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The Effect of Core Vocabulary Therapy on Speech Outcomes for a Child with an Auditory Brainstem Implant: A Pilot Study

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The Effect of Core Vocabulary Therapy on Speech Outcomes for a Child with an Auditory Brainstem Implant: A Pilot Study

by

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Dedication

I can think of no one more deserving of this dedication than my wonderful partner of over six years, Adam Vander Pas. Words simply cannot capture the immense gratitude I have for your unwavering love and support during the journey that has been this graduate degree. It would not have been possible without all the meals you prepared, the therapy materials you laminated and cut, the rides you provided when I missed my bus, and the words of encouragement during moments of stress and doubt. I love you with all my heart and look forward to navigating the post-graduate world hand in hand with you.

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Abstract

The Effect of Core Vocabulary Therapy on Speech Outcomes for a Child with an Auditory Brainstem Implant: A Pilot Study

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Core Vocabulary Therapy (CVT) is a well-studied language-based treatment for speech sound disorders originally designed for hearing children with highly unintelligible speech (Dodd, Holm, Crosbie & McIntosh, 2010). CVT seeks to help children create consistent productions of high-frequency, functional words and to generalize these consistent productions to spontaneous speech. Recently Herman and colleagues examined the efficacy of this treatment approach with pediatric cochlear implant (CI) users, and demonstrated that CVT can enhance consistency of speech production and speech intelligibility of children with severe to profound hearing loss who were fit with a CI (Herman, Thomas, Oyebade, Bennett, & Dodd, 2015). The efficacy of CVT with CI users warrants an exploration of this treatment approach for children with auditory brainstem implants (ABIs). With this in mind, we examined the impact of a CVT treatment approach on speech sound acquisition and word production for a pediatric ABI user. Specifically, this study aimed to determine whether CVT would lead to an increase in elicited vocalizations and spontaneous vocalizations. Secondly, the effects of CVT on phonemic inventory size, syllable shape inventory size, and overall use of syllable shapes were explored. CVT was administered twice a week for five weeks using vocabulary chosen based on relevance to the participant and developmentally appropriate sound and syllable shapes. Pre-and post-speech characteristics were compared following the completion of treatment. Post-test characteristics showed an increase in both elicited and spontaneous vocalizations. Elicited vocalizations demonstrated greater linear growth than spontaneous vocalizations. Post-test data also demonstrated an increase in phonemic inventory size, as the participant added one phoneme to her inventory and demonstrated emergence of two other phonemes. Syllable shape inventory also increased, as the participant acquired two syllable shapes. Finally, overall syllable shape use increased, and the participant demonstrated use of simultaneous voicing while producing the oral posture of syllable shapes. In summary, results from this study demonstrate that CVT may lead to positive changes in speech sound acquisition and development. Based on these results, CVT merits further research as an effective approach for children with ABIs.

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1. Introduction

Hearing loss is one of the most commonly occurring congenital abnormalities, affecting an estimated 2-3 out of every 1,000 children per year (Centers for Disease Control and Prevention, 2010). The majority of permanent hearing loss that is present at birth is sensorineural hearing loss (SNHL), or hearing loss due to deficits in the cochlea or vestibulocochlear nerve (Shah, Kozin, Kaplan, & Lee, 2016). The cochlear implant (CI) has been one of the most widely researched neuro-prosthetics for SNHL, and pediatric CI users have been shown to achieve speech production milestones at similar or slightly delayed rates in comparison to their typically hearing peers (Fulcher, Purcell, Baker & Munro, 2012; May-Mederake, 2012). When HL is caused by damage to the inner and outer hair cells of the cochlea, a CI can be inserted into the cochlea and provide direct electrical stimulation to the auditory nerve, thereby allowing for hearing (Shah et al., 2016). However, a small subset of children with SNHL cannot benefit from a CI due to absence or malformations of the cochlea and/or auditory nerve. For these children, the auditory brainstem implant (ABI) is an option to restore hearing by bypassing the cochlea and auditory nerve, and directly stimulating the auditory processing centers (cochlear nuclei) in the brainstem. A recent technological development, ABIs were only approved by the United States Food and Drug Administration (FDA) for clinical trial in children under 12 years of age in 2013 (Monsanto et al., 2015). Research exploring speech outcomes for young adults with ABIs have shown that ABIs help provide sound awareness (Colletti et al., 2005a, Colletti, 2007). Currently, many clinical trials are underway that examine the efficacy of ABI use and implantation in young children. However, because ABI implantation in very young children is such a recent development, there is little research that examines speech development and appropriate speech sound treatment approaches for children with ABIs.

1.1 EFFECTS OF SEVERE TO PROFOUND HEARING LOSS ON SPEECH ACQUISITION

The effects of hearing loss on speech development can be seen as early as seven to ten months of age during the onset of canonical babbling. At this age, typically developing children will begin to produce reduplicated consonant-vowel (CV) syllable shapes (Oller, Eilers, Bull, & Carney, 1985). Children with hearing loss may experience a delay in canonical babbling, and babble at a lower volume than their typically developing peers (Moeller et al., 2007). Furthermore, while typically developing children demonstrate adult-like timing and intonation in their babble, children with hearing loss will often demonstrate varied and atypical timing and intonation due to a lack of input and ability to self-monitor during the babbling stage (Nathani & Oller, 2008). By 12 months of age, typically developing children are producing variegated babble and first words, using a variety of consonants, vowels and syllable shapes. Children with hearing loss may present with a significantly reduced repertoire of consonants, vowels, and syllable shapes, thus delaying the acquisition of first words (Oller et al., 1985).

A reduced sound and syllable inventory can significantly affect vocabulary growth and language development if hearing loss is not identified and treated. Severe to profound SNHL has been associated with delays in word learning and grammatical development (Davis, Elfenbein, Schum, & Bentler, 1986). In turn these language delays are likely to affect the acquisition of literacy, a skill which requires a solid foundation in language (Carney & Moeller, 1998). Such delays can also impact a child's academic and social achievement, thus necessitating early identification, amplification, and intervention for this population.

