# TOWARDS TEXT-BASED AUGMENTATIVE COMMUNICATION IN INDIVIDUALS WITH INTELLECTUAL DISABILITIES AND DIFFICULT-TO-UNDERSTAND SPEECH

By

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# Abstract

Individuals who have difficult-to-understand speech and minimal reading skills are often limited to icon or picture-based augmentative and alternative communication (AAC) strategies. However, basic phonemic awareness skills could make strategies such as alphabet supplementation, in which the speaker selects the first letter of words they are speaking, a viable AAC option for increasing the extent to which the speaker's words are understandable to listeners (i.e., speech intelligibility). We conducted two studies with adults with severe intellectual disabilities, difficult-to-understand speech, and limited reading skills. The purpose of Study 1 was to teach participants to select the onset letter of a large number of spoken words. Six phonemes were targeted for instruction, and discrimination of onset phonemes was trained by pairing words with the same rime (e.g., mall/call) in a computerized matching-to-sample task. We also assessed if training the onset phoneme in isolation or with multiple word pairs would result in generalization to untrained spoken words beginning with the trained onset phonemes. Participants learned to select the onset letter of more than 60 words. However, consistently high accuracy in tests of generalization was not observed, even as an increasing number of exemplars were trained. In Study 2, our goal was to assess and then train the component skills to use an augmentative keyboard in a contrived communication task. After establishing picture naming responses to evoke speech and onset-letter selection with 30 new words, we assessed the effects of the alphabet supplementation strategy on participants' speech intelligibility. Results showed that listeners understood twice as many words when the augmentative keyboard was used to indicate the first letter of the words being spoken.

*Keywords:* intellectual disabilities, phonemic awareness, abstraction, alphabet supplementation, AAC, speech intelligibility

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The communication skills of most individuals with intellectual and developmental disabilities lag far behind those of their typically developing peers, as evidenced, for example, in vocabulary production and comprehension (Miller & Chapman 1984; Rosenberg & Abbedutto, 1993). These difficulties are compounded for individuals who, in addition to an intellectual disability, also have impairments that make their speech difficult to understand. Although the severity of speech impairments varies widely across individuals and disabilities (Beukelman & Mirenda, 2005, p. 242; Gerenser & Forman, 2007, p. 563), speech deficits are not uncommon among individuals with intellectual disabilities (Cheslock, Barton-Hulsey, Romski, & Sevick, 2008; Snell et al., 2010).

To improve communication and increase functional skills for individuals with intellectual disabilities, speech and language therapy may be recommended and augmentative and alternative communication systems may be used to supplement or provide an alternative to natural speech (Beukelman & Mirenda, 2005, p. 4; Cheslock et al., 2008; Mirenda & Mathy-Laikko, 1989; Rispoli, Franco, VanDerMeer, Lang, & Camargo, 2010). Augmentative communication systems may include voice-output devices, sign language, gestures, symbols, photographs, printed words and letters which increase the efficiency and efficacy of the speaker's communication with listeners (Beukelman & Mirenda).

To determine what augmentative communication strategies or devices to recommend, thorough assessments of barriers to communication may be conducted. These assessments often include evaluation of an individual's cognitive abilities and reading skills. Icon or picture-based systems are frequently recommended for individuals with intellectual disabilities because limited

reading skills preclude the use of systems that incorporate letters and words (Mirenda & Mathy-Laikko, 1989). However, systems using letters may be a viable alternative to icon-based systems for individuals with intellectual disabilities if requisite reading skills are established. Augmentative communication systems that use letters have been shown to increase speech intelligibility substantially (Hustad, Auker, Natale, & Carlson, 2003; Hustad, Jones, & Dailey, 2003), but published research has not yet explored if these systems would be viable for individuals with intellectual disabilities who also have difficult-to-understand speech.

The following review addresses three areas of research that bear on the possibility of individuals with intellectual disabilities using an augmentative communication system that requires reading skills. These areas are: (a) speech intelligibility and augmentative communication strategies, (b) reading instruction for individuals with intellectual disabilities, and (c) phonemic-abstraction instruction for individuals with intellectual disabilities and difficult-to-understand speech. For further elaboration on phonemic-abstraction skills and a review of research conducted with individuals with intellectual disabilities, see Appendix A.

**Speech Intelligibility and Augmentative Communication**

Speech intelligibility is defined as the extent to which an individual's speech is understandable to listeners (Kent, 1993; Kent, Weismer, Kent, & Rosenbeck, 1989; Yorkston, Strand, & Kennedy, 1996). It is defined functionally by measuring the effect of the speaker's spoken words on the listener. Intelligibility is dependent on many variables, including the context of the communication, the familiarity of the listener with the speech of the speaker, and the sound quality of the speech (Kent et al., 1989; Yorkston et al., 1996). In research and clinical environments, speech intelligibility is commonly measured objectively by first obtaining a sample of an individual's speech (e.g., single words, sentences), presenting the recorded sample

to a listener, and then dividing the number of words the listener correctly transcribes by the total number of words in the speech sample (see Beliveau, Hodge, & Hagler, 1995; Beukelman & Yorkston, 1977; Dowden, 1997; Hustad, 2001; Hustad & Beukelman, 2001). The resulting percentage may be used as a measure of speech-impairment severity (Yorkston et al., 1996).

Increasing speech intelligibility is often an important objective of speech intervention, because low intelligibility can be a significant barrier to effective communication (Beliveau et al., 1995; Kent, 1993; Kent et al., 1989). Although the majority of research that addresses improving intelligibility has focused on articulation and speech production therapies, researchers have also evaluated the efficacy of augmentative communication strategies, including gestures, alphabet supplementation, and topic supplementation (Hanson, Yorkston, & Beukelman, 2004). With these strategies, the speaker provides the listener with specific, supplemental contextual information. This information may be in the form of gestures related to what is being spoken, printed letters that indicate the first letter of the word being spoken (alphabet supplementation), or printed phrases or pictures that indicate the forthcoming topic of speech (topic supplementation).

In the alphabet supplementation strategy, the speaker selects the first letter of the word he is speaking on an augmentative device displaying letters of the alphabet. The listener hears the spoken word and also sees the letter cue. The added visual information increases the probability the listener will understand the speaker's speech (Beukelman & Yorkston, 1977; Hustad & Garcia, 2005; Hustad, Jones et al., 2003). To date, speech supplementation research has been conducted primarily with literate adults with motor speech impairments (e.g., dysarthria) whose speech has been affected by stroke, traumatic brain injury, Parkinson's disease, or other chronic

conditions. Within these populations, the alphabet supplementation strategy has repeatedly been shown to increase speech intelligibility more than any other single type of cue.

In a seminal study, Beukelman and Yorkston (1977) assessed the effects of alphabet supplementation on the speech intelligibility of two individuals who suffered traumatic brain injuries as adults. Their speech was less than 15% intelligible prior to intervention. Listeners transcribed 20 single words spoken by the participants and six sentences that were presented in three conditions: (a) speech without supplementation, (b) speech with the first letter of each spoken word selected on an alphabet board, and (c) speech with the first letter selected by the participant, but not visible to the listener. The final condition was conducted to separate the effects of the slowing of speech that often occurs when using alphabet supplementation from the letter cue itself. Speech intelligibility was defined as the percentage of correctly transcribed words. Results showed that when alphabet cues were visible, intelligibility rose substantially and was significantly higher than in the other experimental conditions for both participants.

Although additional published work in this area lagged almost 20 years behind Beukelman and Yorkston (1977), subsequent studies have shown similar effects of alphabet supplementation on intelligibility with individuals without intellectual disabilities. Hustad and Lee (2008) found that alphabet supplementation increased levels of intelligibility for each of 12 participants over that of speech without supplementation. In multiple studies that compared the effects of supplemental alphabet cues, topic cues, and combined cues (i.e., alphabet with topic cues), results have shown that alphabet cues were more effective than topic cues alone (Dowden, 1997; Hustad, Auker et al., 2003; Hustad & Beukelman, 2001; Hustad et al., 2003) and that they increased intelligibility significantly more than topic cues and combined cues (Hustad, 2005).

Despite the positive effects of alphabet supplementation on the speech intelligibility of literate individuals, no published research addresses the effects of this augmentative communication strategy on the speech intelligibility of individuals who have minimal reading skills. However, this group, which includes many individuals with intellectual disabilities, could be taught the necessary reading skills to make alphabet supplementation a viable augmentative strategy.

Although an individual's effective use of alphabet supplementation is greatly aided by established reading and spelling skills, individuals with minimal reading skills could also use this strategy if they were directly taught to select the first letter of a large number of spoken words. By teaching functional, frequently used words, the individual could supplement his speech when using these words in daily life. However, the usefulness of this approach would be limited to the number of words taught. The utility of alphabet supplementation could be greatly increased if the individual were able to recognize the first sound in the all words they were speaking and then select the appropriate letter on the communication device.

The skill of discriminating sounds (i.e., phonemes) within spoken words is known in the reading literature as phonemic awareness (Byrne & Fielding-Barnsley, 1990). We refer to it as phonemic abstraction because it involves abstraction as discussed by Skinner (1957, pp. 107-114) and later defined by Catania (1998, p. 378) as, "discrimination based on a single stimulus property, independent of other properties; thus, generalization among all stimuli with that property." An individual who had learned to abstract phonemes could conceivably select the first letter of almost any word without direct training. For example, having been taught to select the letter F on hearing "fell" and "family", the individual could also select F on hearing "fish" for the first time. For non-readers with low speech intelligibility, demonstration of phonemic

abstraction would open the possibility of using the research-validated strategy of alphabet supplementation to augment their speech.

**Reading Instruction for Individuals with Intellectual Disabilities**

As noted above, phonemic-abstraction skills are beneficial for individuals who use augmentative communication, such as alphabet supplementation, that incorporates letters and sounds. Phonemic abstraction is emphasized in reading instruction for typically developing individuals, due to its widely recognized importance to reading success (Adams, 1994). However, historically, most reading instruction for individuals with intellectual disabilities does not address these skills. These individuals often receive limited reading instruction and do not acquire phonemic-abstraction (Browder et al., 2009; Katims, 2001). Sight word approaches have dominated research and instruction for individuals with intellectual disabilities since the 1970s (for reviews see Conners, 1992; Browder & Lalli, 1991; Browder & Xin, 1998; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Saunders, 2007), with a focus directed toward training functional words for daily living (Katims, 2001). Research in phonemic-abstraction instruction for individuals with intellectual disabilities is lacking despite strong evidence of its importance as a reading skill for typically developing individuals (National Reading Panel [NRP], 2000) and increasing evidence that these skills are equally important to reading in individuals with intellectual disabilities (Saunders & DeFulio, 2007).

A small number of studies have provided some evidence that individuals with intellectual disabilities can be taught phonemic abstraction skills. These skills include segmenting individual phonemes in spoken words (e.g., hearing a word and then saying each individual sound in the word), blending phonemes (e.g., hearing individual sounds and then saying the whole word), and spelling novel words (e.g., hearing a word and selecting a letter for each phoneme within the

word). Demonstration of phonemic abstraction then requires that the trained skills are generalized to untrained stimuli. Throughout this manuscript, phonemes or groups of phonemes are represented as lower-case letters between backslashes (e.g., /s/) and printed letters are represented alone in the upper-case (e.g., S).

Segmenting phonemes is a phonemic-abstraction skill that is commonly taught to typically developing children (Ukrainetz, 2009). It requires the individual to separate units of sound in a spoken word. This is a difficult skill because the sounds in spoken words are not distinct from one another; rather, they are co-articulated in a stream of speech (Adams, 1994). Segmenting is important to reading and also to spelling which requires the individual to discriminate all the sounds in a spoken word in order to spell correctly. Two studies have evaluated procedures for teaching phoneme segmentation to individuals with intellectual disabilities. Hoogeveen, Birkhoff, Smeets, Lancioni, and Boelens (1989) taught 16 children to segment phonemes that occur at the end of words from the rest of the word. Words were spoken by the experimenter with a 1.5 sec pause between the first two phonemes and the final phoneme (e.g., /si/…/p/). Pauses were gradually decreased across training steps until the last step in which whole words were spoken without a pause. Participants were required to segment the word as it was presented by the instructor in the first step (i.e., with a significant pause between the phonemes). Although the participants could not segment spoken words prior to training, all showed high levels of accuracy after training. Eleven participants also responded with greater than 80% accuracy on a generalization probe which assessed segmenting with 30 untrained words; thus, demonstrating abstraction of phonemes in the final position in spoken words.

Kennedy and Flynn (2003) implemented a training program that targeted segmenting of onset phonemes (i.e., the first sound in a spoken word). Three children with Down syndrome

participated in multi-component instruction that included selecting a picture that began with a phoneme spoken by the instructor, identifying phonemes in spoken words using blocks, and tasks requiring letter selection and vocal responses. Following training, increased accuracy of onset-phoneme segmenting was observed in post-tests for all participants. However, post-test measures of generalization showed that none of the participants generalized the onset-segmenting skill to the more difficult skill of segmenting all the sounds in the words.

