The Additive Effects of Augmentative and Alternative Communication Systems on Novel Word Learning

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Thesis

Submitted to the Faculty of the

Graduate School of Vanderbilt University

in partial fulfillment of the requirements

for the degree of

MASTERS OF SCIENCE

in

Special Education

January 31, 2018

Nashville, TN

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CHAPTER 1

INTRODUCTION

1.1 Background

By the age of five, between 5 and 10% of children have an identified language disorder (National Institute on Deafness and Other Communication Disorders, 2010). Language development is closely tied to academic readiness, behavior, and social development (Walker, Greenwood, Hart, & Carta, 1994; Whitehouse, Watt, Line, & Bishop, 2009; Clegg, Hollis, Mawhood, & Rutter, 2005). Early language deficits are often, but not always, associated with developmental disabilities, including autism spectrum disorder (ASD), down syndrome, and cerebral palsy. For children with significant language impairments, development of spoken language may be significantly delayed and some children are at risk for remaining persistently minimally verbal. Effective early interventions are essential to improve long-term outcomes for children with significant language impairment. Early communication interventions increasingly include alternative and augmentative communication (AAC) systems that provide both an alternative means for communication. According to the American Speech-Language-Hearing Association (ASHA), the AAC provides a tool to “compensate (either temporarily or permanently) for the impairment and disability patterns of individuals with severe expressive communication disorders” (ASHA, 1989, p. 107).

The term AAC is used to describe all systems of symbolic communication, other than oral speech, that can be used to express wants, needs, thoughts, and ideas. This term applies to a variety of systems, including manual sign systems, picture-based communication systems and speech generating devices (SGD). AAC systems fall into two categories: unaided and aided. Unaided AAC systems are those that do not require an external tool, for example, use of a manual communication system such as American Sign Language (ASL). Aided AAC systems include visually-based tools, such as Picture Exchange Communication System (PECS; Bondy & Frost, 1994, 1998), and systems that use combined audio and visual components such as Proloquo2Go (Sennott & Niemeijer, 2008, a software system used with the iPad for speech generating capacity) and Dynavox (Johnson, 2010, a speech generating device with embedded soft ware and touch screen display).

Interventions using aided AAC systems have been used to improve a range of communicative behaviors for children with disabilities, including simple requesting (Angermeier, Schlosser, Luiselli, Harrington, & Carter, 2008; Ganz & Simpson, 2004), spontaneous communicative initiations (Kravits, Kamps, Kemmerer, & Potucek, 2002), peer-engagement (Thiemann-Bourque, 2012), and spoken language outcomes (Blischak, Lombardino, & Dyson, 2003).

1.2 Visual AAC Systems

Visually-based AAC systems typically require the communicator to point to, touch, or exchange pictures or symbols to convey a message to a partner. For example, the PECS training system is a multi-stage training system that teaches individuals to communicate through the exchange of picture cards with a communication partner (Bondy & Frost, 1994, 1998). This system of communication uses a six-phase standardized training sequence to teach individuals to request desired objects and activities, discriminate between picture cards, combine pictures to create phrases, respond to questions, and use picture exchange for the purpose of commenting. PECS has been used to increase communication children with significant language impairments. In a review of the literature including 178 children with ASD across eight single-subject design studies and three group design studies, small to moderate gains in communication were found following PECS training (Flippin, Reszka, & Watson, 2010). PECS has been identified as one of the 27 evidence-based practices for children with ASD (Wong et al., 2015). PECS and other picture-based systems have been used effectively to teach early requesting behaviors and social communication with peers (e.g. Charlop-Christy, Carpenter, Le, LeBlanc, & Kellet, 2002; Ganz & Simpson, 2004).

1.3 Speech Generating Devices

Speech generating devices (SGD) are frequently used for communication by individuals with oral and physical motor limitations and with children with ASD. A SGD is a device that emits a digitized or recorded voice output of a word or phrase when activated and relies on programmable software to operate its touch-based screen. SGDs have received recent attention due to increased access to iPad and similar tablets using touch-screen technology and easily programmable communication software (*Proloquo2go* and *GOTalk*) that makes these systems more convenient, portable, and socially acceptable (Sennott & Bowker, 2009). Many studies have demonstrated that SGD-use can be effectively taught to children with disabilities as a functional communication system. A review of the literature summarized 29 interventions that taught 51 children with ASD to use SGDs (Van Der Meer & Rispoli, 2010). Eighty-six percent of the interventions reported positive results indicated by increases communication or SGD-related skills. The included studies used a variety of teaching approaches, with 60% of studies using a behaviorally based instructional approached, such as functional communication training (FCT), and the remaining 40% of studies using incidental and naturalistic teaching procedures, such as modeling. SGDs have been used to effectively increase requesting behavior (Schlosser et al., 2007; Sigafoos et al., 2004) and social communication with peers (e.g., Trottier, Kamp, & Mirenda, 2011).

1.4 AAC Systems and Speech Production

Although there no evidence indicating that AAC use inhibits spoken language, many parents and some professionals still express concerns that children who use AACs will not develop spoken language. Several research studies have examined the relationship between AAC use and increases in spoken language following communication interventions including AAC systems. In a review of the literature, Millar, Light, and Schlosser (2006) found that 89% of high quality cases reviewed showed increased spoken language following an AAC communication intervention for children with developmental delays. The remaining 11 percent showed no change on measures of spoken language. Schlosser and Wendt (2008) reported similar findings for children with ASD in a review of the literature, although increases in speech production following AAC interventions were generally small. Both reviews included both visually based systems, such as PECS, and SGDs.