1.2 SPEECH OUTCOMES IN CHILDREN WITH SNHL

The bulk of the research concerning neuro-prosthetics and speech development for children with profound SNHL has focused on the pediatric CI population. Children with CIs have been shown to follow typical developmental patterns of speech sound acquisition, although they may acquire sounds at a slightly slower rate than their typically developing peers (Salas-Provance, Spencer, Nicholas, & Tobey, 2014). Additionally, pediatric CI users have been shown to be able to reach typical levels of speech sound production and accuracy as early as three years of age (Fulcher et al., 2012). While use of amplification is a positive prognostic indicator for speech development, outcomes for pediatric CI and hearing aid users are still mixed, as many factors can affect speech outcomes including age of implantation, implant characteristics and approaches to intervention, as well as child and family characteristics (Tobey, Geers, Brenner, Altuna, & Gabbert, 2003).

Early identification and implantation are among the most significant factors which can affect speech outcomes for children with profound SNHL (Fulcher et al., 2012). Typically, earlier identification and hearing amplification lead to better outcomes than later identification and amplification (Fulcher, et al., 2012). Technological innovation can also play a role, with newer generation CIs and hearing aids proving to be more effective than previous technology (Geers, 2004). Currently, with the 1-3-6 guidelines proposed by the Joint Committee on Infant Hearing (JCIH), more children are screened for hearing loss by one month, diagnosed by three months, and receiving intervention by six months (JCIH, 2007). Regarding age of implantation, CI surgery at or before 12 months has been associated with better speech and language outcomes (Colletti et al., 2005b; May-Mederake, 2012). With respect to intervention, auditory verbal approaches have been proven to be more effective than signed approaches, as they require the child to rely on speech and hearing as the primary communication modality (Fulcher et al., 2012). Finally, several environmental and family characteristics have been identified as potential factors for successful outcomes, including having fewer siblings, living in a non-remote location, high level of maternal education, integrated school placement, and high degree of child participation and motivation (Fulcher, Purcell, Baker, & Munro, 2015).

1.3 THE AUDITORY BRAINSTEM IMPLANT: HISTORY & PEDIATRIC OUTCOMES

ABIs were first implemented exclusively in adults and children over 12 years of age with damaged auditory nerves due to neurofibromatosis-2 (NF2), a genetic disorder which can cause tumors to develop on nerve tissue (Evans, 1998). ABI research has since expanded beyond NF2 patients and ABIs have been successfully implanted in adults and older children with other abnormalities such as congenital malformation or absence of the cochlea and cochlear ossification (Colletti, 2006). Preliminary studies indicate that non-NF2 patients achieve better auditory outcomes than NF2 patients (Colletti, 2006). Clinical trials for children with hearing loss began as recently as 2013 (Monsanto et al., 2015).

The large majority of clinical trials for the pediatric ABI population have focused on auditory outcomes after implantation. In 2015, Noij and colleagues conducted a systematic review concerning auditory outcomes in the non-tumor pediatric ABI population (Noij et al., 2015). A total of 21 clinical trials and research studies were reviewed which examined auditory outcomes on a total of 105 pediatric patients. Age of implantation ranged from 11 months to 17 years, with a median age of implantation at 4.3

years. Many patients had profound SNHL due to syndromes such as CHARGE, Down Syndrome or Shprintzen Syndrome. The majority of studies used the Categories of Auditory Performance Score (CAP Score) as an outcome measure. Noij and colleagues found that about 50% of patients demonstrated an increased CAP score after 5 years of ABI use (Noij et al., 2015). Other outcome measures included detection of environmental sounds, closed set word recognition, and speech detection, perception and discrimination measures. Auditory outcomes based on these measures were so variable that no definitive conclusions were made.

Monsanto and colleagues also conducted a systematic review of auditory outcomes in the pediatric ABI population (Monsanto et al., 2015). The researchers evaluated a total of 24 studies that examined auditory outcomes for a total of 120 children. Results after implantation showed that 93% of patients in the studies demonstrated increased environmental sound awareness and speech perception. While a majority of participants in these studies demonstrated some degree of improvement, it should be noted that improvement was highly variable within and across studies, and that the majority of studies did not follow participants for a significant amount of time after ABI implantation. For example, Bayazit and colleagues conducted a study of 12 children implanted with ABI. Post-activation auditory results indicated that only two participants acquired environmental sound awareness and speech sound discrimination abilities after implantation, while six participants (50%) demonstrated no response (Bayazit et al., 2014). Post-activation speech results indicated that only one participant demonstrated increased vocalizations and two participants showed use of some words. The majority of outcomes seen by Monsanto and colleagues indicated access to sound and varied ability to discriminate sounds and rudimentary speaking ability (Monsanto et al., 2015).

As demonstrated throughout the literature, speech and language outcomes for pediatric ABI users are quite varied, and range from increased sound awareness to improved vocalization and word use. This variability in outcomes is due to a variety of factors including small population size, the novelty of pediatric ABIs, varying causes of hearing loss, and different outcome measures across studies (Monsanto et al., 2015; Noij et al., 2015). Factors that have been shown to affect variability in CI outcomes such as age of identification and implantation, new vs. old generation technology, and family/environmental characteristics may also affect ABI outcomes. Largely missing from pediatric ABI research are the effects of specific treatment approaches following implantation. The ability of ABIs to give children access to speech and language will not be fully understood until ABI use is researched in a treatment study context.

1.4 SINGLE SUBJECT RESEARCH DESIGN

Because the pediatric ABI population is so small, especially outside of ongoing clinical trials, single subject design studies are best suited for this population. While single subject research design is not considered the gold standard of research approaches, it can provide meaningful information for evidence-based practice in small clinical populations. Single-subject research design has been used for many studies in the field of communication sciences and disorders, and speech and language treatment approaches have been proven to be efficacious using single subject design research (Dollaghan, 2007). While this type of research cannot be generalized to an entire population, valuable insight concerning treatment efficacy in "real world" contexts is provided and informs clinicians in tailoring treatment approaches to their client's specific level and needs (Vance & Clegg, 2012).