Blending might be described of as the opposite of segmenting. Blending tasks typically require the individual to say a word altogether after hearing the individual phonemes spoken separately. Blending skills are essential to reading because in order to "sound out" a word, the individual must say the sound that goes with each printed letter and then blend all those sounds together to make the whole word. Two studies evaluated procedures for teaching individuals with moderate intellectual disabilities to blend phonemes. Hoogeveen and Smeets (1988) taught seven children to blend phonemes and subsequently read words constructed with trained phonemes. Prior to an eight-step training program, participants had some established letter-to-sound correspondences (i.e., they could produce the correct sound when shown a printed letter), but were unable to blend individually presented sounds to make spoken words. Training steps taught increasingly difficult blending in auditory tasks. Initially, participants were taught to blend compound words (e.g., /rain/…/drop/), then syllables (e.g., /ti/…/ger/), word body and final phoneme of words (e.g., /ca/…/t/) and nonwords (e.g., /ku/…/g/, and finally, individual phonemes of words (e.g., /ee/…/r/) and nonwords (e.g., /n/…/i/). Picture prompts were included in the initial steps. The procedures shaped the blending skill by increasing the delay between phonemes in word presentation. Participants then learned to blend phonemes while reading written consonant-vowel (CV) and consonant-vowel-consonant (CVC) words aloud. A multiple-

probe design was used in which the words presented in each training step were tested prior to training and again following each training step. Training resulted in highly accurate responding on each blending skill for all participants. Results for some participants indicated generalization of prior training to some untrained steps. At the completion of training, all participants could read aloud and blend with high accuracy on all words used in the study. Generalization of the trained blending skills to untrained words was not assessed; therefore, we cannot determine if phonemic abstraction was established.

In a similar study, Hoogeveen, Kouwenhoven, and Smeets (1989) taught 16 of 20 children to blend phonemes in 30 spoken words. Participants were initially prompted to respond with an echoic following a spoken model of a CVC word. Then, increasingly longer delays were inserted between the initial phoneme and the rest of the word (e.g., /c/.../at/) and participants were instructed to say the sounds together. Results showed that the procedures were effective in teaching the participants to blend phonemes in the trained words. In tests of generalization with 30 untrained words, participants responded with 20-86% accuracy. The inclusion of these tests were important because they showed that some participants did not need direct training to blend sounds in new words. Participants with highly accurate responding had learned to discriminate sounds regardless of the word in which they were spoken; thus, demonstrating phonemic abstraction.

In many general education classrooms, reading skills including letter identification, phonics, and comprehension are taught together as part of comprehensive curricula. Phonemic abstraction instruction has been shown to facilitate phonics instruction and improve reading outcomes, and is now widely recognized as essential to comprehensive reading instruction (Adams, 1994; Snow, Burns, & Griffin, 1998). In two longitudinal studies, Allor, Mathes,

Roberts, Jones, and Champlin (2010) and Allor, Mathes, Roberts, Cheatham, and Champlin (2010) evaluated the effects of a multi-component reading program on phoneme blending and segmenting with 28 and 59 children, respectively, with mild to moderate intellectual disabilities. Participants were assigned to one of two groups: (a) a treatment group that received 40 minutes of daily small-group direct instruction targeting blending and segmenting of syllables and individual phonemes, along with reading comprehension and fluency or, (b) a control group that received a variety of reading instruction methods that were ongoing in their special education classrooms, but did not include explicit phonemic-abstraction training. In both studies, significant differences were observed between the treatment and control groups in phonemic abstraction skills. Participants in the treatment groups of both studies showed significant gains in blending nonwords and segmenting words and moderate to strong effect sizes were shown across all phonemic-abstraction measures. Despite the positive group differences, participants' individual data revealed the effects of the intervention on segmenting skills were highly variable across participants, with 12 of the 34 children in the treatment group showing no improvement in post-test measures (Allor, Mathes, Roberts, Cheatham, & Champlin, 2010).

Demonstration of phonemic abstraction can also be shown when an individual combines previously learned phonemes to make new words. This can be demonstrated with a vocal response (e.g., "Say rat with /m/ instead of /r/") or, as in Saunders, O'Donnell, Vaidya, and Williams (2003), with a selection response that can provide evidence of the skill. Saunders et al. evaluated the effects of spoken-to-printed-word training on the selection of 32 words, as well as on the selection of untrained words composed of trained word components (i.e., recombinative generalization) for two adults with mild mental retardation. In a computerized matching-to-sample (MTS) task, a spoken CVC word was presented and participants selected the

corresponding printed word from four closely related choices. Eight word sets were pretested and then trained individually using a matrix-training procedure. In each set, four words were directly taught (e.g., pat, mat, mop, mug) and recombinative generalization was assessed with two untrained words (e.g., pop, pug). Results showed that both participants achieved high accuracy on the selection of all trained words and consistently responded with high accuracy on generalization words. Although multiple skills (e.g., discrimination of printed letters, previously learned letter-sound correspondences) were required in this task, the recombinative generalization of the phonemes in the previously taught words was a strong demonstration of phonemic abstraction.

Spelling is interconnected with phonemic abstraction, letter-sound correspondences (i.e., the relation between phonemes presented in isolation and the letters that represent them), reading, and writing and it has been shown to be correlated with future reading skills in typically developing children (Weiser & Mathes, 2011). In order for an individual to spell novel words effectively, they must abstract phonemes in spoken words. Two studies have shown that individuals with intellectual disabilities can be taught to spell untrained words after learning to spell other words with common phonemes. Stewart, Hayashi, and Saunders (2010) and Stewart and Saunders (accepted pending revision) promoted recombinative generalization of onset phonemes (i.e., the first sound) and rimes (i.e., the rest of the word), and individual phonemes in a computerized spelling task. In both studies, adults with intellectual disabilities were taught to spell words by selecting letters on a computer screen upon hearing a spoken word. In the first phase of the studies, participants constructed words with two rimes (e.g., ad/eg) and two onsets (e.g., l, r). Tests for recombinative generalization then assessed if the participants could spell new words in which the rimes were paired with different onset phonemes. In the second phase of

the studies, vowel discrimination was promoted by training words that differed by the vowel sound only (e.g., gap, gep, gip). In Stewart et al., the participant made only vowel-related spelling errors in Phase 1, but reached high accuracy on all words following vowel discrimination training. The three participants in Stewart and Saunders recombined onset phonemes and rimes with high accuracy following training with multiple exemplars in Phase 1. All participants were highly accurate in recombining consonants and vowels in Phase 2, thus demonstrating phonemic abstraction.

The results from this small body of research, although promising, are somewhat limited in their generality due to the small number of individuals with intellectual disabilities for whom phonemic-abstraction instruction was shown to be effective. The extent to which generalization was assessed in many of these studies is an additional limitation of the research, as phonemic abstraction is demonstrated in tests of generalization. In multiple studies, generalization was not measured (Allor, Mathes, Roberts, Cheatham, et al., 2010; Allor, Mathes, Roberts, Jones, et al., 2010; Hoogeveen & Smeets, 1988), was not shown (Kennedy & Flynn, 2003), or the type of generalization (e.g., generalization to words with similar onsets or generalization of a global skill) was unclear because word lists were not provided (Hoogeveen, Birkoff et al., 1989; Hoogeveen, Kouwehoven, et al. 1989). Additional instructional-programming details such as word lists, composition of distracter words (when applicable), and exact testing procedures would aid in analysis of the data presented in these studies because they are relevant to establishing phonemic abstraction (see Saunders et al. 2003; Stewart, Hayashsi, & Saunders, 2010). Another limitation to the generality of the results of the aforementioned studies is the absence of detailed information about participants' previously established reading skills, IQ scores, and language skills. The difficulty in evaluating studies with incomplete or incomparable

descriptive participant data has recently been noted as a concern in research with individuals with intellectual and other disabilities (Snell et al., 2010). With respect to phonemic-abstraction instruction, more comprehensive participant descriptions might allow for a better understanding of the prerequisites necessary to acquire phonemic-abstraction skills. Further research that includes these components may provide stronger evidence of effective instruction methods of phonemic-abstraction skills for individuals with intellectual disabilities.

**Phonemic-Abstraction Skill Instruction for Individuals with Intellectual Disabilities and Difficult-to-Understand Speech**

Individuals with intellectual disabilities who receive phonemic-abstraction skill instruction are likely to encounter another barrier to learning those skills if they have speech impairments. The presentation of any phonemic abstraction task is necessarily auditory because phonemes are the sounds that comprise speech, and spoken responses are the typical way to demonstrate these skills. For example, the teacher instructs the student to say all the sounds in "fall" and the student replies, "/f/… /a/… /l/". The spoken responses of individuals with low speech intelligibility or severe speech impairment are often difficult for listeners to understand and in some cases such responses are not possible.

The difficulty of assessing and teaching phonemic abstraction with severely speech-impaired individuals has long been discussed in the speech-language literature (Blischack, 1994). Researchers have evaluated obstacles to assessing phonemic abstraction accurately (Vandervelden & Siegel, 1999; 2001), the creation of valid assessment measures (Iacono & Cupples, 2004), the development of instructional programs to teach phonemic-abstraction skills to young children with speech impairments (Hesketh, Dima, & Nelson, 2007; Laing & Espeland, 2005), and the importance of reading skill acquisition for effective augmentative communication

use (Foley, 1993). Improvement of reading instruction has also been identified as a priority by individuals with speech impairments who themselves use augmentative and alternative communication (O'Keefe, Kozak, Schuller, 2007).

In order to assess phonemic-abstraction skills, researchers have restructured tasks to eliminate the need for spoken responses (see Blishack, 1994, for extensive task modifications). Yes/no responses that can be made easily with sign language, gestures, or on an augmentative communication device can replace spoken responses (Vandervelden & Siegel 1999, 2001). For example, instead of asking the student to say the first sound in a spoken word (an example of onset-phoneme segmenting), the teacher might ask, "Does fall begin with /m/?" The child could nod "yes" or "no" in response. Tasks have also been adapted to allow speech-impaired individuals to select pictures that represent spoken words rather than saying the word. For example, an individual could demonstrate blending phonemes that are spoken separately by selecting the corresponding picture from an array or demonstrate phoneme segmenting by selecting the picture representing a word in which a targeted phoneme was spoken (Clendon, Gillon, & Yoder, 2005; Dahlgren Sandberg & Hjelmquist, 1996; Hesketh, Dima, Nelson, 2007; Iacono & Cupples, 2004; Smith, 2001; Vandervelden & Siegel, 1999, 2001). Other modifications that circumvent the need for a spoken response include selecting letters on an augmentative communication device upon hearing words or individual phonemes. However, to assess phonemic abstraction in this way, the individual must also have established letter-sound correspondences (Blischak, 1994). Modified assessments may require additional skills and care must be taken to ensure target skills are comparable to those in the typical assessment for the phonemic-awareness task (Vandervelden & Siegel, 1999). A notable difference between vocal and non-vocal assessments is the level of chance responding. When interpreting results from

non-vocal assessments, it is important to consider that chance responding is often 33-50%. This may affect instructional programming decisions such as the required mastery criterion for a skill.

Reading-instruction research with individuals with intellectual disabilities, who use augmentative or alternative communication, is scant and the evidence supporting the efficacy of the interventions is weak (Machalicek, Sanford, Lang, Rispoli, Molfenter, & Mbeseha, 2010). Within this population, only two studies have directly taught and measured the acquisition of phonemic-abstraction skills.

The effects of an instructional program on the segmenting skills of three children with neurological disorders (e.g., cerebral palsy), severely impaired speech, and developmental disabilities were evaluated by Millar, Light, and McNaughton (2004). Five consonant phonemes were targeted for instruction and three training tasks were conducted. All responses were made on an adaptive keyboard that produced the phonemes corresponding to the selected letters. In the first task, the teacher spoke a target phoneme and the child selected the corresponding letter. In the second task, the child was instructed to listen to a spoken word and select the corresponding first letter. In the final task, pictures were presented along with spoken words that began with trained onsets. The child was instructed to spell the corresponding word on the adaptive keyboard. The dependent measure was the percentage of correct selections of onset letters on the augmentative communication device following the presentation of a spoken word that began with a trained phoneme. Effects were evaluated in a multi-probe-across-participants design. Generalization was also measured for onset selection to untrained words represented by pictures, but for which the spoken word was not delivered by the instructor. Two participants learned to select trained onset letters with 80% accuracy, but only one demonstrated generalization to

untrained words in the task without spoken words. The third participant did not learn to select onset letters; therefore, his instruction was terminated and generalization was not assessed.

Truxler and O'Keefe (2007) evaluated the effects of phonemic-abstraction skill instruction on the segmenting skills of four children with cerebral palsy and developmental delays who used augmentative communication. Six letters and their corresponding phonemes were targeted for instruction. A segmenting task was conducted in which the teacher read a storybook, identified onset letters and phonemes as they occurred throughout the book, and then instructed the child to select either the letter or letter corresponding to the target phoneme on a QWERTY keyboard. Ten words that began with the target phoneme were then used to assess skill acquisition. The instructor presented and labeled three pictures, spoke a target onset phoneme or letter name, and then instructed the child to select the picture that began with the spoken target. At the completion of training for each targeted phoneme, comprehensive tests were delivered. These tests were conducted in the same manner as the onset-segmenting training task and included words that began with all six target phonemes. Two tests assessed generalization of onset-phoneme segmenting with two additional segmenting skills: (a) selection of pictures in which trained letters and phonemes occurred in the middle and last position in spoken words and, (b) selection of pictures in which untrained letters and phonemes occurred in the onset position of spoken words. Results showed that one participant reached the 80% accuracy criterion for all trained words in onset-phoneme segmenting task that was demonstrated by picture selection. These results should be interpreted with caution because control was not shown in the multiple baseline design due to limited effects for the remaining participants. Moreover, the only participant who met the criterion on the directly taught words showed low levels of generalization (67%) to the skill of selecting the correct picture with a trained letter or

phoneme in the middle and last positions of spoken words. However, this participant achieved 100% accuracy on generalization to onset segmenting with untrained letters and phonemes. The remaining three participants did not score above baseline levels on the generalization measures.