In a recent randomized control trial using an adaptive treatments design (Kasari et al., 2014), 61 minimally verbal children with ASD, ages five to eight, were randomized to a naturalistic social communication intervention (Joint Attention, Symbolic Play, Engagement and Regulation and Enhanced Milieu Teaching; JASP+EMT) with or without the inclusion of an SGD for 6 months. Parents in both groups received systematic parent training, beginning midway through the intervention period. Using an adaptive treatment design framework, the intervention consisted of two stages. In Stage 1, all children received two intervention sessions per week for 3 months. Stage 2 of intervention was adapted based on the child's early response to the Stage 1 treatment by either increasing the number of sessions or adding the SGD component. Spoken language outcomes included: number of social communicative utterances, number of novel words, and the total number of comments. About 75% of children in both conditions met criteria for treatment response after 24 sessions. Children who began intervention with the JASP+EMT+SGD condition showed significantly more communicative utterances, novel words, and comments than children who began with JASP+EMT without the SGD. On average, children in JASP+EMT+SGD gained 17 different words on a 20-minute language sample after 24 sessions compared to children in JASP+EMT who gained 7 different words; importantly, 90% of the words used by children in the JASP+EMT+SGD condition were spoken words. Adding the SGD as an adaptive treatment for children who were slow to respond the intervention in Phase 2 was relatively more effective than increasing the intensity of the spoken language JASP+EMT protocol after 48 sessions. These findings suggest that incorporating an SGD into a social communication intervention may promote the use of spoken language in minimally verbal children with ASD.

1.5 Comparing Visual AAC Systems to SGD Systems

Some research has compared the relative efficacy of systems that rely on visual components alone to those that include both visual and audio output. In a single subject research design (Flores et al., 2012), five children with ASD and other developmental disabilities were taught requesting behaviors using either picture cards or an iPad with a picture and audio output. While one participant displayed more communication in the iPad condition, the remaining four participants did not show clear differentiation between conditions. A similar pattern of findings in which one system did not show a clear and consistent benefit over another system has been shown in several studies (e.g. Boesch, Wendt, Subramanian, & Hsu, 2012; Sigafoos, Green, Payne, Son, O'Reilly, & Lancioni, 2009; Lorah, Tincani, Dodge, Gilroy, Hickey, & Hantula, 2013). Rather, children have shown increases in communication and in spoken language as a result of both picture-based and speech-generating systems (Mirenda, 2003).

These studies have provided evidence that AAC systems, in general, improve natural spoken language production across a variety of children with language delays. However, the mechanism behind the observed growth in spoken language following an intervention using an AAC is not well understood. While some experts highlight the benefit of picture/word pairing, others identify the consistent verbal output of the SGD as the driving factor for word learning (Romski & Sevcik 1996). The benefit of picture and word pairing would suggest that picture-based AAC systems, such as PECS, are adequate for promoting spoken language without the added cost of electronic systems. However, if it is the consistent auditory production of the SGD that is driving spoken language outcomes following AAC interventions, these costlier devices would be warranted. Some researchers have suggested that this mechanism by which added visual and auditory supports impact spoken language could be diagnosis-specific. For example, there is some evidence that children with ASD benefit from visual supports (e.g., Quill, 1995). However, there has yet to be a controlled group design study using a scientific manipulation of the visual and auditory components of AAC systems to demonstrate how the different components potentially contribute to the effectiveness and efficiency of language learning.

Although the purpose of this line of research is to ultimately understand how AAC systems function to increase word-learning in populations with significant language impairment, studying this process in the typically developing population is beneficial for several reasons. First, it is necessary to teach children nonsense words to ensure that word learning it specific to the context of the experiment and not to history effects. Teaching nonsense words to children who have already limited language poses ethical concerns. Determining how visual and auditory AAC components facilitate learning in typically developing children contributes to developing a research paradigm that allows researchers to subsequently ask the same questions in children with atypical language development. Establishing a viable study design may minimize unnecessary teaching of nonsense words for children with language impairments. Second, it is important to understand how language development occurs and may be more efficient when supplemented by visual and auditory supports in typically developing children. Having descriptions of learning by typically developing children allows researchers to compare variations in the trajectories of children with delayed language development and may provide insights about the underlying differences in processes of language development across populations. It is also possible that examining word learning under different conditions would allow researchers to identify asymmetries in language growth trajectories that need to be addressed in early intervention.

1.6 Purpose

The purpose of this study was to examine the benefits of including the visual and audio components of an alternative and augmentative communication (AAC) system in facilitating novel word learning for typically developing children between the ages of 3 and 4 years. A within-subject group design was implemented to measure children's ability to learn novel words across four teaching conditions. Each teaching session included a spoken model of the word paired with: (1) an auditory AAC component, (2) a visual AAC component, (3) a combined auditory and visual AAC component, and (4) no AAC. This study sought to answer the following questions: (1) Did the addition of audio and/or visual components of the AAC system to teaching sessions result in better expressive identification of novel words than instruction without the AAC device? (2) Did the addition of audio and/or visual components of the AAC system to teaching sessions result better receptive identification of novel words than instruction without the AAC device? A third, exploratory question was included to understand the immediate effect of the AAC component on word learning by examining the likelihood the child was to use the novel word during teaching sessions: (3) Did the addition of audio and/or visual components of the AAC system to teaching sessions result in more frequent use of the novel words during teaching sessions compared to use of the novel words in teaching sessions without an AAC device?

CHAPTER 2

METHODS

2.1 Participants

Each child's parent or primary caregiver consented for the child's participation in the study, following study procedures approved by the Vanderbilt Institutional Review Board. After giving consent to participate, parents or caregivers completed a demographics questionnaire about their child and family. All paperwork was sent home in the child's backpack in sealed envelopes to maintain confidentiality. The demographics form is in Appendix A.

A total of 13 children participated in the study. Demographic and pretest scores are shown in Table 1. Children were on average 4.10 (sd=0.45) years old. All children were Caucasian and came from homes where the primary language was English. The majority of children who participated in the study had above average language development based on standardized language assessments. Participants' receptive vocabulary scores were measured using the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007). The PPVT mean standard score was 122.69 (SD=13.83; range 94-142). Participants' expressive language and auditory comprehension were assessed using the Preschool Language Scales, 5th Edition (PLS_5; Zimmerman, Steiner, & Pond, 2011). Participants' mean standard score on the expressive communication subscale of the PLS-5 was 133.15 (sd=13.65; range 116-143). The mean standard score on the auditory comprehension subscale of the PLS-5 was 128.76 (sd=8.37, range 113-150). Both the PPVT and the PLS are normed to have a mean of 100 and a standard deviation of 15.