Single subject design research incorporates elements of experimental research, including hypotheses, independent and dependent variables, and statistical data analysis (Vance & Clegg, 2012). Incorporating such elements into single-subject design adds a level of experimental control, which increases power (Dollaghan, 2007). However, single-subject designs differ from higher level research in terms of comparison group. While experimental research typically compares group performances, single-subject research compares different conditions within one participant over time (Meline, 2006). A common method to compare conditions in a single participant over time is the A_1-B-A_2 case design. In an A_1-B-A_2 design, A_1 consists of a baseline or control phase, where targeted behaviors are observed in a natural context. The A_1 phase provides a basis for comparison for the rest of the study (Meline, 2006). The B phase consists of an intervention phase, and A_2 represents a second baseline phase after the course of treatment. The value of A_1-B-A_2 designs are that they offer a controlled way to observe a variable over the course of time, but are flexible enough to be modified for the individual. Baseline and treatment phases can be lengthened or shortened as needed to observe desired variables and behaviors. Additionally, the A_2 phase allows researchers to see the prolonged effects of treatment and whether the effects of a particular treatment approach are easily maintained, which is a key question for researchers.

Such flexibility of single-subject design is ideal for small populations such as the pediatric ABI. Because pediatric ABIs are a relatively new innovation and because this population is so small and variable, it is impossible to conduct group comparison designs to assess outcomes for speech development and production, making single-subject design research an appropriate level of research. Single-subject research design can allow researchers to modify treatment as needed for an individual child, while still providing a level of experimental control throughout the course of research.

1.5 CORE VOCABULARY THERAPY

One way to boost the research validity of a single-subject treatment design is to use a treatment approach that has been studied in higher level research. Core Vocabulary Therapy (CVT) is a well-researched language-based speech treatment for children with highly unintelligible speech (Dodd et al., 2010). The primary goal of CVT intervention is to help children create consistent productions of words that are meaningful to the child, and to generalize these consistent productions to spontaneous speech. Productions are not required to be phonologically accurate, and may contain developmental errors or phonological processes (Dodd et al., 2010). A list of 50-70 target words are chosen for a course of CVT intervention and are targeted twice weekly for five to eight weeks. Target words typically include names, places, foods, functional vocabulary, and other words relevant to the child's life. Techniques involved in CVT include modeling the production of target vocabulary using articulatory cues such as syllable segmentation and imitation (Dodd et al., 2010).

CVT has been shown to effectively improve speech consistency for children with inconsistent speech sound errors in several case studies and correlational studies (Dodd & Bradford, 2000; Dodd & Iacono, 1989; McIntosh & Dodd, 2008). In recent years, more rigorous research has also demonstrated the efficacy of this approach. Broomfield & Dodd conducted a randomized control study which examined the effects of CVT on 30 children with inconsistent speech sound errors and severe to profound unintelligibility (Broomfield & Dodd, 2005). Clinicians administered CVT once a week for six weeks to 20 children, while 10 children received no treatment. Results indicated that after six weeks, those children who had received intervention showed increased intelligibility compared to the children who had received no intervention. Crosbie and colleagues conducted a quasi-experimental study comparing the effects of CVT and Phonological Contrast Therapy on speech accuracy and consistency for children with severe speech sound disorders (Crosbie, Holm & Dodd, 2005). Both children with consistent speech sound errors and inconsistent speech sound errors were recruited for the study. Using a multiple-baseline alternating treatment design, both groups of children received each type of therapy in two 8-week blocks, with a four-week withdrawal period between treatments. Results of this study indicated that children with inconsistent speech sound errors made more significant gains with CVT, while children with consistent speech sound errors made more significant gains with phonological contrast therapy. Overall, CVT has been shown to help increase both consistency and intelligibility of speech for children with severe to profound speech sound disorders.

The CVT approach has also been researched for children with severe to profound hearing loss. Herman and colleagues implemented CVT with four 9-11 year-old children with profound SNHL who use CIs and examined the effects of the treatment on speech accuracy, consistency, and intelligibility (Herman et al., 2015). All participants had been implanted between three to five years of age and demonstrated very low intelligibility due to inconsistent speech sound errors. CVT was administered twice a week for eight weeks using a list of 50 words that were educationally or socially relevant to the child. Each week 10 words were selected at random and targeted throughout the two sessions of the week through drill play using strategies including syllable and sound segmentation, tactile cueing, and finger spelling. By the end of therapy, three out of the four children demonstrated significant improvement in speech consistency and accuracy, leading to an overall increase in intelligibility. Overall, these results indicate that CVT should be further explored as an effective approach for children with hearing loss. Given the success Herman et al. (2015) had with using CVT for children with CIs, exploring the efficacy of this therapy approach for children with ABIs is certainly warranted. Children with ABIs demonstrate similar speech sound errors as children with CIs, including inconsistent speech sound errors and low intelligibility, which suggests CVT may be an appropriate approach in increasing consistency and intelligibility for children with ABIs.

One aspect of CVT that researchers have begun to explore is the question of whether client selected vocabulary leads to better outcomes than clinician vocabulary selected for sound or syllable shape (Dodd et al., 2010). This question is of particular relevance to the use of this approach for children with hearing loss, because choosing developmentally appropriate speech sounds and syllable shapes for this population may lead to better consistency and intelligibility outcomes. Such a question can be examined in a single-subject experimental design, where researchers may modify treatment targets as they monitor progress over the course of treatment.

1.6 Current study

Efficacy of CVT for children with profound SNHL has been established by a small number of single-subject design studies (Herman et al., 2015). However, this research has not been extended to children with ABIs. In this pilot study, we examined the impact of a CVT approach on speech sound acquisition and word production for a pediatric ABI user. The goal of the study was to determine whether CVT would result in the use of more frequent and independent vocalizations, and whether CVT would be beneficial in aiding in acquisition and use of consonants and syllable shapes. Our specific aims include the following:

1) Does CVT result in an increase in elicited vocalizations for pre-school age ABI users? Elicited vocalizations are defined as vocalizations that require a clinician prompt. Elicited vocalizations include labeling items upon clinician request,

answering questions, and requests that required prompting from the clinician. We hypothesize that CVT will result in an increase of elicited vocalizations by the participant.

2) Does CVT result in an increase of spontaneous vocalizations for pre-school age ABI users? Spontaneous vocalizations are defined as communicative vocalizations that do not require prompting from a clinician. Spontaneous vocalizations include labeling, commenting, requesting, and negating. We hypothesize that CVT will lead to an increased number of spontaneous vocalizations and that over the course of the therapy, spontaneous vocalizations would begin to outnumber elicited vocalizations.
3) Does CVT lead to gains in speech sound acquisition and phonetic inventory growth for pre-school aged ABI users? We hypothesize that CVT will lead to an increase in the participant's phonemic inventory relative to baseline.
4) Does CVT lead to gains in syllable shape acquisition and use for pre-school age ABI users? We hypothesize that CVT will lead to an increase in overall syllable usage and an increase in the participant's syllable shape inventory.