In sum, the literature addressing instruction in skills that demonstrate phonemic-abstraction with individuals with intellectual disabilities and speech impairments is extremely limited by the small number of studies that have been conducted, the weak demonstration of experimental control, and the failure to teach the skills necessary to produce phonemic abstraction. Evidence that individuals with intellectual disabilities and speech impairments can learn phonemic-abstraction skills and use them to augment their communication would extend the research literature in the areas of both reading and augmentative communication.

Our purpose in Study 1 was to teach adults with severe intellectual disabilities to select the onset letter of a large number of spoken words that began with six different phonemes. We first evaluated if training phoneme-letter relations would affect onset-letter selection with spoken words. If improved accuracy was not observed, we directly trained onset-letter selection with 60 spoken words. We also evaluated if our procedures would result in generalization of onset-letter selection to untrained words with the trained onsets (i.e., phonemic abstraction). In Study 2, our goal was to assess the effects of alphabet supplementation on participants' speech intelligibility. To that end, we taught the skills needed for the participants to use an augmentative keyboard in a contrived communication task. Participants' speech intelligibility was then assessed with and without the keyboard by unfamiliar listeners.

## General Method

**Participants**

We recruited six men with intellectual disabilities who were identified by their work supervisors as having difficult-to-understand speech. Of those six individuals, three met our initial inclusion criteria of: (a) mean score of less than 45% on a measure of speech intelligibility (see appendix B), (b) hearing within normal range, (c) 90% accuracy or greater on a receptive letter identification task, and (d) 90% accuracy or greater in a computerized, 30-trial, four-choice, spoken-word-to-picture MTS session.

Additional descriptive characteristics were gathered for our participants Mark, Jimmy, and Aaron, who met the inclusion criteria (see Table 1). Subtests of the Woodcock Reading Mastery Test – Revised (Woodcock, 1987) were delivered to measure basic reading skills. The Woodcock Word Attack subtest presents increasingly difficult nonwords. Neither Mark, nor Jimmy, both of whom had Peabody Picture Vocabulary Test-4 ([PPVT-4] Dunn & Dunn, 2007) standard scores of 20, read any nonwords correctly. In the Woodcock Word Identification subtest, which presents increasingly difficult sight words, Mark read one word and Jimmy read five words correctly. Aaron, who had a PPVT-4 standard score of 43, read four words in the Word Attack subtest and 29 words in the Word Identification subtest (grade level equivalents of 1.2 and 1.7, respectively). In a test designed by the experimenter, phoneme-letter correspondence was assessed in a four-choice MTS task with the six phoneme-letter relations that were used throughout Study 1. Mark, Jimmy, and Aaron selected the letter that corresponded to the phoneme spoken by the experimenter in 50%, 17%, and 100% of opportunities, respectively.

**Setting**

Sessions were conducted in the participants' sheltered workshop, Monday through Friday, in a private room containing a table and chairs. One to five consecutive sessions, ranging from 2.4 to 5.1 min duration, were conducted daily dependent upon participant availability and instructional programming requirements.

Because participants left their work in order to participate in these studies, we compensated income loss by paying $1.00 for daily assent and $.05 for each correct response. However, participants were unaware of these contingencies and no money was presented during sessions. Because money could not be paid directly to participants due to Social Security earning restrictions, it was held in an account by the experimenter. Participants were taken on monthly shopping trips to local businesses where they purchased items of their choosing up to the dollar amount they had accrued. To reinforce assent, participants received one or two of these items approximately once per week.

**Apparatus and Stimuli**

Participants made selection responses on an iBook laptop computer fitted with an add-on, touch-sensitive screen. MTS software (Dube, 1991) controlled all aspects of sessions and automatically recorded participant responses. A response was defined as touching a letter or picture presented on the computer screen. Words and isolated phonemes comprised the auditory stimuli that were prerecorded in the experimenter's voice (standard Midwestern-English female) and presented through the computer speakers. Visual stimuli were 3 cm black capital letters in Arial font that were presented on the computer screen in touch-sensitive zones.

**General Procedure**

The predominant MTS procedures used in the study are described here with variations (e.g., number of comparison stimuli, specific sample and comparison stimuli) described in subsequent procedures when relevant.

Sessions consisted of 30 trials and all stimuli were presented via the computer. On each trial, a spoken word was repeated every 1.5 s as the auditory sample stimulus and a 2.5 cm by 2.5 cm black square was presented in the center of the screen (see Figure 1). Following an orienting response of touching the black square, the square disappeared and capital letter comparison stimuli appeared on the screen. Selection of the correct letter produced 1.5 s of chimes and a display of colored stars on the computer screen. Selection of an incorrect letter produced a .5 s buzz with a 1.5 s black screen. Screen touches in areas without letters had no effect and the trial continued until a letter was selected. Following each trial, a white screen was presented during a 1.5 s inter-trial interval (ITI). Responses on the touch screen during the ITI reset the interval in an effort to ensure that responses during the ITI were not adventitiously reinforced by the presentation of the next trial. The experimenter delivered praise for effort from two to four times per session.

Feedback of chimes, stars, or a buzzer was delivered in training sessions and also in the comprehensive tests in which any test stimulus (i.e., word or phoneme) was presented on two or fewer trials. In tests in which the test stimuli were presented more than twice, there was a greater chance of learning occurring within the test itself; thus, feedback was not delivered.

The position of the visual comparison stimuli varied quasirandomly across the four corners of the computer screen and the number of presentations in each position were approximately equal in each session. A given spoken word was presented as the sample on no

more than three consecutive trials and a given letter was presented in the same position as the correct comparison on no more than three consecutive trials.

## Study 1: Onset-Letter-Selection Training

**Method**

**Participants.** Mark and Jimmy participated in all training and testing procedures in Study 1. Aaron scored at mastery level in the baseline comprehensive test and therefore did not participate in the onset-phoneme-abstraction training. However, in order to be included in Study 2, Aaron required training in a six-choice task. Those procedures and results will be described in later sections.

**Word sets.** Sixty words were used to train onset-letter selection following the presentation of a spoken word (see Table 2). Sheltered workshop staff, who worked directly with the participants, identified words from a 744-word vocabulary list (Yorkston, Dowden, Honsinger, Marriner, & Smith, 1988) that they considered to be functional for the participants. From the staff's lists, we selected words that were single syllable, began with frequently occurring letters in the English language, and from which pairs of words with the same rime (i.e., the remainder of the word following the onset letter) could be formed (e.g., mall, call). Although we attempted to maximize the number of real words used, our method of promoting abstraction via exemplar pairs necessitated the inclusion of eight nonwords.

The letters M, C, T, S, P, and L comprised the onsets of the 60 words. We formed onset-letter pairs of M and C, T and S, and P and L. In each set, the two onset letters were combined with 10 rimes, resulting in 20 words per set. In training and testing, the onset letters were presented exclusively in the pairs as comparison stimuli. That is, M was only presented with C, T was only presented with S, and P was only presented with L.

**Pretraining.** To familiarize participants with the computerized MTS procedures and to ensure they were able to make auditory and visual discriminations relevant to the study, four-choice MTS sessions were conducted with differential feedback. In two identity matching sessions, participants matched either pictures or individual capital letters. In one spoken-word-to-picture session, common objects (e.g., scissors, train, baby) were presented as comparison stimuli and their labels were presented as auditory samples. Each of 15 pictures served as the correct comparison and incorrect comparison on multiple trials, conditional upon the sample. All participants met a 90% mastery criterion after three sessions each of identity and spoken-word-to-picture MTS sessions.

**Experimental design and sequence.** A multiple-probe-across-onset-letter-pairs design (cf. Horner & Baer, 1978) was used to assess the effects of MTS training on the accuracy of onset-letter selection. This design also allowed for the assessment of maintenance of onset selection after training, as the sets were repeatedly tested over the course of the study.

Figure 2 shows the overall training and testing sequence of Study 1. Comprehensive tests of the 60 study words were delivered prior to any training and again following training for phoneme-letter relations. After a participant reached mastery level responding with phoneme-letter relations, the comprehensive test was delivered again to determine if the training resulted in onset-phoneme abstraction with the 60 untrained study words. If participants did not select the correct onset letter for 90% of the study words in the comprehensive test, training and testing for the first of the three word sets was initiated. Comprehensive tests and training for the second and third word sets were delivered upon mastery level responding in each prior set.

*Comprehensive test.* The 60 study words were presented in the comprehensive tests of onset-phoneme abstraction. In the baseline comprehensive test, each word was presented twice.

In all subsequent comprehensive test presentations (i.e., following the training of isolated phonemes and each word set), each word was presented once.

Due to the large number of presumably unknown exemplars in the comprehensive tests, we made two programming decisions meant to increase the likelihood that the onset selection skill would be demonstrated during the comprehensive test if it was in the participants' repertoires. First, we programmed feedback for all trials. As Sidman (1981) points out, demonstrating low accuracy in tests with feedback provides evidence that low accuracy cannot be attributed to absence of feedback, thus strengthening the argument that the skills were not in the participants' repertoires prior to the study.

The second programming decision designed to maintain responding in comprehensive tests was to intermix spoken-word-to-picture trials (described in the pretraining section) with the study-word test trials. In each 30-trial session of the comprehensive test, five words from each of the three word sets were presented once as the auditory sample and were distributed in a quasirandom order across the session. Spoken-word-to-picture trials comprised the remaining 15 trials in each session. Because these trials had high probability of evoking correct responses, they increased the overall rate of reinforcement in the test and reduced the probability that responding would deteriorate during the session.

*Phoneme-to-letter training.* Training was delivered for phoneme-letter relations for all of the onsets targeted to promote abstraction (/m/, /c/, /t/, /s/, /p/, /l/). Rather than presenting a whole word as the auditory sample, each phoneme was presented in isolation (i.e., without a rime) in a two-choice task. For example, /*m*/ was presented as the auditory sample and the participant selected from the visual comparisons M and C. A correct response was defined as selection of the letter that corresponded to the isolated phoneme. To assess if phoneme-to-letter

training resulted in increased accuracy of onset-letter selection with whole words, comprehensive tests were repeated once all three pairs of onset phonemes had been taught.

*Spoken-word-to-onset-letter training*. The order in which the three word sets were trained was determined for each participant by his accuracy on words in each word set in the first comprehensive test. The set in which the participant selected onset letters most accurately was trained first, and the set in which they scored least accurately was trained last. Similarly, the 10 word pairs within each set were trained in order of highest-to-lowest accuracy based on comprehensive test scores. These procedures allowed for the maximization of generalization opportunities. By reserving a participant's least accurate word pairs as the last to be trained in a set, we were able to assess if training other words in that set resulted in generalization to untrained (and previously inaccurate) words.

Figure 3 shows the training and testing sequence within word sets. Three types of training sessions were delivered. All sessions consisted of 30 trials and differential feedback was delivered in Type 1 and Type 2 sessions. Trials were reordered in any session that was repeated more than once.

In Type 1 training sessions, one spoken word (e.g., mall) from a pair (e.g., mall/call) was presented with a visual prompt of the correct onset-letter comparison (e.g., M) in the center of the screen instead of the usual black square to which an observing response was made. Following a touch to this letter, the two onset-letter comparisons (e.g., M and C) appeared on the screen and the visual prompt remained throughout the trial in order to increase the probability of accurate letter selection. Trials with a visual prompt continued until the participant made two consecutive selections of the onset letter that corresponded to the onset phoneme of the spoken-word sample. If two correct selections were made, the session branched to a block of trials in which the same

spoken word (e.g., mall) was the sample, but the visual model was replaced by the black square. In this block, the participant was required to meet a criterion of five consecutive selections of the correct letter. If this criterion was met, the session branched to train the second word in the pair (e.g., call) using the same procedural sequence (i.e., trial block with visual prompt, then trial block without visual prompt). If the criterion was not met in the blocked trials with either the first or second word in the pair, a Type 1 session was redelivered, starting again with the first word and a visual prompt. If the criteria were met for both words in blocked trials, the session branched again and the two spoken words (e.g., mall/call) alternated quasirandomly as the sample for all remaining trials. Type 1 sessions were repeated until the participant completed a session in which the final block of the session (i.e., alternating word samples) was at least 12 trials in length and in which one or fewer errors were made per word.

A Type 2 training session was delivered after meeting the final criterion in a Type 1 session. In Type 2 sessions, the two words in the training pair alternated quasirandomly as the spoken sample throughout the 30-trial session. If the participant made more than one error per word in a Type 2 session, the session was repeated. If they made more than four errors on either word, they moved back to a Type 1 session.

A Type 3 training session was conducted the day following a Type 2 session in which the participant met a criterion of one or fewer errors per word. In Type 3 sessions, both words again alternated as the sample on an equal number of trials, but feedback was not delivered. These sessions prepared the participant for the absence of feedback in the upcoming generalization tests and maintenance sessions. Participants were told that they would not see any stars during the session, but that they should, "keep going and do their best."

*Maintenance sessions.* In order to assess participants' retention of trained spoken-word-to-onset-letter relations throughout the study, maintenance sessions were delivered following the training of the first three word pairs in each word set and after training every subsequent pair. Maintenance sessions included all trained words in the set and thereby provided an opportunity for the participant to practice selecting same onset letters for words with different rimes in a single session. As additional word pairs were mastered and included in the tests, session length varied to keep the number of presentations of each word approximately equal. Thus, tests consisted of 30 to 40 trials each and were delivered across two sessions, dependent upon the number of words being tested.