The researcher who conducted all testing and teaching sessions was a female doctoral student in Special Education with approximately 6 years experience in child language assessments and previous experience providing language instruction using an AAC device and language modeling in a play context.

2.2 Materials

A total of 16 three-dimensional unfamiliar objects were paired with novel words. The object-word pairs were divided into four sets of four so that each set had one object/word pairing per condition. Each object was unique. Each object was monochromatic; objects within sets were matched on size (about 2in by 2in). During the developmental phase of the study, three adults were asked independently to name each object and their responses were recorded and evaluated; this process was completed to ensure that no objects were associated with a specific name. Any object that was named by the three adults was replaced with another unfamiliar object. An example of an object is shown in Figure 1.

Novel nonsense words were chosen in sets of four. Words within sets were matched for complexity of consonant sounds and syllables. Each novel word began with a different consonant sound. A speech language pathologist consulted on selection of the words and confirmed that words were equivalent within each group. A list of the novel words in each set is shown in Table 2.

An iPad Mini with the application Proloquo2Go was used as an AAC device. This device was chosen because pictures of the objects could be shown with or without associated audio output. A photo was taken of each the 16 objects on a white background. The photo of each object was presented on a full-page display (7.9 in by 5.3 in) on the Proloquo2go application. Only one picture was shown on the screen at a time. Each displayed photo had the name of the object printed directly below the photo. An example of the iPad display for a single object is shown in Figure 1. The guided access feature of the program was used so that only the researcher could navigate away from the display.

2.3 Setting

Pretest assessments and teaching sessions were completed in small clinic rooms in the children's school or in a room in the child's home. Ten of the 13 participants participated in sessions conducted in their preschool; three participants participated in sessions conducted in their homes. Children who participated at home sat at a child-sized table in an area away from ongoing activities; a tripod, camera and timer were in the immediate area. The clinic rooms each had a child-sized table and two chairs, a tripod, a camera, and a timer. A variety of toy sets were available for the child to choose from. Toy sets were used during teaching sessions. Toys sets were arranged behind the researcher but within view of the child so that the child could select new toy sets. Toy sets included: Play Doh, rollers, cookie cutters, and cutlery; car ramps with small cars and trucks; pretend food with dolls, dishes, and cooking utensils; blocks; a dollhouse with small people and furniture; a fire house with a truck and small firemen figures; and a construction site with trucks, tools, and small figures.

2.4 Pretest

Pretest data were collected during a single day for each participant prior to the teaching sessions. The researcher administered the PLS-5 (Zimmerman, et al., 2011) and the PPVT (Dunn & Dunn, 2007) following the protocols outlined in the administration manuals. The PLS-5 and the PPVT were administered to determine the child's global language skills and receptive vocabulary, respectively.

During the pretest session, a preference assessment was completed using a multiple stimulus without replacement (MSWO) format to evaluate participants' preferences for specific objects to be used in the study. A total of four preference assessments were conducted, one for each of the four sets of objects. The four objects from a single set were placed on the table in front of the child. The child was instructed to choose one. Following the child's choice, he or she was permitted to handle the object for 30s while the researcher recorded his or her response. During the time the child handled the objects, the remaining objects were removed from the table. The researcher then took the object from the child, placed the remaining three objects from the set on the table, and again instructed the child to choose one. Chosen objects were not replaced in the array. This was repeated until all four objects were chosen. This process was repeated for the remaining three sets of objects. The researcher used the preference information to assign objects to conditions so that, across the four teaching days, each condition contained one object that was the child's first choice, one object that was the child's second choice, one object that was the child's third choice, and one object that was the child's fourth choice.

2.5 Schedule

Teaching sessions occurred during four consecutive school days. One set of object/word pairs was taught each day. Each set of objects contained one novel word from each of four conditions: auditory model, visual model, combined auditory and visual model, and no AAC. One word from each condition was taught each day. Each day included two teaching sessions and two probing sessions, described below. A schedule of the teaching sequence is provided in Table 3. The order of the teaching sessions and probing sessions were counterbalanced across days to account for primacy and recency effects. This schedule is shown in Table 4.

2.6 Teaching Sessions

Each teaching session lasted 10-minutes and was segmented into 4 2-minute segments, followed by a 2-minute break. The researcher and child sat at the child sized table to complete these sessions. The child was asked to choose one toy set from the sets displayed prior to the start of the teaching session. Additional toy sets were positioned at eye level (e.g, placed on a low shelf) and the child was free to request a new toy set at any time. The researcher began by engaging the child in play with the selected toy set. The child and the researcher played together with the chosen toy set. The researcher then introduced the first novel object into the play set. She modeled the name of the object a total of 10 times during the 2-minute segment. The word was modeled in short phrases (five words or fewer). For example "Here is my *glop*!" and "My *glop* goes here." The researcher paired the label with a gesture (point, show, or give) to the object. This modeling procedure was chosen to be congruent with the naturalistic teaching procedures used in Kasari and colleagues (2014), although presentation of modeled words occurred at a higher rate in the current study to promote more rapid word learning. In addition to the verbal model and gesture, the researcher labeled the word according to its assigned condition as follows.

No AAC. The researcher verbally labeled the object and gestured toward the object. The AAC device was not accessible to the child.

Visual model. The researcher labeled the object, gestured toward the object, and pointed to the corresponding single-icon picture display on the AAC. The AAC device was placed on the table between the child and the researcher so that the child could see the visual representation (picture) of the object for the entire duration of the 2-minute teaching session. The AAC device was set on mute and did not produce any auditory output. The child saw the visual representation of the object but did not hear any additional auditory output from the AAC device.