2. Methods

2.1. Participants

One participant was recruited for this pilot study. The participant was recruited as part of a larger study comparing different speech approaches for children with varying types of hearing loss. Participant background information concerning speech, language, and hearing history was collected during the baseline phase using a parent questionnaire. The participant was given a fake name for the purposes of this study, and will hereby be referred to as Kate.

Kate is a 3 year 9-month-old female, who was diagnosed with CHARGE syndrome shortly after birth. CHARGE is a congenital syndrome characterized by several anomalies including vision defects, heart defects, atresia of the nasal passages, delayed growth and development, urinary defects, and ear anomalies and hearing loss (Blake & Prassad, 2006). Kate presents with hearing, vision, urinary and growth deficits secondary to CHARGE.

Kate was also diagnosed shortly after birth with profound SNHL secondary to CHARGE. Kate qualified as a candidate for an ABI and underwent surgery in 2014 at one year of age. Kate used this ABI for 18 months, at which point it was determined that the ABI had failed, and she underwent another surgery to replace the original ABI with an updated model in 2016. Kate has now been using the Cochlear® N6 ABI for six months. Kate is reported to consistently use her ABI both at home and at school.

Kate is exposed to both manual and oral forms of communication on a daily basis. At home, Kate's parents use Signed Exact English (SEE) in conjunction with oral English to communicate with Kate. Kate also uses ASL with her nanny on a daily basis. At school Kate uses sign but is also exposed to oral communication. Per parent report, Kate does not consistently use spoken language to communicate, and when she vocalizes she typically produces vowel or nasal-like vocalizations while signing. Kate currently receives speech and language therapy both at school and privately where a primary goal is to increase her use of oral communication. Table 1 provides a summary of Kate's hearing, speech, and language background.

Table 1. Participant Characteristics

Name Age & Gender	Diagnoses	Amplification	Language Background	Speech Production at Baseline
Kate, 3;9, girl	• SNHL • CHARGE Syndrome	• Cochlear® N6 ABI - activated in 2014, failed and replaced 2016 • Consistent use at home and school	• Parents use SEE in conjunction with spoken English • Speaks ASL with nanny • Sign and oral language at school	• Vocalizes vowels and /m/ while signing • Does not use speech sounds consistently during communication

2.2. PROCEDURE

This study consisted of three phases: (a) Baseline, (b) Intervention, and (c) Post-Treatment. The baseline phase consisted of two 30 minute sessions, while intervention consisted of ten 45-minute treatment sessions over the course of 5 weeks (i.e. two treatment sessions per week). The post-treatment phase consisted of two 30 minute sessions one week after the intervention phase had concluded. All sessions took place in a quiet therapy room at the UT Speech and Hearing Center at the University of Texas Austin, and were conducted by a graduate student clinician in speech language pathology who used only spoken language. A second graduate student clinician proficient in ASL was also present in all sessions, and provided instruction or clarification concerning therapy tasks to the participant. All sessions were audio and video recorded. Parents were encouraged to watch all sessions. The parent-child dyad was reimbursed for their participation in this study. Reimbursement was made following completion of the post-treatment sessions.

2.2.1 Baseline and Target Selection

The baseline phase consisted of two 30-minute play sessions with the participant. These sessions were used to measure the frequency with which the participant used vocalizations to communicate and to determine the participant's existing phoneme and syllable shape inventory. To elicit spontaneous speech in free play, a graduate student clinician who did not use sign played with the child with various toys including a doll house, a kitchen set, and toy farm animals. The play sessions were transcribed offline and were coded for the following items: number of elicited vocalizations, number of spontaneous vocalizations, phonemic inventory, and syllable shape inventory/use. After reviewing baseline data, a list of 30 target words was devised with the participant's parent to use in therapy. Words were chosen based on importance to the child's social and educational needs and on sound and syllable shape. This list of words is provided in Appendix A.

2.2.2 Intervention

Each week 10 target words were selected at random and used for the two sessions. All sessions contained at least five target words that had bilabial phonemes (/p, b, m, w/). The first 15 minutes of each session were spent teaching the 10 target words to the participant. Words were taught by the clinician using cues such as sound segmentation, imitation, and cued articulation. The rest of the session was spent practicing the words and eliciting vocalizations in drill and naturalistic play. Drill play activities included naming and turn taking games, while naturalistic play included using toy farm animals to practice target words (e.g. eating target food or completing target actions). Each session was coded for number of elicited vocalizations, number of spontaneous vocalizations, phonemic inventory, and syllable shape inventory/use.

2.2.3 Post-Treatment

After intervention, two 30-minute post-treatment sessions were conducted to determine the participant's maintenance of progress. To elicit spontaneous speech in free play, a graduate student clinician who did not use sign played with the child with various toys including a doll house, a kitchen set, and toy farm animals. The post-treatment session was coded for number of elicited vocalizations, number of spontaneous vocalizations, phonemic inventory, and syllable shape inventory/use.

2.2.4 Storing data

Consent forms and background information forms were stored in a locked file cabinet in the primary investigator's office at the University of Texas Speech and Hearing Center. Only IRB personnel had access to these forms. Data from baseline, intervention, and post treatment sessions was coded on Excel spreadsheets and participant identifiers were not used. Audio/Video recordings from all sessions and data spreadsheets were stored electronically on a password-protected computer.