Maintenance sessions were delivered first with feedback and then without feedback on the following day. If more than one error was made on any word in either a feedback or no-feedback session, both words in the pair were retrained to criterion and the maintenance session was redelivered. When the accuracy criterion for all words was reached in a maintenance session, a generalization test for the next untrained word pair was given, followed by the training sequence described previously in the spoken-word-to-onset-letter training procedures.

*Generalization tests.* Following the training of each word pair and high accuracy in maintenance sessions, a generalization test was conducted to assess the accuracy of onset-letter selection with the next untrained word pair in the set. The most recently trained pair of words comprised 20 trials and the words in the untrained pair comprised 10 trials. Feedback was not delivered. The mastery criterion was 80% accuracy or greater for each untrained word (i.e., one error per word).

If the criterion was met with the new word pair, a minimum of three Type 2 training sessions were delivered. This provided an opportunity for the participant to practice onset

selection with the new word pair with feedback in an effort to promote maintenance of the response. When a 90% accuracy criterion on each word was met in these practice sessions, maintenance sessions were conducted. If the 80% criterion was not met in the generalization test, the complete training sequence (i.e., Type 1, 2, and 3 training sessions) was delivered for the new word pair.

For the purpose of this study, onset-phoneme abstraction was defined as meeting the 80% accuracy criterion across at least the last three consecutive generalization tests (i.e., three untrained word pairs) in word set. If a participant did not meet this criterion, we continued to test for generalization and train onset selection with additional word pairs in order to promote onset-phoneme abstraction. Training of a word set was considered complete when a participant either met the 80% accuracy criterion with three consecutive, additional word pairs or when nine additional pairs had been tested and trained. The comprehensive test was then redelivered and training for the next word set was begun.

***Tests for sample-S+ control.*** As described previously, onset letters were always presented in their pair (i.e., M with C, T with S, P with L) as comparison stimuli in a two-choice task. To ensure that high accuracy was not dependent on these specific letter pairings, we assessed stimulus control under additional conditions. Following training and testing of the second word set and again following completion of the third word set, all possible pairings of the trained onset letters were made and the accuracy of onset-letter selection with a subset of words from each set was measured. New letter pairings comprised 10 trials and original pairings comprised 20 trials. Tests were conducted without feedback. Table 3 shows an example of new onset letter pair comparisons after two word sets were trained.

To prepare participants for the augmentative communication task that was evaluated in Study 2, we assessed, and trained if necessary, onset-letter selection with a greater number of comparison stimuli. This test was delivered upon completion of training for all three word sets in Study 1in order to assess letter selection in a six-choice task. In this test, all six trained letters (M, C, T, S, P, L) were simultaneously presented on the computer screen as comparison stimuli and each of the 60 trained words was presented once as the auditory sample. Letter comparisons were positioned in a quasirandom order across eight positions around the edge of the computer screen and feedback was delivered. Participants who did not meet a 90% accuracy criterion in this test received training specific to their individual error patterns using the MTS procedures described previously. The six-choice test was then redelivered. Training and testing was continued until the mastery criterion was met.

**Results**

**Comprehensive tests.** Figure 4 shows the comprehensive test results for Mark and Jimmy. Results are separated by word set and panels are arranged in the order in which the sets were trained with each participant. In the baseline comprehensive test, neither participant met the mastery criterion of 90% accuracy for any of the three word sets. Mark selected the onset letter upon hearing spoken words in the T/S word set with 83% accuracy, followed by the M/C set with 58% accuracy, and the P/L set with 55% accuracy. Jimmy selected the correct onset with 75% accuracy in the M/C set, 70% accuracy in the T/S set, and 63% accuracy in the P/L set.

The first phase change line indicates the completion of phoneme-to-letter training (i.e., training with isolated phonemes). Mark and Jimmy completed this training in 11 and 14 sessions, respectively. In the comprehensive test following this training, neither participant showed an increase in onset-letter selection when spoken words were the sample. These data indicate that

for Mark and Jimmy, learning the phoneme-letter correspondences for the six onset phonemes was not sufficient for establishing onset-letter selection with spoken words with the same onsets.

The second phase change line indicates the completion of spoken-word-to-onset-letter training for individual word sets. For both Mark and Jimmy, accuracy of onset-letter selection in each word set increased markedly above baseline levels when and only when training was completed for that set. Following training, Mark demonstrated accuracies of 90% in the T/S and M/C word sets, and 100% in the P/L word set. Mark maintained high accuracies of 95% or more in each trained word set in all subsequent comprehensive tests. Jimmy demonstrated accuracies of 100%, 90%, and 100% in the M/C, T/S, and P/L word sets, respectively. Jimmy demonstrated accuracies of 95% or more in successive comprehensive tests, providing evidence of the maintenance of onset-letter selection in trained word sets.

Further evidence of maintenance of trained relations was evident in the maintenance sessions that were delivered repeatedly during word set training (data not shown). In these sessions, which were delivered after each new word pair was trained and included all trained words within a given set, both Mark and Jimmy consistently responded with 85-100% accuracy.

**Generalization tests.** Figure 5 shows the results of the generalization tests delivered in each word set. These tests determined whether training participants to select the onset letters for multiple word pairs with the same two onset phonemes (e.g., mall/call, more/core) resulted in generalization of onset-letter selection to other word pairs with the same onsets (e.g., map/cap, mold/cold).

In all sets, both participants maintained 80% or greater accuracy on the trained words that served as a foundation for testing the untrained word pairs (represented by filled circles). Mark's accuracy of onset-letter selection with untrained words in generalization tests in his first word set

(T/S) was at least 80% for all but one word pair. Because Mark demonstrated at least 90% accuracy in the last three untrained pairs, he met the onset-phoneme abstraction criterion for this word set. In his second set (M/C), Mark's accuracy was at least 80% on six of the generalization tests with word pairs from the original word set (i.e., the pretested word pairs, represented by striped bars). However, because he did not show generalization in the last two word pairs of this set, we continued to deliver generalization tests with additional word pairs (represented by light grey bars). Because Mark met the 80% accuracy criterion in the next three tests, his training in the M/C set was complete. In his final word set (P/L), Mark's accuracy was at least 80% with five untrained word pairs from the original word set, again requiring testing and training with additional word pairs. After scoring at chance levels in four additional generalization tests, we began to deliver these tests first with feedback (represented by black bars) and then without feedback. Under these conditions, Mark met criterion with four of five new word pairs. However, he did not demonstrate 80% accuracy in three consecutive generalization tests and training in the P/L word set was terminated when nine additional word pairs were trained.

In generalization tests with the original word pairs in each set, Jimmy demonstrated at least 80% accuracy in five tests in the M/C set, four tests in the T/S set, and four tests in the P/L set. Because the onset-phoneme abstraction criterion was not met with the original word pairs in any set, we delivered generalization tests with more word pairs. Jimmy required three additional generalization tests in the M/C set and seven additional tests in the T/S set before he reached 80% accuracy on three consecutive generalization tests. Jimmy did not meet this criterion in the P/L set, and training was stopped when nine additional word pairs were trained.

**Tests for sample-S+ control.** Following the training of the first two word sets, we conducted tests to determine whether letter selection was dependent upon the specific letters

used in training. Mark and Jimmy selected the correct onset letters with 100% and 98% accuracy, respectively, when onset letter comparisons were mixed. When all three word sets (60 words) had been trained and all possible combinations of onset-letter pairings were made with a subset of words, both Mark and Jimmy selected the correct onset letters with 97% accuracy.

**Six-choice MTS tests.** Mark, Jimmy, and Aaron (who had not participated in training due to high baseline test scores) were given the tests in which all six onset letters were presented as comparisons in the spoken-word-to-onset-letter MTS task. Although Mark met the overall mastery criterion of 90% in this test, he responded with only 40% accuracy on words beginning with L. On trials in which erred, Mark selected M instead of L. These letters were not paired in training and this error pattern did not occur when L and M words were presented in the tests with mixed comparisons (described above). Mark received training in a two-choice MTS task in which study words beginning with M and L were paired. As a result of this remedial training, Mark met the mastery criterion in the six-choice test.

In the six-choice test, Jimmy selected the correct onset letter with 90% accuracy. Because Jimmy's errors were spread across five of the six onset letters targeted in the study, we did not deliver remedial training.

Aaron's accuracy in the six-choice test was 82%. Error analysis showed that Aaron primarily made errors on words with the onset letters P, M, and S. When he made errors on spoken-word samples beginning with /p/ he selected M and when he made errors on /m/ words he selected P. Aaron primarily selected C when he made errors on spoken-word samples beginning with S. Based on these results, Aaron received training sessions in which P and M words and S and C words were presented in a two-choice MTS task. Following this remediation, the six-choice test was presented again and Aaron achieved 93% accuracy.

**Discussion**

In reading instruction for typically developing individuals, it is strongly recommended that phonemic abstraction skills are taught with letters. In addition, research has shown that phonics instruction, which focuses on phoneme-letter relations, is more effective when taught with phonemic abstraction (NRP, 2000). Based on these findings, we provided phoneme-to-letter training for our six target phonemes (/m/, /c/, /t/, /s/, /p/, and /l/) prior to spoken-word-to-onset-letter training (i.e., the phonemic abstraction skill). This training was also delivered because it would be unlikely for an individual to select the onset letter that corresponded to the first phoneme in a spoken word without previously established phoneme-letter relations. Prior to any training, Mark and Jimmy selected the letters corresponding to the six target phonemes presented in isolation (i.e., not in a spoken word) with low accuracy. During phoneme-to-letter training, both participants made very few errors and completed training in close to the minimum number of sessions possible. There was, however, no evidence that phoneme-to-letter training affected onset-letter selection with spoken words in the comprehensive tests that immediately followed. These results are consistent with Byrne and Fielding-Barnsley's (1989) assertion that it is possible to know the sounds that correspond to letters without knowing that those sounds are parts of words. Mark and Jimmy's comprehensive test results indicate that demonstration of phoneme-letter relations was not sufficient for the abstraction of phonemes in spoken words.

Therefore, our first goal in this study was to teach our participants to select the onset letters for a large number of spoken words to promote abstraction of onset phonemes. Mark and Jimmy's comprehensive test results across three word sets clearly show that our procedures were responsible for the large increases in accuracy of onset-letter selection following the presentation

of spoken words. Both participants learned to select the onset of the 60 original study words and maintained high accuracy over successive tests throughout the duration of the study.

Although our procedures were effective in teaching Mark and Jimmy to select the onset letters of directly trained spoken words, neither participant showed strong evidence of generalization following the training of multiple word pairs across word sets. In only one case (Mark's T/S set) was the onset-phoneme abstraction criterion met with the original word pairs in a set. Because the promotion of abstraction was a goal of this study, when the phonemic abstraction criterion was not reached with the original word pairs, we continued to test and train new pairs. However, because baseline data were not collected for these additional words, it is not possible to conclude with certainty that accurate scores in the additional generalization tests showed generalization rather than preexisting skills. Thus, we cannot draw firm conclusions regarding the achievement of onset-phoneme abstraction.

The tests for sample-S+ control were conducted because training in a two-choice task may produce high overall accuracy that is an artifact of training rather than evidence of the actual controlling relations (Sidman, 1987). In the current study, for example, it would be possible for a participant to learn that when /s/ is the onset phoneme in a spoken word sample, select S and when /s/ is not the sample, select T. In the two-choice task with this onset pair, 100% accuracy could be achieved by knowing just one relation (/s/=S). If this were the case, when new onset-letter pairings were made, we would expect to see errors in spoken words beginning with /t/ because S was not available as a comparison. That is, the participant could not respond "away from" the known comparison. Mark and Jimmy were highly accurate in the tests in which onset-letter comparisons were presented in new pairs. These data indicate that the participants had

learned the relation between the onset phonemes in all spoken-word samples and the correct

comparisons, and that there were not unintended sources of stimulus control.

The test of the 60 study words in a six-choice task was conducted to determine if

participants would select the correct onset letter when presented with a larger comparison array.

In this test, Mark and Aaron made errors that were specific to particular onsets and words. It is

unclear why Mark made these errors when his responding had been highly accurate in the tests in

which each letter comparison was paired with every other letter. The source of Aaron's errors

was also unclear. Because Aaron had not received spoken-word-to-onset-letter training, the

errors could not be attributed to training artifacts. The primary importance of these results was

that additional training was required for Mark and Aaron to become highly accurate in onset-

letter selection in a six-choice task, such as that which would be presented in Study 2.

## Study 2: Speech with Alphabet Supplementation

The onset-letter selection skill established in Study 1 is one of multiple skills necessary to

augment speech using alphabet supplementation. In Study 2, we sought to establish the

remaining component skills for this augmentative communication strategy with our participants,

such that they could demonstrate the use of an alphabet supplementation board in a contrived

communication task. The purpose of Study 2 was then to measure the effects of alphabet

supplementation on participants' speech intelligibility (i.e., the percentage of spoken words

correctly transcribed by listeners).

**Method**

**Participants.** Two categories of participants were involved in Study 2. Our primary

participants were those with whom we assessed the effects of alphabet supplementation on

speech intelligibility. These participants had achieved either an accuracy of 90% or greater in

either (a) the final comprehensive test (Mark and Jimmy), or in (b) the baseline comprehensive test of Study 1 (Aaron), and also (c) met criterion in the tests for sample-S+ control that were delivered at the end of Study 1.