Auditory model. The researcher labeled the object and gestured to the object while also activating the auditory component of the AAC device. The AAC device was not accessible to the child. The child heard the auditory output from the AAC but did not see the visual representation (picture) of the object.

Combined auditory and visual model. The AAC device was placed on the table between the child and the researcher so that the child could see the visual representation (picture) of the object for the entire 2-minute teaching session. The researcher labeled the object and gestured toward the object. In addition, she pressed the corresponding icon on the AAC which produced an auditory model of the object label (e.g., *'glop')* and visual model of the object (the single-icon picture display).

At the end of the 2-minute teaching segment, the researcher removed the novel object and presented the next object from the set while interacting with the child and toys. The order of the object presentation was counterbalanced across conditions. If the child said the target word or attempted to say the word, the researcher responded but did not repeat or recast the child's use of the word. Once all four objects were presented, the child was allowed to play with the toy set without any of the novel objects for 2 additional minutes. The 2-minute play period created a break between the teaching session and probing session. The novel objects were not available during these 2 minutes.

Following the probe session (described below), a second teaching session occurred using the same word set. This second teaching session was implemented to allow for measurement of the participant's word learning after 10 and 20 exposures to each word in the selected set.

2.7 Probes

Following the 8-minute teaching session and 2-minute break, the researcher presented expressive and receptive probe trials to measure the child's learning of the novel words. During the expressive probes, the researcher held up one object at a time and asked the child "What is it?" If the child did not respond, the researcher repeated the question. The child's response to second question (if no response to the first) was recorded as correct or incorrect. No response was recorded as incorrect. During the receptive probes, the researcher placed the four objects from the teaching set on the table and asked the child "Where is the (novel word)?" If the child did not respond, the question was repeated once. If the child still did not respond, he/she was encouraged to take a guess. The child's responses to the receptive probes were scored as correct or incorrect. Objects selected by the child were not removed; the array of four objects remained throughout the receptive probe. Responding during both expressive and receptive probes was reinforced regardless of the correctness of the child's response. Each response (correct or incorrect) was consequated with praise (e.g. "Good job!") or with tangible reinforcers (e.g., toys or snacks) provided by the researcher. The order of the object presentation in the probes was counterbalanced across conditions, such that the order in which items were probed did not match the order in which they were taught, and the order in which conditions were probed differed every day.

2.8 Follow-up

Follow-up probes were conducted to measure the child's retention of the object labels one day after the teaching session. Follow-up probes were identical to the expressive and receptive probes described above, but assessed the child's expressive and receptive object labeling for the words taught the previous day. Follow-up probes were conducted before the teaching sessions each day, except on the fifth day when no teaching sessions occurred and only a probe session was conducted.

2.9 Dependent Variable

Correct expressive labeling. The dependent variable for the first research question was the number of correct responses to the expressive probes. A correct response to an expressive probe was defined as correctly producing a word approximation that contained at least 75% of the letter sounds of the word (i.e., three of four sounds in a four sound word).

Correct receptive identification. The dependent variable for the second research question was the number of correct responses to the receptive probes. A correct response to the receptive probe was defined as pointing to or touching the object corresponding to the verbal label. The answers were recorded as correct or incorrect using the data sheets shown in Appendix B.

Novel word use. The dependent variable for the third research question was the number of times a child expressively used the novel word during the teaching session. Novel word use could be spontaneous or imitated. An expressive use of the word was coded as correct if the child produced at least 75% of the letter sounds (i.e., three of four sounds in a four-sound word). Word-use was coded only during the 2-minute period in which the object was available in order to ensure equal opportunity to use each word from each condition. Word-use was coded from video recordings of the sessions.

2.10 Interobserver Agreement

Interobserver agreement data were collected during 20% of all sessions by a second observer watching video recordings of the session and recording each of the three dependent variables. Sessions were randomly selected using a random numbers generator. Reliability on the receptive identification during probes was 97.1% (sd=8.1; range: 75%-100%), 97.4% (sd=7.7; range: 75%-100%), for expressive labeling during probes, and 95.3% (sd=5.6, range: 86.7%-100%) for novel word use.

2.11 Fidelity

Fidelity of implementation data were collected during 20% of all teaching sessions.

Sessions were randomly selected using a random numbers generator. Fidelity data were coded by a second observer from video recordings using the 58-item checklist in Appendix C. Fidelity of implementation averaged 93% (sd=0.03; range 86-98%) across teaching sessions.

2.12 Analysis

Repeated measure ANOVAs were used to test differences between conditions during Probe 1 (after 10 models of each word), Probe 2 (after 20 models of each word), and Follow-up for the number of correct expressive and receptive responses and for novel word use within sessions. Novel word use occurrences were pooled across the two teaching sessions.

CHAPTER 3

RESULTS

3.1 Correct Expressive Labeling

Expressive probe results are shown in Table 5 and Figure 2. Data for individual children are in Appendix D.

Expressive Probe 1. Following the first 10-minute teaching session (with 10 models of each novel word), children expressively identified an average of 0.07 words (sd=0.27) in the audio condition, 0.07 words (sd=0.27) in visual condition, 0.23 words (sd=0.43) in the audio plus visual condition, and 0.23 words (sd=0.43) in the no AAC condition. There was not a significant difference among the four conditions on expressive word identification (F=0.78, p=0.50).

Expressive Probe 2. Following the second 10-minute teaching session (with a cumulative total of 20 models of each novel word), children expressively identified and average 0.15 words (sd=0.37) in the audio condition, 0.23 words (sd=0.43) in visual condition, 0.30 words (sd= 0.48) in the audio plus visual condition, and (0.15) words (sd=0.37) in the no AAC condition following the second teaching session. There was not a significant difference among conditions on expressive word identification (F=0.388, p=0.76).

Expressive follow-up. Follow-up data were collected one day following each teaching session. On average, children expressively identified 0.07 words (sd=0.27) in the audio condition, 0.07 words (sd=0.27) in visual condition, 0.30 words (sd=0.48) in the combined condition, and 0.15 words (sd=0.37) in the no AAC condition during the follow-up probe. There was not a significant difference among conditions on expressive word identification (F=1.09, p=0.36).