2.3 Outcome measures and data analysis

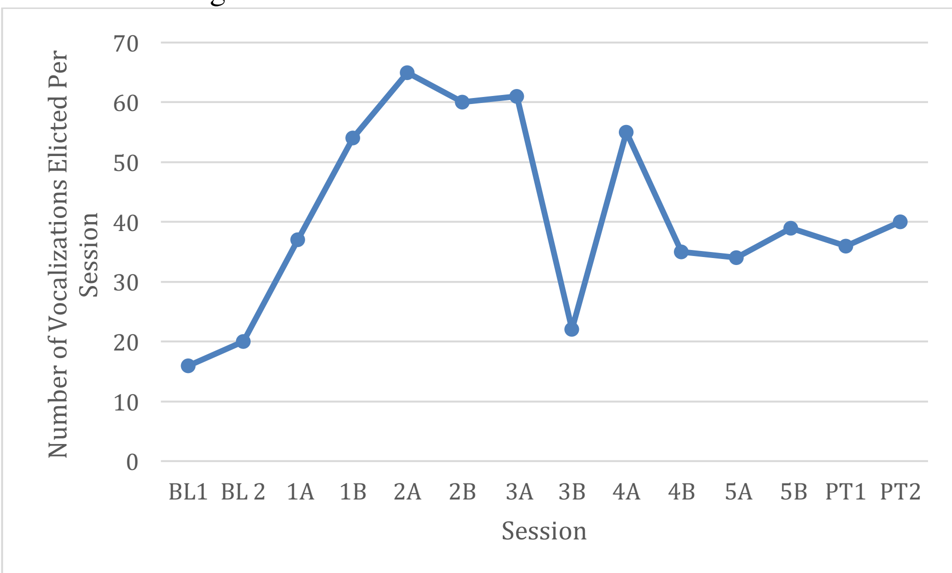
The primary outcome measures were the pre- to post-treatment changes of the dependent variables. These pre-post treatment changes include (a) the difference between number of independent vocalizations from at baseline relative to the number of independent vocalizations at post-treatment, (b) the difference between average number of spontaneous vocalizations at baseline sessions relative to the number of spontaneous vocalizations at post-treatment, (c) the difference in number of phonemes in the phonemic inventory at baseline relative to the number of phonemes in the phonemic inventory at post-treatment, (d) the difference in number of syllable shapes in the syllable inventory at baseline relative to the number of syllable shapes in the syllable inventory at post-treatment, and (e) difference in overall use of syllables at baseline relative to overall use of syllables at post-treatment. Due to a small sample size, no statistical analyses could be calculated. Visual data analysis was conducted to compare changes between baseline and post-treatment. Production of elicited and spontaneous vocalizations were analyzed for linear growth, while phonemic and syllable inventories were monitored for growth in size.

3. Results

3.1 Elicited vocalizations

Kate increased use of elicited vocalizations over the course of treatment. Figure 1 demonstrates the number of elicited vocalizations observed each session.

Figure 1. Production of Elicited Vocalizations



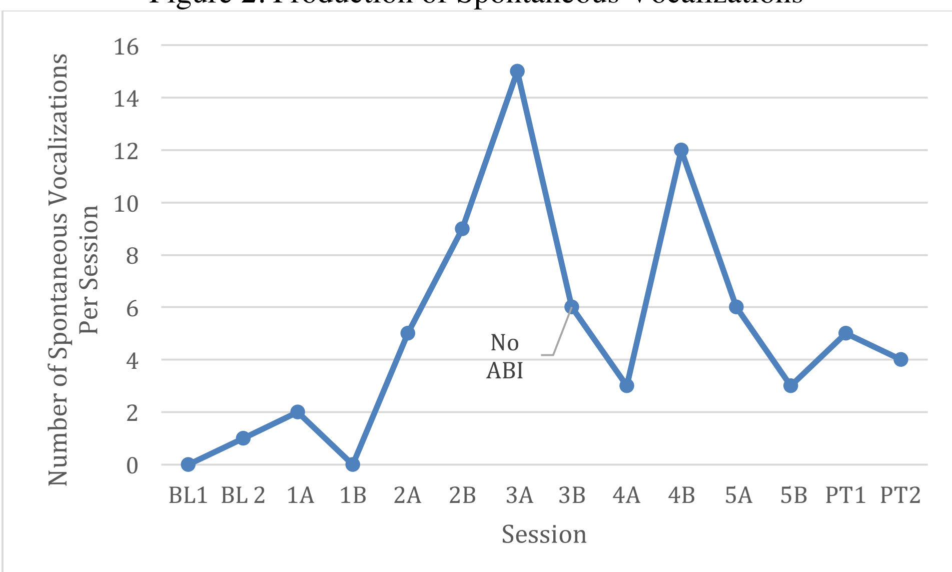
The x axis represents the session number, with BL referring to baseline and PT referring to post-treatment. All other sessions are treatment and are labeled according to week (1-5) and first (A) or second (B) session.
The y axis reflects the number of elicited vocalizations Kate produced each session.

At baseline, Kate relied heavily on use of sign to request, comment or label, and produced 16 elicited vocalizations during the initial baseline session and 20 elicited vocalizations during the second baseline session. Kate's use of elicited vocalizations displayed linear growth during the course of treatment and peaked at session 2A where Kate produced a total of 65 elicited vocalizations. Session 3B demonstrated a sharp decrease in vocalizations which was due to Kate not having her ABI for the majority of the session. During weeks 4 and 5 of treatment, Kate began to imitate more oral postures and syllable shapes, which resulted in a slight decrease in elicited vocalizations. Syllable shapes are discussed further in section 3.4. At post-treatment, Kate had increased in overall elicited vocalizations from baseline, producing 36 elicited vocalizations during the first post-test session and 40 elicited vocalizations during the second post-test session compared to 16 and 20 vocalizations at baseline.

3.2 Spontaneous Vocalizations

Kate slightly increased in the use of spontaneous vocalizations over the course of treatment. Figure 2 demonstrates the number of spontaneous vocalizations observed each session.

Figure 2. Production of Spontaneous Vocalizations



The x axis represents the session number, with BL referring to baseline and PT referring to post-treatment. All other sessions are treatment and are labeled according to week (1-5) and first (A) or second (B) session.
The y axis reflects the number of elicited vocalizations Kate produced each session.

At baseline, Kate did not use spontaneous vocalization to request, comment or label, and did not produce any spontaneous vocalizations during the first baseline session and produced one spontaneous vocalization during the second baseline session. Kate's use of spontaneous vocalizations displayed linear growth during the course of treatment and peaked at session 3A where Kate produced a total of 15 spontaneous vocalizations. Session 3B demonstrated a sharp decrease in vocalizations which was due to Kate not having her ABI for the majority of the session. During weeks 4 and 5 of treatment, Kate began to imitate more oral postures and syllable shapes, which resulted in a decrease in spontaneous vocalizations. Syllable shapes are discussed further in section 3.4. At post-test, Kate increased in overall spontaneous vocalizations from baseline, producing 5 spontaneous vocalizations during the first post-test session and 4 spontaneous vocalizations during the second post-test session.