Five additional adults participated as listeners in the speech intelligibility assessment. The listeners were native English language speakers who, based on self-report, had no hearing difficulties or learning disabilities. All listeners were unfamiliar with our participants with intellectual disabilities (Mark, Jimmy, and Aaron) and had only incidental experience communicating with individuals with speech impairments.

**Apparatus and materials.** A lap-top computer with touch-sensitive screen, identical to that described in Study 1, was used for all computer-based tasks. In picture-naming tasks, 7.6 cm x 12.7 cm printed color pictures were used to represent Study 2 words.

A keyboard modified to show only the six capital letters targeted in the current studies served as an augmentative communication device (i.e., alphabet supplementation board). The keyboard was fitted with a metal key guard key guard to prevent accidental selection of more than one key at a time.

Participants' vocal and letter-selection responses were recorded with a JVC GZ-MG130U camcorder in the session room described previously in which background noise was negligible. Videos were transferred to a PC computer via USB and presented to listeners on a 76 cm LCD computer monitor using Apple QuickTime player and stereo speakers. Audio levels were equivalent to conversational speech (approximately 60 dB SPL).

**Scoring and interobserver agreement.** This section describes IOA for the experimenters' scoring of participants' vocal responses and letter selection responses.

Intelligibility scoring conducted by the participants serving as listeners will be described separately.

In sessions that required vocal responses, observers who were familiar with the participants' speech used printed data sheets that listed test words in the order in which they were presented. A vocal response was scored as correct if it closely approximated the test word as it was consistently spoken by a participant. In sessions involving the augmentative keyboard, observers recorded selection responses as correct if the participant depressed the letter that corresponded to the onset phoneme of the pictured word.

A second familiar observer independently recorded the accuracy of vocal and selection responses in 100% of test sessions and in 20% of training sessions that required either or both of those responses. Records were compared on a trial-by-trial basis and were scored in agreement if both observers recorded a correct or incorrect response on the same trial. Agreement was calculated for vocal and selection responses separately. The percentage of agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements, and multiplying by 100. Mean agreement across the three participants was 99% (range, 97% to 100%) for both responses across training and testing sessions.

**Word sets.** The six letters (M, C, T, S, P, L) and their corresponding phonemes (/m/, /c/, /t/, /s/, /p/, /l/) from Study 1 were targeted again in Study 2. Common words with those onsets, that could also be easily pictured, comprised the word sets (see Table 4). Five words were selected for each onset, resulting in a total of 30 words. In an effort to include words that had a high probability of being familiar to the participants and also functional in their daily lives, some multi-syllable words were selected (e.g., medicine).

**Procedure.** To evaluate the effects of alphabet supplementation on our participants'

speech intelligibility, we first needed to ensure that participants reliably performed the terminal

task of speech with alphabet supplementation, using an augmentative keyboard. To maximize the

probability of success on this task, we tested the component skills for alphabet supplementation,

and we trained skills that were not evident in the tests. The sequence of steps is shown in Figure

6. First, we tested and then established consistently accurate picture naming with the Study 2

words (Step 1). Next, we pretested the terminal task (Step 2).  We then assessed and trained, if

necessary, onset-letter selection with the Study 2 spoken words (Step 3). In Step 4, participants

were exposed to a task that was analogous to the terminal task but that could be demonstrated in

computerized MTS sessions just like those used throughout Study 1. This task allowed the

participants to practice naming the pictures and selecting the onset-letter that corresponded to the

onset phoneme of the word they spoke (prior to this, they had only selected onsets when they

*heard* a spoken word). Finally, we conducted a posttest of the terminal task (Step 5).

Participants' speech intelligibility was assessed by unfamiliar listeners following Step 5. For

expository purposes, we will describe each step's procedures and results together.

        *Step 1: Pretest, training, and posttest - Picture naming.* To ensure that participants could

name the 30 pictures prior to conducting pretests for the terminal skill (i.e., speech with alphabet

supplementation) we assessed picture-naming accuracy, trained words on which the participant

erred in the pretest, and then delivered a posttest.

        *Procedure.* A pretest was conducted in which 30 pictures that represented each of the 30

study words were presented in a table-top task. The experimenter presented each picture once as

a discriminative stimulus and asked the participant, "What is it?" An accurate response was

defined as the correct picture name as it would be pronounced phonetically or as it was

consistently spoken by the participant (e.g., if a participant consistently replaced /l/ with /y/ when saying words beginning with L, then responses in which that replacement was made were scored as correct). A response was scored as incorrect if it (a) did not approximate the participant's usual response (e.g., when shown a picture of laundry the participant responded "yaun" but their usual response was "yaundry", (b) was not the name being used in the study (e.g., responding "clothes" when shown the picture of laundry) or, (c) if no response was given within 5 s of the presentation of the picture.

For pictures that were named inaccurately in the pretest, names were taught in a table-top task, using the same presentation procedures as in the pretest. Praise was delivered following an accurate vocal response and the experimenter delivered a spoken-word model following an incorrect response or if the participant did not respond within 5 s. The picture and question, "What is it?" were then presented again until the participant either responded correctly or until the trial had been presented three times. A new picture was then presented and the sequence was repeated. In each session, accuracy of the spoken response was recorded for the first presentation of each picture. Picture order was randomized each day.

A posttest identical to the pretest was conducted when the participant responded with 100% accuracy on all 30 study words in two consecutive training sessions.

*Results.* Aaron, Mark, and Jimmy named 87%, 79%, and 73% of the pictures correctly in the pretest, respectively. All participants completed training within 25 sessions and scored 100% in the picture-naming posttest.

***Step 2: Pretest - Speech with alphabet supplementation.*** A pretest of the terminal task of speech with alphabet supplementation was conducted to determine if training additional component skills was necessary.

*Procedure.* The 30 pictures used in Step 1 were presented to evoke a vocal response. The participant was seated at a table and the keyboard fitted with a key guard was positioned in front of them. Gesturing to the keyboard, the experimenter delivered the instructions, "I am going to show you a picture. I want you to tell me what it is and touch the letter for the first sound in the word." The experimenter then presented each picture once for 5 s, in a random order, and asked, "What is it?" If no response was made, the next trial was initiated. If the participant named the picture within 5s, the experimenter waited an additional 5 s before initiating the next trial to provide an opportunity for the participant to select a letter on the keyboard. No feedback related to performance was delivered, but the experimenter delivered praise for effort approximately every five trials. Accuracy of the picture naming response and the letter selection response were recorded separately.

*Results.* Aaron accurately named the 30 pictures and selected the corresponding onset letter on the augmentative keyboard for 27 words. Aaron received one training session (described in Step 5) to meet the 100% mastery criterion in this task. His speech intelligibility was then assessed with and without the augmentative keyboard.

Mark named 29 pictures correctly in the alphabet-supplementation pretest, but did not make any letter selections on the augmentative keyboard.

Jimmy named 29 pictures correctly in the pretest. Although Jimmy selected a letter on the augmentative keyboard in 24 trials, his accuracy was close to chance levels (23%)

***Step 3: Pretest, training, and posttest - Spoken-word-to-onset-letter.*** To ensure that participants would select the correct onset-letter comparison when they heard each Study 2 word, we assessed spoken-word-to-onset-letter relations and trained those on which the participants made errors.

*Procedure.* All sessions consisted of 30 trials and were conducted on the computer with touch-sensitive screen. Sample and comparison presentation, feedback, and ITI were the same as those described in Study 1, with the exception that six onset-letter comparisons appeared on the screen and the position of the comparisons varied quasirandomly across eight screen positions.

In the pretest, the 30 Study 2 words were divided quasirandomly between two sessions and were presented once as the auditory sample. Thirty words from Study 1 comprised the remaining 50% of trials in each session. As described previously, these known spoken-word-to-onset-letter trials were included as a foundation for testing the untrained words and feedback was delivered on all trials.

We modified the spoken-word-to-onset-letter training procedures used in Study 1 to expedite the training of words on which participants made errors in the Study 2 pretest. Words with different onsets were paired; however, no words had identical rimes (as they did in Study 1). A training session was delivered in which one spoken word from a pair was presented as the sample with a visual prompt of the correct onset-letter comparison in the center of the screen. Trials with a visual prompt were continued until the participant made a correct letter selection on two consecutive trials. The second word in the pair was then presented as the auditory sample, with a visual prompt of the corresponding onset letter. When the participant made two consecutive correct selections, the visual prompt was removed and the two spoken words alternated quasirandomly as the sample in all remaining trials. Sessions were repeated until the participant reached a criterion of 90% or above on both words in the pair, at which time training began for a new pair of words.

After the participant met the 90% accuracy criterion in training sessions for all words on which he had made errors in the pretest, a final training session was conducted in which all

trained words were presented as auditory samples. If a 90% overall accuracy criterion was not met or if more than one error was made per word, training was delivered again for those words on which errors were made.

A posttest, identical to the pretest, which included all Study 2 words as spoken-word samples, was delivered following training. Remedial training (described above) was delivered again if a participant did not meet the 90% accuracy criterion in the posttest.

*Results.* Mark selected the correct onset letter for 21 of the 30 spoken words in in the Study 2 pretest. Therefore, training was provided for nine words. In the posttest, Mark achieved 97% accuracy.

In the pretest, Jimmy selected the correct onset letter for 12 of 30 words. Training was delivered for the 18 words on which he made errors. Jimmy's accuracy was 100% in the posttest.

***Step 4: Pretest, training, and posttest - Analogue task.*** To this point, participants had only selected an onset letter in the presence of a spoken-word sample. We therefore designed a task that required the skills necessary for speech with alphabet supplementation and presented it via the computer used for teaching. This task allowed us to assess if participants would engage in both responses they had learned (picture naming and onset-letter selection) in a familiar modality, prior to presenting the augmentative keyboard.

*Procedure.* A pretest using the MTS procedures described previously was conducted on the computer with touch-sensitive screen and differential feedback was delivered. On each trial, one of the pictures that represented the 30 Study 2 words was presented in the center of the screen. The experimenter asked the participant, "What is it?" After the participant named the picture, they touched it on the screen, and the six onset-letter comparisons appeared. The participant then selected the onset letter that corresponded to the onset phoneme of the word.

If accuracy in the analogue pretest was less than 100% for both naming the picture and selecting the correct onset, training was delivered for the words on which the participant had erred. MTS training sessions consisted of 15 trials as described above and 15 spoken-word-to-picture trials. If the participant named the picture incorrectly in a training trial or did not provide a response within 5 s of the onset of the trial, the experimenter named the picture and the participant was required to repeat the name before touching the picture to continue the trial. Differential feedback was delivered by the computer for onset-letter selection. When the 100% accuracy criterion for trials requiring a vocal response was met, a posttest of the analogue task was delivered.

*Results.* Both Mark and Jimmy accurately named all 30 pictures in the analogue task session. However, neither participant met 100% criterion for onset-letter selection. Mark selected the correct onset letter in 83% of trials and Jimmy selected the correct onset letter in 90% of trials. Therefore, Mark received training for five words and Jimmy received training for three words on which they had made errors. In the posttest of the analogue task, both participants achieved 100% accuracy on naming and letter-selection responses.

**Step 5: Posttest - Speech with alphabet supplementation.**

After criterion was reached in the analogue task session, a speech-with-alphabet-supplementation posttest was conducted to determine whether the combined response of picture naming and onset-letter selection would be exhibited with the augmentative keyboard.

*Procedure.* This test was procedurally identical to the pretest described in Step 2. If participants did not meet the 100% accuracy criterion on both picture naming and onset-letter selection on the augmentative keyboard, training was delivered. In training, the task was presented in the same way as in the pre and posttests. Error correction was delivered by the

experimenter with a model prompt of the picture name or the letter selection response, dependent upon the type of error. Following the model, the trial was repeated and praise was delivered for a correct response. When the participant achieved 100% accuracy on all naming and selection responses, they moved on to the speech intelligibility assessment.

*Results.* Jimmy responded with 100% accuracy on picture naming and onset-letter selection in the speech with alphabet supplementation posttest. Mark made one naming error and eight onset-letter selection errors in the posttest. After two training sessions, he met the 100% accuracy criterion on both responses.

***Speech intelligibility assessment.*** To assess the effects of alphabet supplementation on the listeners' transcription of the participants' speech, video recordings were made of participants saying the 30 Study 2 words without the alphabet supplementation keyboard following Step 1 and with the keyboard following Step 5.

*Procedure.* Five listeners transcribed each participant's speech from the video recordings. A minimum of 1 week separated listeners' transcription of the participants' speech without alphabet supplementation (presented first) and speech with supplementation (presented second). Listeners were seated 1 meter from a computer monitor and recordings were played at audio levels equivalent to conversational speech. Instructions to the listeners were: (a) watch the participant as he speaks, (b) watch the participant's letter selection on the augmentative keyboard in the speech-with-supplementation condition, (c) listen to each word spoken by the participant, and (d) write down each word to the best of your ability. Listeners were given as much time as they needed to transcribe a participant response and they were allowed to view a response a second time if they requested to do so. Listeners were not given a context for the participants'

speech. That is, they were not informed that all the words were nouns, that responses were evoked by pictures, or that the words began with only six different onset letters.

Intelligibility was measured by calculating the percentage of words transcribed correctly. A correct transcription was defined as a phonemic match of the target word, irrespecive of spelling. Words transcribed with a plural S at the end of a word were scored as correct whether or not the test word ended in S. The number of correctly transcribed words was tallied, divided by the total number of words, and multiplied by 100. A mean intelligibility percentage for each participant's speech was calculated by averaging the five listeners' scores.