3.2 Receptive Identification of Objects

Data on receptive identification of objects are shown in Table 6 and Figure 3. Data for individual children are in Appendix E.

Receptive Probe 1. On average, children receptively identified 1.30 words (sd=1.10) in the audio condition, 1.46 words (sd=1.26) in visual condition, 1.69 words (sd=0.85) in the audio plus visual condition, and 1.61 words (sd=1.12) in the no AAC condition following the first teaching session. There was not a significant difference among conditions on receptive word identification ($F=0.40$, $p=0.75$).

Receptive Probe 2. On average, children receptively identified 1.53 words (sd=0.96) in the audio condition, 1.30 words (sd=0.94) in visual condition, 1.76 words (sd=0.92) in the combined condition, and 1.30 words (sd=0.94) in the no AAC condition following the second teaching session (20 total trials per object). There was not a significant difference among conditions on receptive word identification ($F=0.86$, $p=0.46$).

Receptive Follow-up. On average, children receptively identified 1.76 words (sd=0.83) in the audio condition, 1.46 words (sd=0.96) in visual condition, 2.15 words (sd=0.89) in the combined condition, and 2.07 words (sd=0.95) in the no AAC condition during the follow-up probe. There was not a significant difference among conditions on receptive word identification ($F=2.36$, $p=0.08$).

3.3 Novel Word Use

Novel word use results are shown in Table 7 and Figure 4. Data for individual children are in Appendix F. On average, children verbally produced the novel word 8.76 times (sd=7.31) in the audio condition, 8.07 times (sd=6.19) in visual condition, 8.84 times (sd=10.70) in the combined condition, and 6.07 times (sd=5.34) in the no AAC condition. There was not a significant difference among conditions on novel word use ($F=0.82$, $p=0.48$). When an AAC component was available during teaching sessions, children used an average of 2.48 more expressive utterances of the novel word than when no AAC was present. This pattern was not significant ($t=1.03$, $p=0.30$).

3.4 Additional Analyses

Given the null results, a post-hoc examination of the data was conducted to examine if differential learning occurred for certain objects or words. There was no observed pattern of word preference. Further, post-hoc analyses of correlations between pretest measures and outcome variables were conducted and are shown in Table 8. Given the small sample size and the low variability in pretest language measures, there were not significant correlations between pretest measures and outcome variables after accounting for multiple significance testing.

CHAPTER 4

DISCUSSION

4.1 Summary

The purpose of this study was to investigate potential contributions of the auditory and visual components of an AAC system to novel word learning in typically developing children. Across the 13 participants included in the study, there were no significant differences in expressive or receptive word learning when children were exposed to a brief teaching period in the following conditions: (1) audio AAC, (2) visual AAC, (3) combined audio and visual AAC, and (4) no AAC. Further, although children, on average, expressively produced the novel words more frequently in the three conditions that included an AAC component compared to the condition without the AAC, this difference was not statistically significant.

4.2 Limitations

The null findings of this study do not indicate there is no benefit of adding an AAC component to support word learning in early language intervention. Rather, the null finding may be due to the limitations of the current study. A primary limitation of the study was that the limited instruction was not sufficient to ensure learning in any condition. Comparison among conditions was constrained by the "floor" effects observed across all conditions. The participants of the study learned few words expressively. On average, across all four conditions, with a total of 16 possible words, each child learned a total of 0.59 words after 10 word exposures (Probe 1), 0.84 words after 20 word exposures (Probe 2), and retained an average of 0.61 words one day following teaching. Children learned more words receptively, with an average total of 6.00 words after 10 word exposures (Probe 1), 5.92 words after 20 word exposures (Probe 2), and remembered an average of 7.46 words one day following teaching. Given the receptive probe field size of four, children would be expected to correctly select four words by chance alone. Thus, across both expressive and receptive probes, children learned relatively few of the novel words thus constraining comparisons among conditions.

The limited word learning could have been due to several factors. First, the children were exposed to relatively few word exposures (20 exposures over two teaching sessions) during brief teaching sessions (4-min over two teaching sessions). A longer or more intensive teaching procedure may be required. Modeling was used as the teaching procedure for this study to simulate a naturalistic word-learning paradigm in which children learn words from exposure alone. However, given the short duration of the modeling sessions, a more intensive teaching procedure, such as requiring the child to say the word, may have been necessary to observe differentiated results. A second factor was the reinforcement contingency implemented during the probe sessions. All attempted answers were consequated in reinforcement (tangible or social). Given the undifferentiated reinforcement contingency, children may not have been motivated to learn the novel words. Offering differential feedback on correct responding would have provided additional teaching that would not have been equal across conditions, so differential reinforcement was not possible.

A major limitation was the small sample size for the study. There was a high amount of between subject variability between conditions. Given this between subject variability, many more participants would be required to detect a significant difference between conditions. In order to detect a significant effect size using a repeated measures ANOVA with an expected small effect size ($F=0.1$), 138 participants would be required (Intellectual Statistics, 2017).

Despite these limitations, the pattern observed in novel word use during teaching sessions was interesting. When an AAC component was available during teaching sessions, children used an average of 2.48 more utterances containing novel words than when no AAC was present. This represents more than one expressive use of the word per minute. Although the frequency of word-use was highly variable within and across participants and this difference was not statistically significant, this observed pattern warrants further exploration. It could be that the presence of an AAC results in more frequent expressive use of the word, which might ultimately result in more rapid word learning. Further, this pattern in which the type of AAC support (auditory, visual, or combined) did not show a clear differentiated pattern of benefit is consistent with previous single case studies that have compared the relative efficacy of systems that rely on visual components alone to those that include both visual and audio output (Flores et al., 2012; Boesch, Wendt, Subramanian, & Hsu, 2012; Sigafoos, Green, Payne, Son, O'Reilly, & Lancioni, 2009; Lorah, Tincani, Dodge, Gilroy, Hickey, & Hantula, 2013). These studies indicate that although the presence of an AAC contributes to spoken language, the type of AAC (auditory or visual) has not shown a clearly differentiated pattern of benefit. This possible relationship should be explored in future research.