3.3 Phoneme Inventory

Kate's phoneme inventory increased over the course of therapy. Table 2 demonstrates the number phonemes observed over the course of the study. A phoneme had to be observed at least 2 times per session to be added to Kate's phoneme inventory.

Table 2. Consonant and Vowel Production

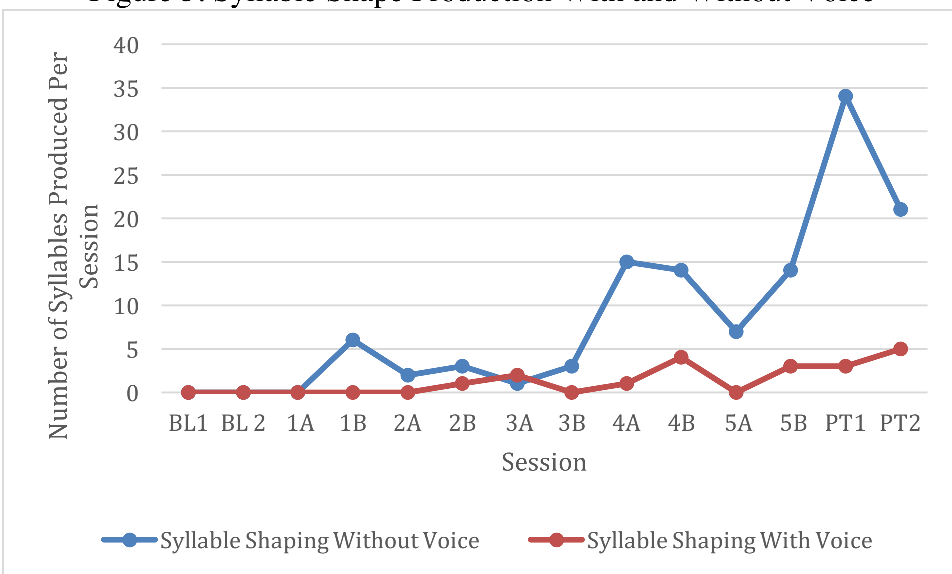
Date	Vowels	Consonants
Baseline 1	/ə, a/	/m/
Baseline 2	/ə, a/	/m/
Week 1A	/ə/	/m/
Week 1B	/ə, o/	/m/
Week 2A	/ ə, a, o/	/m, n/
Week 2B	/ ə, a, o/	/m/
Week 3A	/ə, a/	/m, w/
Week 3B	/ə/	/m/
Week 4A	/ə, a/	/m/
Week 4B	/ə, a/	/p, m/
Week 5A	/ə/	/p, m/
Week 5B	/ə, a/	/m/
Post Test1	/ə, a/	/p, m/
Post Test2	/ə, a/	/p, m/

At baseline, Kate's phonemic inventory contained one consonant, the nasal bilabial /m/. Over the course of treatment, the client produced two additional bilabial consonants: /p/ and /w/, and one additional nasal consonant, /n/. The phoneme /p/ was maintained after treatment and was observed during the post-test sessions. Regarding vowels, Kate's initial vowel inventory included two vowels, /ə/ and /a/. Kate demonstrated use of one additional vowel over the course of treatment: /o/. The vowel /o/ was only observed during Week 2 of treatment and was not observed in additional treatment sessions or at post-test. Kate produced an average of 3-4 different phonemes during each session.

3.4 Syllable use and inventory

To produce a syllable, it is necessary to both produce voice and form an oral posture with the articulators. Throughout the course of treatment, Kate would frequently imitate the oral postures of different syllable shapes. When imitating oral posture of syllable shapes, Kate would frequently imitate the oral posture of the syllable without voicing, but produced fewer instances of simultaneous voicing and oral posture imitation when producing a syllable. This led the researchers to track Kate's syllable shape production with and without voicing. Figure 3 demonstrates Kate's imitation of oral postures with and without voice.

Figure 3. Syllable Shape Production With and Without Voice

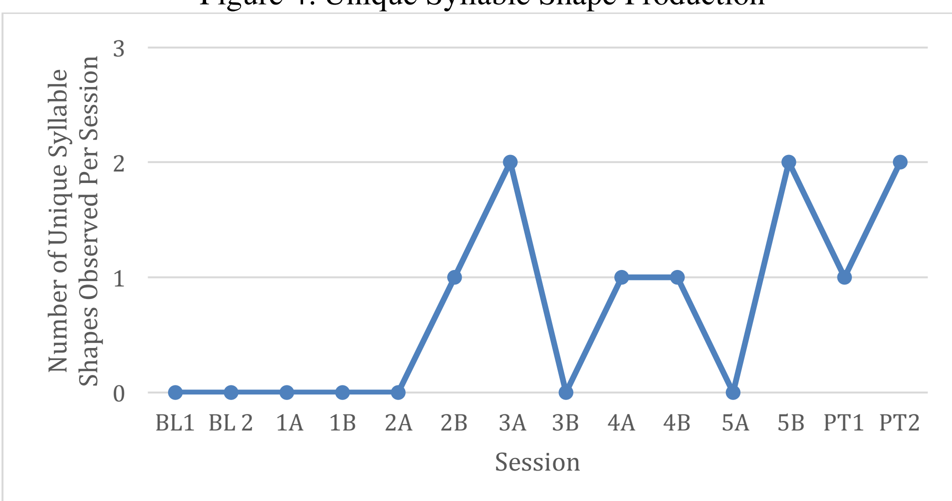


The x axis represents the session number, with BL referring to baseline and PT referring to post-treatment. All other sessions are treatment and are labeled according to week (1-5) and first (A) or second (B) session.
The y axis reflects the number of syllable productions observed each session.

At baseline, Kate did not produce any syllable shapes. During the first three weeks of treatment Kate only produced a maximum of six imitations of syllable shapes without voice (Session 1B), and began to produce instances of syllable production with voicing in sessions 2B and 3A. Kate exhibited a dramatic increase in syllable production without voicing during Weeks 4 and 5. Kate syllable production without voicing continued to increase throughout post-treatment, and Kate produced 34 instances of syllable production without voicing in the first post-treatment session and 21 instances in the second post-treatment session. Whereas syllable production without voicing increased significantly, syllable production with voicing only increased slightly during Weeks 4 and 5, with Kate producing no more than four instances of syllable production with voice at the end of treatment. At post-test, Kate produced three instances of syllable production with voice during the first session and five instances of syllable production with voice during the second session.