*Results.* Figure 7 shows the mean intelligibility percentage for each participant without and with the augmentative keyboard. Listeners correctly transcribed 44% of the words Aaron spoke when his speech was not supplemented. Aaron's mean speech intelligibility increased to 73% with alphabet supplementation. Mark's mean speech intelligibility percentage was 18% without alphabet supplementation and his speech intelligibility rose to 39% with alphabet supplementation. Jimmy's mean speech intelligibility percentage without alphabet supplementation was 15% and it increased to 37% with alphabet supplementation.

**Discussion**

To achieve our main goal of assessing speech intelligibility with and without alphabet supplementation, we first defined three component skills necessary for our participants to use an augmentative keyboard to supplement speech in a contrived communication task. These skills were to: (a) name pictures, (b) select the onset letter corresponding to the onset phoneme of spoken words they heard, and (c) select the correct onset letter when they named a picture themselves.

All three participants required some training to accurately name the 30 pictures used to evoke the vocal responses from which speech intelligibility would be scored. After reliable picture naming was established, Aaron performed the communication task without training of the other two component skills. Mark and Jimmy, however, required training to meet the mastery criterion for onset-letter selection with the 30 Study 2 words and also required training to accurately select onsets when they named pictures themselves. After these component skills were established, highly accurate responding was observed in the posttest of the terminal task.

The reliable demonstration of these skills allowed us to measure the effects of alphabet supplementation on participants' speech intelligibility. Our findings were similar to those of prior research with literate individuals with motor speech impairments in which alphabet supplementation resulted in improved intelligibility (Beukelman & Yorkston, 1977; Dowden, 1997; Hustad, 2005; Hustad, Auker et al., 2003; Hustad & Beukelman, 2001; Hustad, Jones et al., 2003). When the listeners in the current study knew the first letters of the words that were spoken by participants, on average, they correctly transcribed more than twice the number of words they transcribed when the speech was not supplemented.

## General Discussion

The current studies sought to extend two separate literatures that are relevant for individuals with intellectual disabilities: (a) phonemic-abstraction instruction, and (b) augmentative communication for speech-intelligibility improvement. The significant effects of alphabet supplementation on the speech intelligibility of literate individuals *without* intellectual disabilities led us to ask what skills might be needed for individuals *with* intellectual disabilities and very minimal reading skills to use this strategy. To that end, we sought in Study 1 to (a) establish onset-letter selection with a large number of spoken words, and (b) evaluate

generalization to untrained spoken words, which would demonstrate phonemic abstraction. In Study 2, we (a) trained component skills for supplementing speech by pointing to letters on an augmentative keyboard, and (b) assessed the effects of alphabet supplementation on speech intelligibility.

The onset-letter selection skill established with Mark and Jimmy in Study 1 provides evidence that individuals with severe intellectual disabilities can learn phonemic-abstraction exemplars. At the completion of Study 1, Mark and Jimmy could select the onset letter for a total of 78 and 92 spoken words, respectively, which began with six different phonemes. Although our procedures did not fully develop onset-phoneme abstraction (i.e., generalization of the trained skill to untrained words) in these participants, these participants' acquisition of onset-letter selection with such a large body of spoken words is noteworthy. There is no published evidence of individuals with this level of intellectual disability and reading skills learning the number of spoken-word-to-letter relations that were taught in the current study. In fact, Browder et al. (2006) found that no studies had even attempted to teach phonemic abstraction to individuals with moderate to severe intellectual disabilities. Browder et al. suggested that this gap in the literature may be due to continued emphasis on sight word acquisition for this population. The results from Study 1 support the increasing calls for reading instruction that emphasizes phonics and incorporates phonemic abstraction for individuals with intellectual disabilities (Allor, Mathes, Champlin, & Cheatham, 2009; Browder et al., 2008; Katims, 2001; Machalicek et al., 2010; Saunders, 2007).

Our participants' success in learning to select onset letters when presented with a spoken word may have, in part, been related to their preexisting ability to select letters given the letter name. This skill has been shown to be a good predictor of future reading achievement (Adams,

1994; NRP, 2000). Although it is unclear why neither Mark nor Jimmy showed strong evidence of phonemic abstraction, their overall low reading skills should be considered. On standardized measures of reading, both participants read fewer than five real words and read no nonwords (a level equivalent to kindergarten skills). They were also initially highly inaccurate in selecting the letter that corresponded to an isolated phoneme in a four-choice task. Aaron, who had a much higher receptive vocabulary score and reading skills than Mark or Jimmy, demonstrated onset-phoneme abstraction in the Study 1 baseline comprehensive tests without training. In our reading skills pretests, Aaron also selected the correct letter given the phoneme in a four-choice task. The differing abilities of our participants on reading and vocabulary tests may explain differences in the development of onset-phoneme abstraction. The generality of our results are limited due to the small number of participants, therefore further research is needed to determine requisite characteristics (e.g., level of intellectual disability) and reading prerequisites (e.g., nonword reading) for phonemic abstraction.

The procedures used in the current studies to assess and teach onset-phoneme segmentation allowed our participants to engage in a phonemic abstraction skill non-vocally. Traditional tests require that an individual produce a vocal response to demonstrate phonemic abstraction skills. The traditional equivalent of our task would be for an individual to say the first sound of a word after the whole word was spoken by an instructor. Our computerized MTS procedures allowed participants to select letters on a computer touch-screen that corresponded to the onset-phonemes in spoken words. This method eliminated the vocal response that may have been hard for some individuals to produce, and thereby also eliminated the difficulty of scoring the vocal response of an individual whose speech is difficult to understand. Although previous studies have demonstrated phonemic-abstraction skills via selection responses (Millar, Light, &

McNaughton, 2004; Truxler & O'Keefe, 2007), the current study extends the use of computerized phonemic abstraction instruction and non-vocal responding to individuals with severe intellectual disabilities and speech impairments. With a greater emphasis on phonemic abstraction in reading instruction for all individuals, the development of procedural adaptations of traditional skills will be critical to meet the needs of individuals who also have speech impairments (Barker, Saunders, & Brady, 2012; Hesketh, Dima, & Nelson, 2007; Iacono & Cupples, 2004; Laing & Espeland, 2005; Vandervelden & Siegel, 1999, 2001).

Another concern in developing procedures for the assessment and training of phonemic abstraction without vocal responses is the reliance on two and three-choice tasks in which individuals are likely to make accurate responses by chance. In tests that require vocal responses, there are no chance levels. We considerably reduced chance levels from 50% in Study 1 to 17% in Study 2 by adding four more letter comparisons for participants to choose from. Our computerized procedures made it possible to easily change the number of comparisons we presented in the MTS task. Researchers have noted a need for the development of non-vocal tests in which results are comparable to those from typical tests of phonemic abstraction (Barker, Saunders, & Brady, 2012; Vandervelden & Siegel, 1999). The procedural manipulations we used in the current studies may be useful when constructing modified tests that are more similar to typical tests.

In the current studies, we taught skills using computerized procedures in a majority of our training and testing. Feedback (e.g., flashing stars, chimes, and a buzzer) was reliably delivered via the computer; thus, our training was not affected by procedural fidelity concerns that can arise when teachers must manage all aspects of training and testing (e.g., delivering instructions, rearranging stimuli on a table, randomizing trial presentation). Other potential benefits of our

computerized training sessions include their minimal length (approximately 3-5 min), and the large number of opportunities to practice the desired response in each session (30 trials). The NRP (2000) recommended additional research to determine how computers might be used to teach phonemic abstraction more effectively. Further investigation is needed to evaluate if aspects of training such as we used will result in greater gains for learners with intellectual disabilities over traditional teacher led instruction.

In Study 2, our participants learned the component skills needed to use alphabet supplementation in a contrived communication task through table-top procedures and computerized MTS training. The teaching of component skills has not been necessary in other empirical evaluations of speech intelligibility because participants in those studies have been literate and thus able to generate speech samples from printed text, as well as follow spoken directions for using the augmentative communication device (Hustad & Garcia, 2005). The amount of training that was needed for two of our participants to learn the component skills for speech with alphabet supplementation might be impractical for implementation in an educational or clinical setting. However, refinement of our procedures might lead to more efficient instruction and quicker acquisition with children in rich educational environments. The results for one of our participants may have more immediate applied implications. Although Aaron's first-grade level reading and basic phonemic-abstraction skills were well below those of participants in previous studies with literate adults, they appear to have been sufficient for learning to use alphabet supplementation with only minimal teaching. Practitioners may consider evaluating letter-based augmentative communication strategies for individuals with similar skills, for whom these strategies have not been historically recommended (Beukelman & Mirenda; Mirenda & Mathy-Laikko, 1989).

The effects of alphabet supplementation on the speech intelligibility of our participants were substantial. Unfamiliar listeners understood more than twice the number of words spoken by Mark and Jimmy when they indicated the first letter of the word they were speaking. The percentage of Aaron's speech that was understood by listeners increased by over two-thirds. These results not only support the findings of previous research that has shown significant positive effects of alphabet supplementation on speech intelligibility, but also they represent an extension of the literature to a population with whom alphabet supplementation had not been evaluated. Investigation of the utility of alphabet supplementation for enhancing communication in the natural setting is warranted as the effects of this strategy on the quality of life of individuals with both intellectual disabilities and difficult-to-understand speech could be significant.

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| Participant | Age | Speech Intelligibility[a] | PPVT[b] | Word Identification[c] (grade) | Word Attack[c] (grade) | Receptive Letter Identification[d] | Receptive Phoneme-letter Relations[e] |
|---|---|---|---|---|---|---|---|
| Mark | 31 | 14% | 20 | K.5 | K.0 | 24 | 50% |
| Jimmy | 38 | 10% | 20 | K.8 | K.0 | 26 | 17% |
| Aaron | 50 | 28% | 43 | 1.7 | 1.2 | 26 | 100% |

[a]Modified assessment of speech intelligibility. Scores reported as percentage of speech sample correctly transcribed by listeners. [b]Peabody Picture Vocabulary Test – Fourth Edition. Standard scores are reported. [c]Woodcock Reading Mastery Tests – Revised. Scores reported as grade level: months. [d]Four-choice experimenter-constructed assessment. Scores reported as total number of letters of the alphabet correctly identified. [e]Four-choice experimenter-constructed assessment. Scores reported as percentage of correct responses.

*Table 1.* Participant characteristics.

| M / C Set | | T / S Set | | P / L Set | |
|---|---|---|---|---|---|
| mall | call | time | sime | pog | log |
| mold | cold | tip | sip | pid | lid |
| mup | cup | tell | sell | pail | lail |
| make | cake | take | sake | pit | lit |
| morn | corn | tub | sub | pub | lub |
| map | cap | tap | sap | peach | leach |
| man | can | teach | seach | pan | lan |
| mut | cut | tay | say | pay | lay |
| moat | coat | tick | sick | pick | lick |
| mad | cad | tad | sad | pad | lad |

*Table 2.* Sixty words that comprise the word sets used to test and train onset-letter selection.

| Spoken Sample | Original Comparisons | New Comparisons |
|---------------|---------------------|-----------------|
| mall | M, C | M, T |
|  |  | M, S |
| call | M, C | C, S |
|  |  | C, T |
| tap | T, S | T, M |
|  |  | T, C |
| sap | T, S | S, C |
|  |  | S, M |

*Table 3.* Example of stimuli in tests for sample-S+ control.

| Onset Letters | | | | | |
|---|---|---|---|---|---|
| M | C | T | S | P | L |
| man | car | table | salt | pencil | laundry |
| magazine | corn | tape | salad | pop | lips |
| medicine | coat | ten | socks | pizza | lock |
| milk | cup | teeth | seatbelt | pants | lunchbox |
| money | candy | toothbrush | soap | paper | light |

