features of the facilitator boards; symbol colour background; and supports for motor, cognitive, and visual processing.

Treatment intensity should be provided in a manner that provides the best possible outcomes; in order to do so, decisions about treatment intensity should be as precise as possible and consider empirical models of the relationship between treatment intensity and outcomes (Justice et al., 2017). The current study explored dosages of 40% and 70%. Future research should explore varying doses, including algorithm-based dosages suggested by Justice et al.

Conclusion

Overall, the results revealed that three participants showed the greatest receptive vocabulary acquisition with a intervention dosage of 70%, two participants showed the greatest receptive vocabulary acquisition with a dosage of 40%, and one participant showed equal receptive vocabulary acquisition in the intervention with a dosage of 40% and 70%. The dosage of augmented input impacts receptive vocabulary development for children with complex communication needs and severe intellectual disability, and the current study found that higher dosages as being more effective. These findings highlight the importance of clinicians carefully considering the dosage at which they provide aided language stimulation. A dosage of 70% or higher results in effective receptive vocabulary acquisition in children with complex communication needs and severe intellectual disability.

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