In regards to syllable shape inventory, Kate increased the number of shapes in her syllable shape inventory over the course of treatment. Figure 4 demonstrates the number of unique syllable shapes observed over the course of therapy. Only syllable shapes produced with voice were used to determine syllable shape acquisition.

Figure 4. Unique Syllable Shape Production



The x axis represents the session number, with BL referring to baseline and PT referring to post-treatment. All other sessions are treatment and are labeled according to week (1-5) and first (A) or second (B) session. The y axis reflects the number of unique syllable shapes observed each session.

At baseline, Kate had no syllable inventory. As production of syllable shapes with voicing began to increase, Kate began to add syllable shapes to her inventory. At post-test Kate had two syllable shapes in her inventory. Table 3 demonstrates syllable shapes used by Kate.

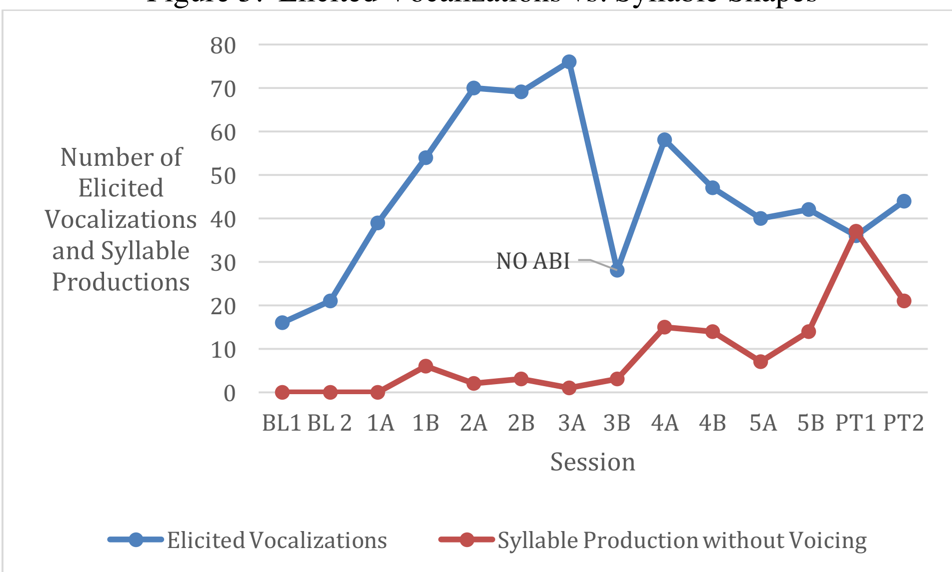
Table 3. Syllable Shapes and Transcriptions

Session Number	**Syllable Shapes**	**Transcription**
2B	CVCV	/məmə/ for "byebye"
3A	CVCV, VCV	/wa. ə. for "water" /əmə/ for "milk"
4A	CV	/mə/ for "baa"
4B	CV	/mə/ for "pig," "pizza," and "mama"
5B	CVCV, CV	/məmə/ for "pony" and "byebye" /mə/ for "pig"
Post Treatment 1	CV,	/mə/ for "one," "water" and "up"
Post Treatment 2	CVCV, CV	/məmə/ for "bunny" and "byebye" /mə/ for "moo," "pig," and "one"

Overall, Kate produced primarily CV and CVCV syllable shapes, using /mə/ as the vocalization for most words. Kate did not consistently vocalize the correct number of syllables in a word in session 4B or Post Treatment 1, but vocalized the appropriate number of syllables in a word for all other sessions.

As Kate began to produce more syllable shapes without voicing, the overall number of vocalizations dropped. Figure 5 compares use of syllable shapes without voicing with total number elicited vocalizations.

Figure 5. Elicited Vocalizations vs. Syllable Shapes



The x axis represents the session number, with BL referring to baseline and PT referring to post-treatment. All other sessions are treatment and are labeled according to week (1-5) and first (A) or second (B) session. The y axis reflects the number of elicited vocalizations (blue) vs. the number of syllables without voicing (red) produced each session.

As demonstrated in Figure 5, during Session 4A, as syllable production without voicing began to increase, the number of elicited vocalizations began to decrease. Elicited vocalizations continued to decrease during sessions 4B and 5A. Both elicited vocalizations and syllable productions increased relative to baseline at post-treatment.

In summary, Kate increased both elicited and spontaneous vocalizations relative to baseline. Kate added one syllable to her phonemic inventory, the voiceless bilabial, /p/. Kate also developed a syllable shape inventory consisting of two syllable shapes and increased her overall use and production of syllables. As Kate began to produce more complex speech tasks such as syllables, her overall number of vocalizations decreased, as she focused on mimicking the oral posture of syllable shapes, and slowly but steadily increased production of syllable shapes with voicing.

4. Discussion & Conclusions

To date, there is little to no research that explores effective therapies for speech production in children with ABI. CVT is a therapy approach that was originally designed to increase consistency and accuracy of word productions for hearing children with inconsistent speech production (Dodd et al., 2010). Research has demonstrated that CVT effectively increases consistency of production for target words (Broomfield & Dodd, 2005; Crosbie, Holm & Dodd, 2005). Previous research has also indicated that CVT is an effective therapy for children with severe SNHL who use CIs (Herman et al., 2015). This study was designed to use components of research studies to investigate the effects of CVT on speech acquisition for a pre-school aged child with an ABI using a single subject experiment design. Specifically, we examined the effects of CVT on elicited and spontaneous vocalizations, phonemic inventory growth, and syllable shape inventory and use. We hypothesized that using the CVT approach for a child with ABI who has minimal speech would lead to an increase in both elicited and spontaneous vocalizations, an increase in phonemic and syllable shape inventory size, and an increase in use of syllable shapes.