*Table 4.* Thirty words that comprise the word sets used for testing and training picture naming

and onset-letter selection, and in the assessment of speech intelligibility.
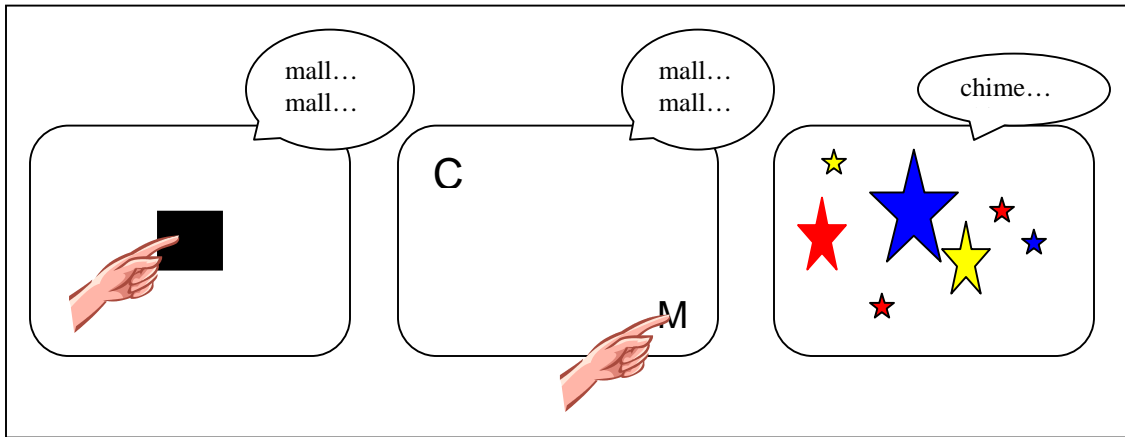
*Figure 1*. Computer screen displays for one trial of the onset-letter selection training procedure.
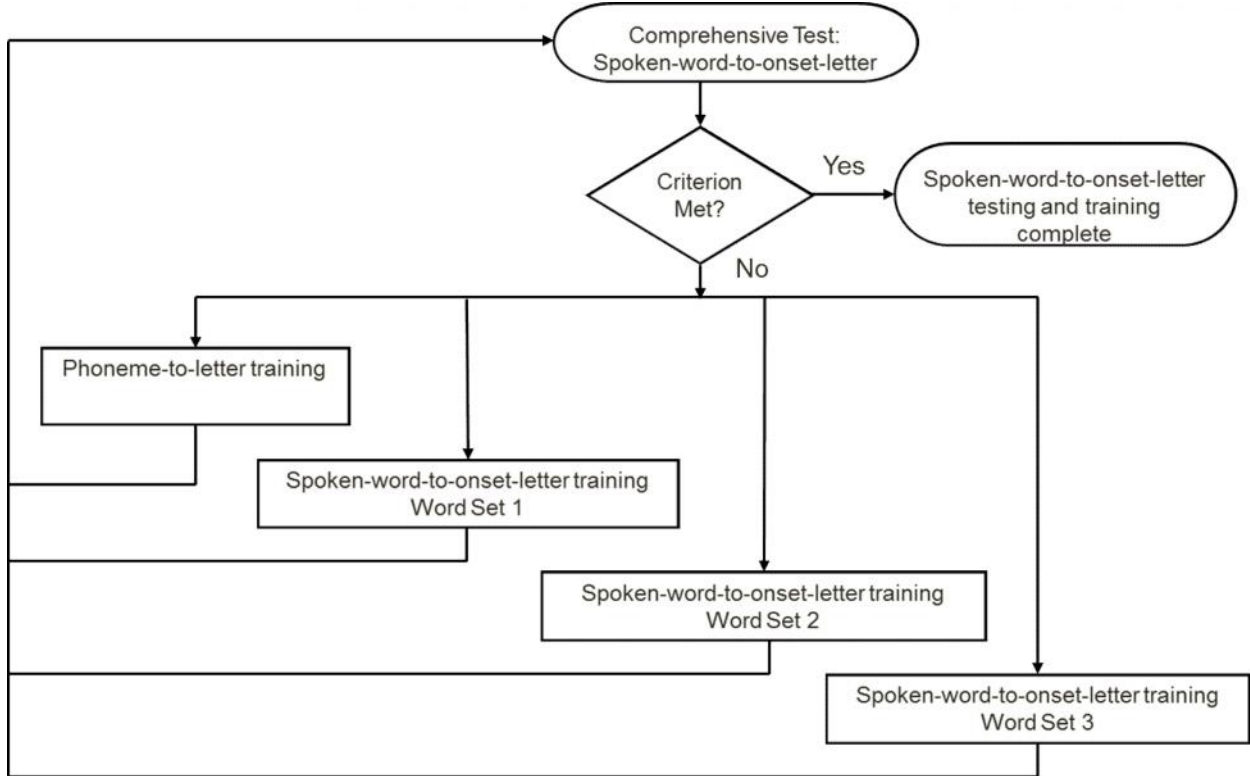
*Figure 2.* Flowchart of overall sequence of onset-letter-selection testing and training.
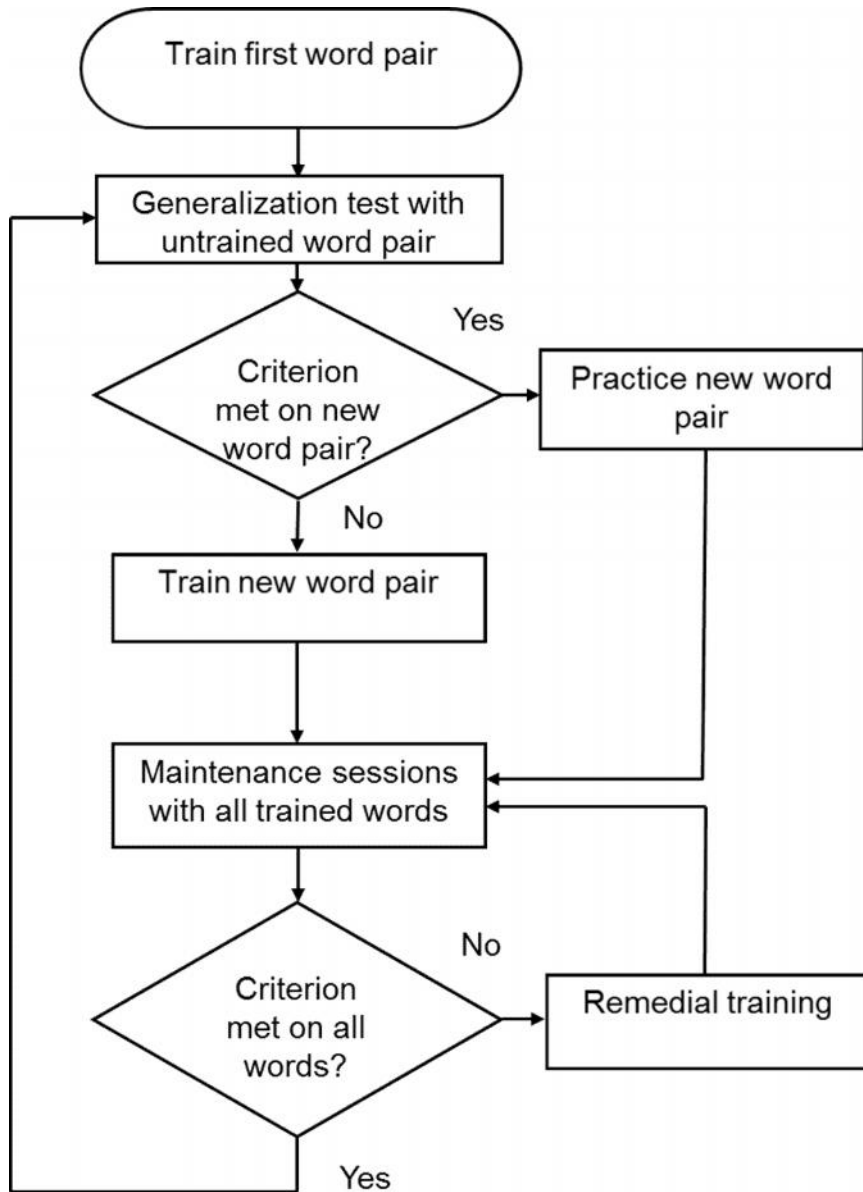
*Figure 3.* Flowchart of training and testing sequence within a single word set.
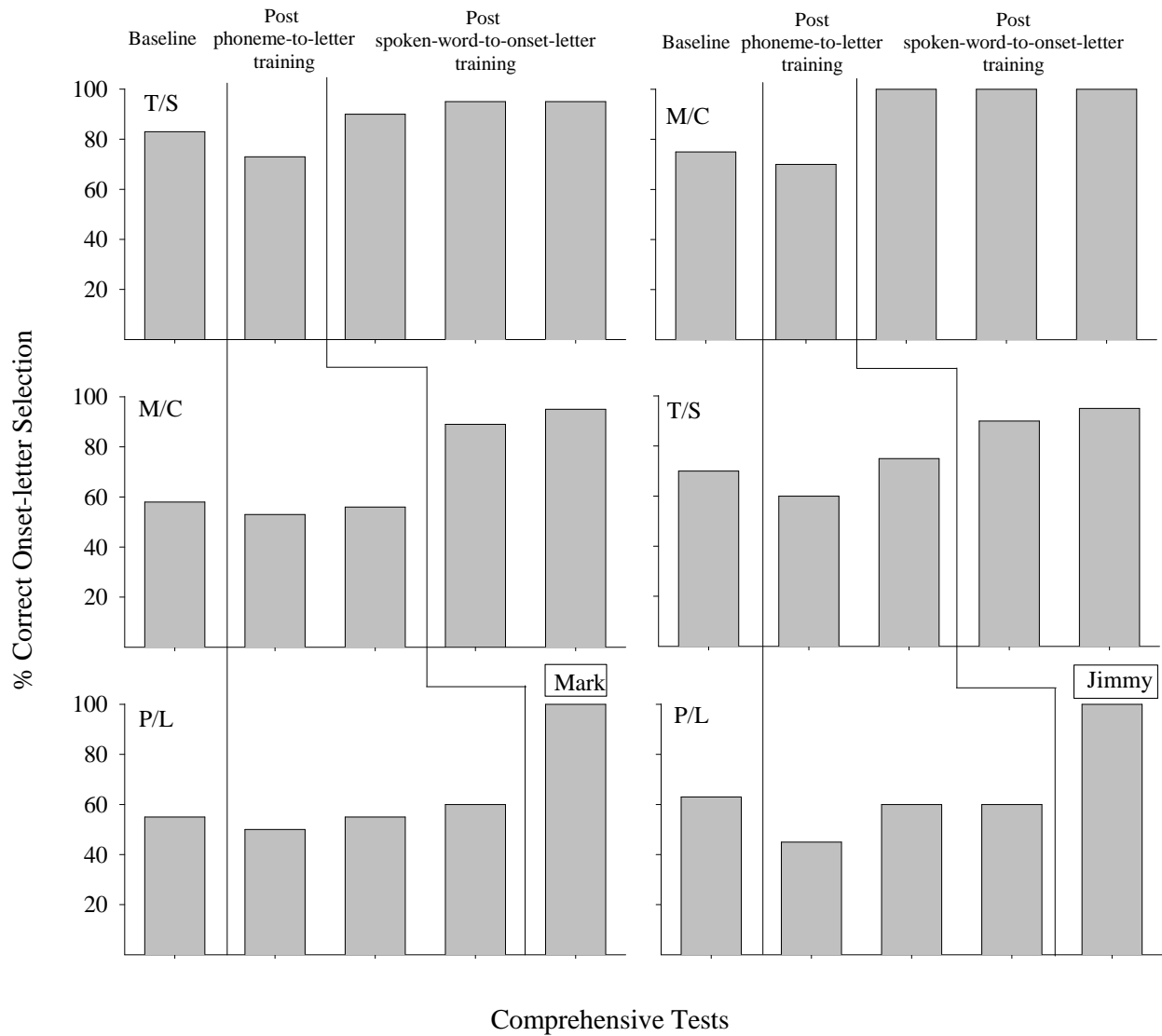
*Figure 4.* Percentage of correct onset-letter selections in the comprehensive tests for Mark and Jimmy. Panels represent word sets and are arranged from top to bottom in the order in which they were trained with each participant.
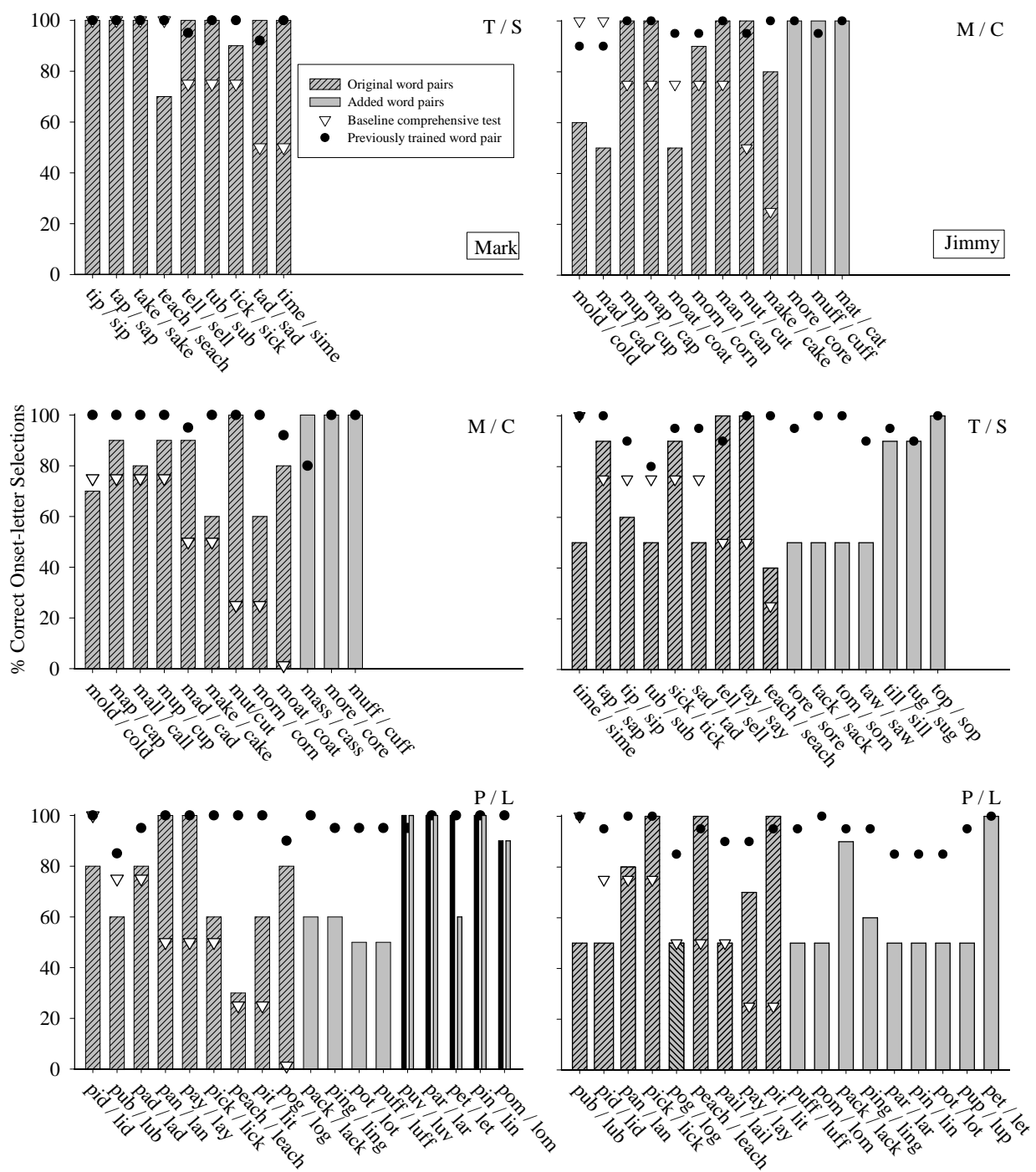
*Figure 5.* The percentage of correct onset-letter selections in generalization tests for Mark and Jimmy.