4.3 Future Research

Future research should continue to explore the potential benefit of AAC devices as a tool for novel word learning. The current study should be replicated with a larger number of participants and more intensive teaching to adequately detect potential differences between AAC supported word-learning conditions. Further, different measures may be required to detect more subtle differences in child learning. For example, the number of word exposures required to learn a word may be a better dependent variable for indicating how AAC components contribute to the efficiency of word learning. Another option would be to use biometric measures such as an EEG to measure how audio and visual components of the AAC stimulate areas of the brain differently from the no AAC condition, and how this may contribute to word learning. For example, event-related potentials (ERP), an EEG measure of brain response to stimuli, have been used to demonstrate early recognition of novel words (e.g., Holcomb & Grainger, 2006). Using a biometric measure allows researchers to evaluate the exact point at which a novel word is recognized by the brain without having to rely on behavioral responses.

Further, research should examine how the AAC modalities support word learning for children with complex communication needs. The process of word learning may differ depending on disability type. For example, it may be that children with receptive language delays benefit more from visually-based systems, whereas children with expressive language delays benefit more from auditory-based systems. In this case, we would expect the role of the AAC as a tool in word learning to differ by modality and effectiveness. It also may be necessary to test this paradigm in a population of younger children whose vocabulary and language level are more closely matched to children with language impairments than the children in the current study who were skilled word learners.

4.4 Implications

Forming a better understanding of the role of AAC components in novel word learning will help researchers and practitioners understand the process of word learning and the potential benefit of visual and auditory modes of assistive technologies. AAC systems have the potential to increase the efficiency of early word learning. Ultimately this line of research is an important foundation for providing effective tools for individuals with complex communication needs. Forming a better understanding of AAC systems and the contribution of these systems as a bridge to word learning will help practitioners and families make informed decisions in selecting the types of systems that are best for individual children.

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Table 1.
Participant characteristics.

	Mean (sd)
Age (years)	4.10 (0.45)
PLS-5 expressive communication	133.15 (13.65)
PLS-5 auditory comprehension	128.76 (8.37)
PPVT	122.69 (13.83)
Percent male	65%
Percent white	100%
Percent English as primary language	100%
Percent male	46%

Note. PLS-5: Preschool Language Scales, 5^{th} Edition (Zimmerman et al., 2011). PPVT: Peabody Picture Vocabulary Test (Dunn & Dunn 2007).

Table 2.
Novel words by group.

Group 1	Group 2	Group 3	Group 4
Tror	Modi	Jorn	Wonan
Stig	Dawnoo	Lart	Zayma
Plon	Koba	Nork	Risit
Glop	Vooko	Bist	Fordo

Table 3.
Teaching session and probe schedule.

Pretest	Teaching day 1	Teaching day 2	Teaching day 3	Teaching day 4	Follow-up
PLS-5	Group 1 Teaching Session	Group 1 Expressive Probe	Group 2 Expressive Probe	Group 3 Expressive Probe	Group 4 Expressive Probe
PPVT	Group 1 Expressive Probe	Group 1 Receptive Probe	Group 2 Receptive Probe	Group 3 Receptive Probe	Group 4 Receptive Probe
Preference assessment	Group 1 Receptive Probe	Group 2 Teaching Session	Group 3 Teaching Session	Group 4 Teaching Session	
	Group 1 Teaching Session	Group 2 Expressive Probe	Group 3 Expressive Probe	Group 4 Expressive Probe	
	Group 1 Expressive Probe	Group 2 Receptive Probe	Group 3 Receptive Probe	Group 4 Receptive Probe	
	Group 1 Receptive Probe	Group 2 Teaching Session	Group 3 Teaching Session	Group 4 Teaching Session	
		Group 2 Expressive Probe	Group 3 Expressive Probe	Group 4 Expressive Probe	
		Group 2 Receptive Probe	Group 3 Receptive Probe	Group 4 Receptive Probe	

Table 4.
Counterbalance schedule of preference, teaching order, and testing order.

Preference	Object	Condition	Teaching Order	Testing Order
Group 1				
1		No AAC	1	2
2		Audio	2	4
3		Visual	3	1
4		Combined	4	3
Group 2				
1		Audio	1	3
2		Combined	2	1
3		No AAC	3	4
4		Visual	4	2
Group 3				
1		Visual	1	3
2		No AAC	2	1
3		Combined	3	4
4		Audio	4	2
Group 4				
1		Combined	1	2
2		Visual	2	4
3		Audio	3	1
4		No AAC	4	3

Table 5.
Expressive probes.

	Probe 1	Probe 2	Follow Up
Audio	0.07 (0.27)	0.15 (0.37)	0.07 (0.27)
Visual	0.07 (0.27)	0.23 (0.43)	0.07 (0.27)
Combined	0.23 (0.43)	0.30 (0.48)	0.30 (0.48)
No AAC	0.23 (0.43)	0.15 (0.37)	0.15 (0.37)

Note. Means (sds) reported.

Table 6.
Receptive probes.

	Probe 1	Probe 2	Follow Up
Audio	1.30 (1.10)	1.53 (0.96)	1.76 (0.83)
Visual	1.46 (1.26)	1.30 (0.94)	1.46 (0.96)
Combined	1.69 (0.85)	1.76 (0.92)	2.15 (0.89)
No AAC	1.61 (1.12)	1.30 (0.94)	2.07 (0.95)

Note. Means (sds) reported.

Table 7.
Teaching session word use.

	Mean Word Use (sd)
Audio	8.76 (7.31)
Visual	8.07 (6.19)
Combined	8.84 (10.70)
No AAC	6.07 (5.34)

Table 8.
Correlations of pretest variables and outcome measures.