Comparative analysis of the data between baseline and post-treatment revealed that Kate increased her elicited vocalizations at post-test relative to baseline. At baseline, Kate rarely vocalized to request, label, or comment produced between 16-20 elicited vocalizations. Over the course of therapy, Kate demonstrated an increased production of elicited vocalizations, and produced a maximum 65 elicited vocalizations during session 2A. Increased vocalizations were maintained through post-treatment, with 76 elicited vocalizations observed over the two post-treatment sessions. Consistent use of vocalization as a means of communication is necessary for speech sound and syllable shape acquisition. Given that Kate rarely used vocalization for communicative purposes at the beginning of the study, this increase in vocalizations was a major achievement in terms of speech acquisition and communication.

Analysis of spontaneous vocalizations revealed that Kate only slightly increased in spontaneous vocalizations relative to baseline, demonstrating only one spontaneous vocalization at baseline and 10 spontaneous vocalizations at post-test. While Kate demonstrated a significant increase in spontaneous vocalizations over the course of therapy, use of spontaneous vocalizations was not maintained. These results may be due to the fact that Kate uses ASL as a primary means of communication, and is therefore does not need to vocalize to communicate wants and needs in daily living.

Analysis of phonemic inventory demonstrated that Kate increased her phonemic inventory size. At baseline, Kate only used one consonant, the bilabial nasal /m/, and two vowels, /ə/and /a/. At post-test, Kate demonstrated consistent use of one additional bilabial consonant, /p/. Two additional consonants, /n/ and /w/, and one additional vowel, /o/, were observed in treatment sessions but not at post-test. The phonemic growth seen in this study parallels that of typical speech language development, as bilabial sounds are among the earliest acquired speech sounds. These findings align with previous research with children with inconsistent speech sound errors showing that CVT can lead to phonemic inventory growth (Dodd & Iacono, 1989). Cite studies. While phonemic inventory growth demonstrated in this study is small, it demonstrates promise that CVT can lead to speech sound acquisition.

Analysis of syllable shape inventory demonstrated that Kate increased her syllable shape inventory size. At baseline Kate did not have any syllable shapes, and only produced vocalic like vocalizations. Over the course of therapy, Kate demonstrated an increase in use of syllable shapes. Kate first began to produce syllable shapes without voicing, and mimicked the oral postures of the clinicians. Over the course of therapy, Kate began to demonstrate instances of syllable shape production with voicing in session 1B, and increased her voiceless syllable production up to 15 voiceless syllables at session 4A. During session 2B, Kate produced her first instance of a voiced syllable and produced 5 voiced syllables in session 4B. At post-treatment, Kate was using both CV and CVCV shapes to name core vocabulary targets, producing 55 unvoiced and 8 voiced syllables over the course of post treatment. All productions of syllables were typically produced using the bilabial /m/ and the neutral vowel /ə/. While the same CV syllable was used for production of all targets, this CV production is still considered to be an improvement from baseline, where Kate only produced vocalic vocalizations. Overall, these results indicate that CVT may lead to an increase in syllable shape inventory and use for pediatric ABI users.

Previous research on CVT therapy has almost exclusively focused on consistency and intelligibility outcomes. Overall, CVT has been shown to significantly improve these measures for children with severe phonological disorders and for special populations including children with severe-profound hearing loss (Broomfield & Dodd, 2005; Herman et al., 2015). Both of these outcome measures necessitate that children receiving CVT have a relatively high level of speech and language development. However, CVT may also prove to be a viable approach for children with lower levels of speech and language production. Because CVT targets vocabulary that is relevant and meaningful to the child, it may be a useful approach for children who need to develop both speech and language. At baseline, Kate did not use spoken language for communicative purposes, but demonstrated growth over the course of CVT therapy in both elicited and spontaneous vocalizations for communicative purposes. Additionally, Kate demonstrated improved speech outcomes in terms of phonemic and syllable shape growth. This study is one of the first studies to examine CVT therapy for children with limited speech and language production. Results of this study suggest that CVT may be a beneficial approach for children with limited speech and language production, including children with ABIs. Larger group studies are needed to further examine the efficacy of CVT on speech and language outcomes (i.e. syllable shape production, vocabulary development) for children with low levels of speech and language production.

While this study is novel in its examination of CVT for children with ABI, it is not without limitations. A critical limitation of this study is sample size. This single-subject study reports the effects of CVT for one child with an ABI, and therefore generalizations cannot be made to an entire population. Kate in this study was still in the speech sound acquisition stage of speech development, and did not consistently use speech as a means of communication at the onset of this study. Further studies will need to be conducted to further examine the efficacy of CVT for children with ABI. Specifically, it would be beneficial to determine the efficacy of this approach for children with ABI who have acquired and use speech consistently, but demonstrate inconsistent speech sound production. Furthermore, no statistical analyses were conducted as the sample size for the study was one participant. Future studies with a larger number of participants may be able to provide more concrete statistical analysis related to the efficacy of this therapy. One final drawback to the study was the length of treatment. Traditional CVT typically consists of 18 sessions over the course of 9 weeks. Due to time constraints, treatment for this study consisted of 10 sessions over the course of 5 weeks. However, we expect to see Kate continue to benefit from ongoing CVT therapy.

Results of this study align with previous research that suggests CVT may be an effective treatment for children with severe to profound SNHL and this study indicates that CVT may be an effective approach for pediatric ABI users. At baseline, Kate demonstrated limited use of vocalizations, and a minimal phonemic and syllable shape inventory. At post-treatment, Kate increased her use of elicited vocalizations, and slightly increased her use of spontaneous vocalizations. Kate also demonstrated growth in both her phonemic and syllable shape inventories. Overall, these results indicate that CVT may lead to progress in Kate's early speech sound acquisition and use. These results indicate that CVT is a viable treatment approach for this population, and one that could lead to large gains in speech sound acquisition, especially if treatment is lengthened to the standard 18 weeks. While this study was limited due to sample size, and future research is needed to further assess the efficacy of this approach for children with ABI, this study shows promise for CVT as a viable therapy approach for pediatric ABI.

Appendix A: Core Vocabulary Targets

Apple
Baby
Ball
Bear
Bubble
Bunny
Byebye
Eat
Fast
Drink
Go
Mac (i.e. mac n cheese)
Mama
Mickey
Milk

Moo
More
Off
On
Open
Piggy
Pizza
Plate
Please
Pony
Puppy
Stop
Up
Walk
Water

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