	PPVT	PLS Expressive	PLS Receptive	Age
PPVT	1.00	0.47	0.24	-0.08
PLS Expressive	0.47	1.00	0.73	-0.10
PLS Receptive	0.24	0.73	1.00	-0.13
Age	-0.08	-0.10	-0.13	1.00
Audio Expressive Probe	0.14	0.28	0.40	0.15
Audio Receptive Probe	-0.35	0.07	0.19	0.42
Audio Word Use	0.07	-0.15	-0.29	-0.06
Visual Expressive Probe	0.14	0.28	0.40	0.15
Visual Receptive Probe	-0.04	-0.11	-0.23	0.17
Visual Word Use	0.32	-0.17	-0.29	-0.39
Auido/Visual Expressive Probe	-0.21	0.19	0.02	-0.09
Auido/Visual Receptive Probe	-0.28	0.10	0.29	-0.64
Audio/Visual Word Use	-0.01	-0.15	-0.21	-0.08
No AAC Expressive Probe	-0.41	-0.47	-0.19	0.27
No AAC Receptive Probe	-0.55	-0.56	-0.20	0.39
No AAC Word Use	0.05	0.20	0.03	-0.63

Figure 1. Example visual display of AAC device.

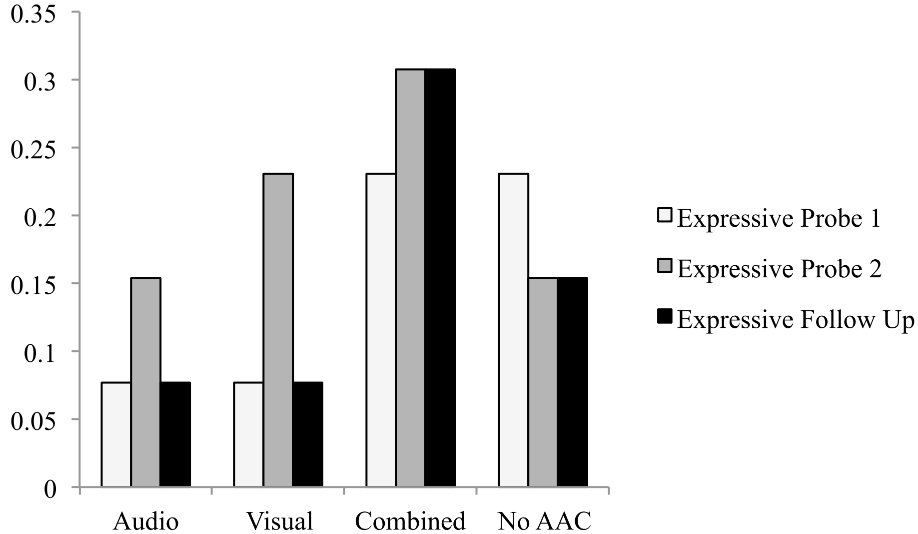

Figure 2. Expressive probes.

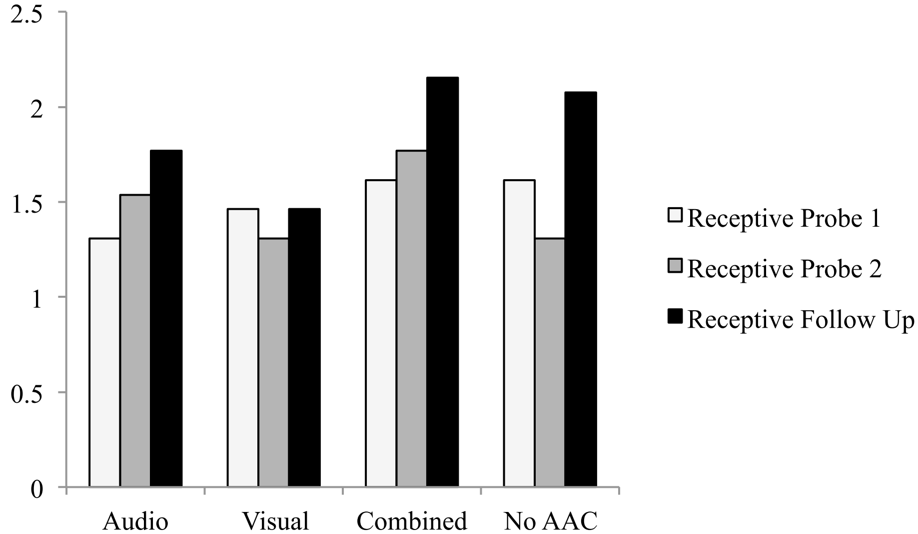

Figure 3. Receptive probes.

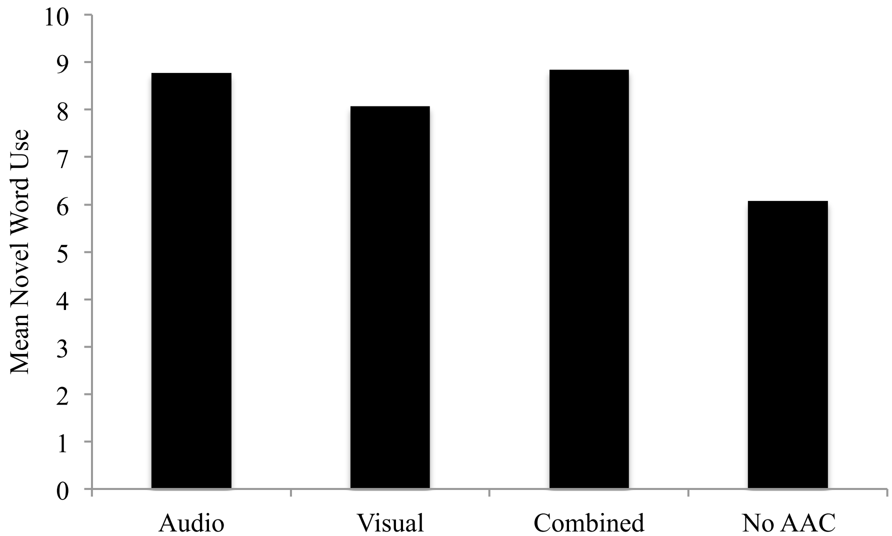

Figure 4. Novel Word Use.

Appendix A

Demographic Information

Child's Name____________________ Address _____________________________

Respondent ____________________ Relationship to child__________________

Phone_________________________ Parent(s) email ________________________

Child's birth date_____/_____/_____ Gender: (circle one) male female

Child's School Program: ________________ Hours per week: _______________

Race of the child: (circle all that apply)

1. American Indian or Alaska Native
2. Asian
3. Native Hawaiian or Other Pacific Islander
4. Black
5. White
6. Other, specify____________

Ethnicity of the child:

1. Hispanic or Latino 2. Not Hispanic or Latino 3. Other, specify____________

Child lives with: (circle one)

1. Biological mother and father
2. Biological mother and stepfather
3. Biological mother only
4. Biological father only
5. Biological father and stepmother
6. Adoptive parents
7. Foster parents
8. Relatives
9. Other, specify________________

Biological Mother's birth date ____/____/____

Custodial mother's birth date (if different) ____/____/____

Mother's education: (circle one)

1. Less than 7th grade
2. Junior High
3. Some High School
4. High School graduate
5. Some college
6. Special training after high school
7. College graduate
8. Graduate/professional training

Primary caregiver's first language: ____.

Language(s) currently used when interacting with the child: ________________________.

Appendix B
Daily Data Sheet

Participant ID				
Day		Day 1 Day 2 Day 3 Day 4		
Date				
Assessor				
Follow-Up				
Word		**Condition**	**Expressive Probe**	**Receptive Probe**
			0 1	0 1
			0 1	0 1
			0 1	0 1
			0 1	0 1
Teaching				
Word Order	1	2	3	4
Condition				
Probe 1				
Word	**Test Order**	**Condition**	**Expressive Probe**	**Receptive Probe**
			0 1	0 1
			0 1	0 1
			0 1	0 1
			0 1	0 1
Probe 2				
Word	**Test Order**	**Condition**	**Expressive Probe**	**Receptive Probe**
			0 1	0 1
			0 1	0 1
			0 1	0 1
			0 1	0 1

Notes:

Appendix C
Teaching Session Fidelity

Session Fidelity			
Child ID			
Day			
Date			
	Options	Score	Notes
Presession			
Did the therapist offer a variety of toys?	1=yes 0=no		
Did the therapist allow the child to choose the toy they wanted to play with?	1=yes 0=no		
Teaching Set 1			
Object 1	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		Actual number:
Object 2	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		

Object 3	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Object 4	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Teaching Set 2			
Object 1	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		

The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Object 2	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/-10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Object 3	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		
The object was on the table for 2:00 (+/-10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Object 4	A=audio, V=Visual, B=Both, N=None		
The appropriate materials were on the table (target object and iPad)	1=yes 0=no		
Other target objects were not on the table.	1=yes 0=no		
The therapist kept the child engaged for the majority of the time (at least 1:30 of the 2 min)	1=yes 0=no		

The object was on the table for 2:00 (+/- 10s)	1=yes 0=no		
The therapist correctly modeled the word 10 times.	Score 3 for 10, Score 2 for 9 or 11, Score 1 for 8 or 12, Score 0 for all else		
Total	Sum all numbers		
Percentage	Divide by 58		

Appendix D
Participant Data: Expressive Probes

	Probe 1				Probe 2				Follow-Up			
Study Id	Audio	Visual	Audio + Visual	No AAC	Audio	Visual	Audio + Visual	No AAC	Audio	Visual	Audio + Visual	No AAC
101	0	0	0	0	0	0	1	0	0	0	1	0
102	0	0	0	0	0	0	1	0	0	0	1	0
103	0	0	0	0	0	0	1	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	1	0	1	0	0	0	0	0	0
106	0	0	1	1	0	0	1	1	0	0	1	1
107	0	0	0	0	0	0	0	0	0	0	1	0
108	1	1	0	0	1	1	0	0	0	1	0	0
109	0	0	0	1	0	0	0	1	0	0	0	1
110	0	0	0	0	0	0	0	0	0	0	0	0
111	0	0	1	0	1	1	0	0	1	0	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0
113	0	0	1	0	0	0	0	0	0	0	0	0

Appendix E
Participant Data: Receptive Probes

	Probe 1				Probe 2				Follow-Up			
Study Id	Audio	Visual	Audio+ Visual	No AAC	Audio	Visual	Audio + Visual	No AAC	Audio	Visual	Audio + Visual	No AAC
101	2	3	3	2	2	0	3	0	1	2	4	3
102	0	1	2	1	3	2	1	1	2	2	2	2
103	1	1	2	0	1	1	2	1	2	3	2	3
104	0	0	1	1	0	1	0	1	0	1	2	1
105	0	1	2	2	2	3	3	2	2	3	3	3
106	3	2	2	4	2	2	3	2	3	1	1	3
107	2	1	1	3	2	1	2	3	1	0	2	2
108	0	0	2	2	1	0	2	1	2	0	2	0
109	2	4	2	2	1	2	2	1	3	2	3	3
110	1	2	0	1	1	0	1	1	2	1	1	2
111	1	1	3	0	2	2	1	0	2	2	3	2
112	3	0	1	1	3	1	1	3	1	1	2	2
113	2	3	1	2	0	2	2	1	2	1	1	1

Appendix F
Participant Data: Novel Word Use

Study Id	Audio	Visual	Audio + Visual	No AAC
101	10	7	25	8
102	7	16	7	12
103	6	3	2	4
104	10	17	3	5
105	8	2	2	1
106	6	5	3	9
107	3	5	8	1
108	1	0	0	2
109	27	14	34	5
110	9	8	8	5
111	20	18	20	20
112	1	2	0	1
113	6	8	3	6