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┌─────────────────────────────────┐
│            STEP 1               │
│                                 │
│          Pretraining:           │
│         Picture naming          │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│            STEP 2               │
│                                 │
│           Pretest:              │
│  Speech with alphabet supplementation │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│            STEP 3               │
│                                 │
│   Pretest, training, posttest:  │
│    Spoken-word-to-onset-letter  │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│            STEP 4               │
│                                 │
│   Pretest, training, posttest:  │
│          Analogue task          │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│            STEP 5               │
│                                 │
│           Posttest:             │
│  Speech with alphabet supplementation │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│                                 │
│   Intelligibility Assessment    │
│                                 │
└─────────────────────────────────┘
```
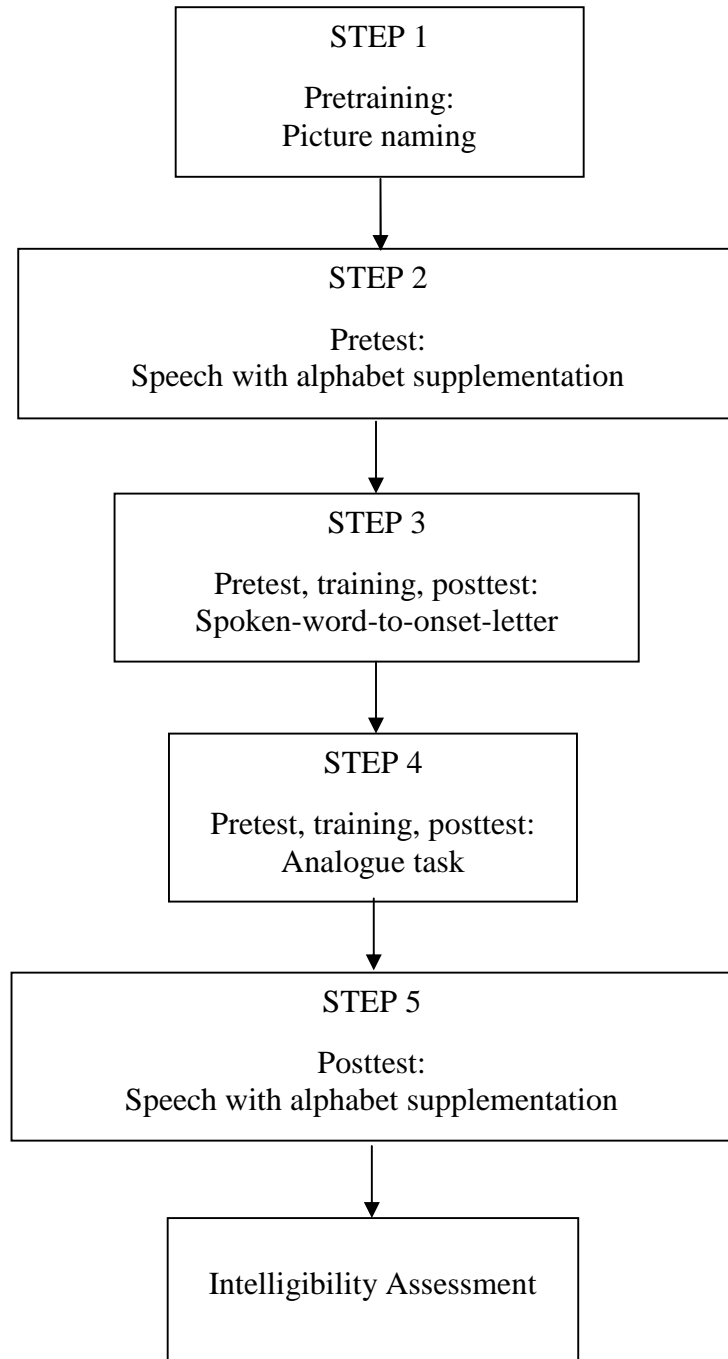
*Figure 6*. Flowchart of the sequence of testing and training steps and the speech intelligibility

assessment.
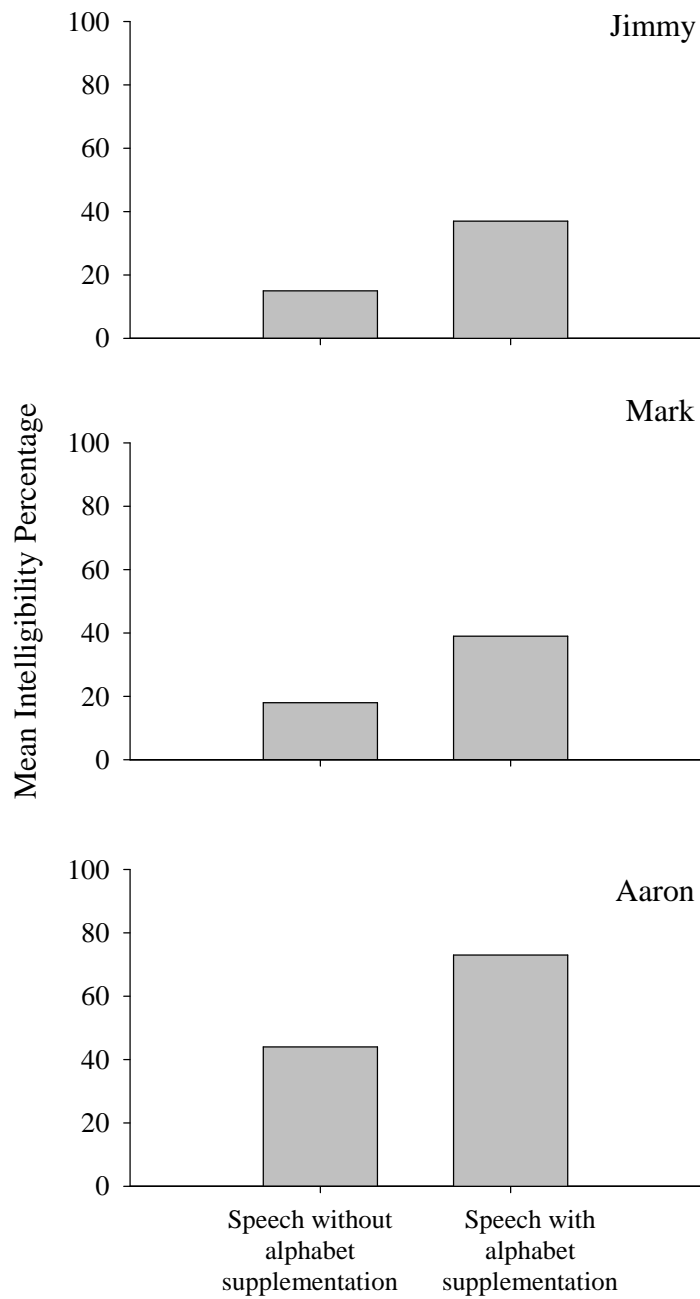
*Figure 7.* Mean speech intelligibility percentages in the speech-without-supplementation

condition and in the speech-with-supplementation condition for Jimmy, Mark, and Aaron.

Appendix A

**A Review of Phonological and Phonemic Awareness Research**

**Conducted with Individuals with Intellectual Disabilities**

Individuals with intellectual disabilities often receive limited reading instruction and acquire only minimal literacy skills (Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers, 2008; Katims, 2001). Sight word approaches have dominated research and instruction for individuals with intellectual disabilities since the 1970s (for reviews see Browder & Lalli, 1991; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Browder & Xin, 1998; Conners, 1992) with their focus directed toward training functional words for daily living (Browder et al., 2008; Katims, 2001). Although sight-word approaches have been shown to be very effective to teach discrete words (Browder et al., 2006; Conners, 1992), they do not teach the skills necessary for a person to read novel words. Thus, individuals are limited to reading only the words they have been taught directly.

Reading instruction delivered to individuals without intellectual disabilities differs drastically from sight-word approaches. Although methods have varied throughout the years, substantial research now supports reading instruction that teaches phonological and phonemic awareness skills, phonics, vocabulary, and comprehension (National Reading Panel [NRP], 2000; Snow, Burns, & Griffin, 1998). In contrast to sight-word approaches, instruction that combines phonological and phonemic awareness and phonics allows the individual to "decode" most words. This skill increases opportunities for independence throughout the lifespan. When individuals are not dependent on others to teach them each new word they encounter, they have more options within their vocations and greater access to activities of daily living (Browder et al., 2009; Conners, 1992).

Recognition of the importance of phonological and phonemic awareness (i.e., discrimination of the sounds that comprise spoken language) to reading has been relatively recent. Bradley and Bryant's (1983) seminal paper provided strong evidence that phonological awareness predicts future reading ability and that phonological awareness instruction improves reading acquisition in beginning readers. Since Bradley and Bryant, an abundance of research has shown phonological and phonemic awareness are correlates of single-word reading in typically developing individuals, and there is strong evidence for the positive effects of phonological and phonemic awareness instruction on overall reading success (NRP, 2000; Adams, 1994; Snow et al., 1998). Despite these well-established findings, it is only recently that researchers have begun to determine whether the same correlates of reading might be found in individuals with intellectual disabilities. In addition, researchers have begun to determine experimentally if phonological and phonemic awareness instruction will result in acquisition of those skills in individuals with intellectual disabilities. Positive findings from these research areas would support a shift from sight-word instruction to instruction that emphasizes decoding words, with the expectation that greater reading achievement would follow for individuals with intellectual disabilities.

In the following review, we describe phonological and phonemic awareness skills and briefly discuss their clearly established relation to reading as found through research with typically developing individuals. We then summarize research that has looked for correlations between reading and phonological and phonemic awareness skills in individuals with intellectual disabilities and discuss the similarity of those findings to correlations found with typically developing individuals. Finally, experimental research in phonological and phonemic awareness skill instruction with individuals with intellectual disabilities will be comprehensively reviewed.

Implications from the findings in this literature and future directions for research that could

impact the lives of individuals with intellectual disabilities are then discussed.

**Phonological and Phonemic Awareness Defined**

Reading is a complex system of skills that involves language comprehension, letter and

word recognition, as well as a set of auditory skills that can be separated from skills that involve

printed text (Adams, 1994). These auditory skills are commonly called phonological and

phonemic awareness and although they are auditory in nature, they become intricately related to

text in the process of learning to read. The distinction between phonological awareness and

phonemic awareness is the size of the unit of speech to which they refer. Phonological awareness

encompasses the auditory discrimination of syllables, rimes, and alliteration in spoken words,

whereas phonemic awareness involves the discrimination of the individual sounds (i.e.,

phonemes) that comprise spoken words. Phonological awareness subsumes phonemic awareness

and is typically acquired prior to phonemic awareness (Ziegler & Goswami, 2005).

At its most basic level, phonemic awareness can be described as the recognition that the

same sound occurs in different words (Byrne & Fielding-Barnsley, 1989). Thus, it involves

abstraction as discussed by Skinner (1957, p. 107) and later defined by Catania (1998, p. 378) as;

"discrimination based on a single stimulus property, independent of other properties; thus,

generalization among all stimuli with that property". A classic example of abstraction is naming

the color of an object. As a child learns to identify red, a parent might ask the child to give them

all of the red toys in a toy box. The toys are a variety sizes, shapes, and colors, but the child's

discrimination must be based solely on the color of the toy. Responses to red toys of any shape

or size are reinforced by the parent. In addition, reinforcement is withheld or responses may be

punished if they are made to items of any other color. The child thereby learns to discriminate

the property "red" and generalizes that discrimination to all toys (and likely other objects) that

are red. Thus, after exposure to numerous exemplars, abstraction of the property red has

occurred. Similarly, phonological and phonemic awareness skills demonstrate generalized

discrimination of units of sound in spoken language. For example, an individual learns to

identify the sound /p/ in spoken words following differential reinforcement with multiple

positive and negative exemplars. The individual can ultimately identify /p/ no matter where it

occurs in any word. They can identify the sound /p/ when it occurs at the beginning of "pill", at

the end of "clip", and in the middle of "staple". Because the individual generalizes among all

spoken words with /p/, we can say that abstraction of the sound has occurred. Although referred

to as phonological and phonemic awareness in the reading literature, we define these concepts

further and refer to them jointly as Phonological and Phonemic Abstraction (PPA) throughout

this review.

PPA may be best understood through the tests used to measure it in classrooms and in

reading research. Individual PPA skills are demonstrated in these tests. These tests include, but

are not limited to: (a) phoneme categorizing, (b) phoneme segmenting, (c) deletion of phonemes,

(d) and phoneme blending. In typical tests of PPA, words are spoken to the individual and the

individual responds vocally. For example, in categorization tests, the individual hears a series of

words and identifies either the word that has a different sound or the words that have the same

sound (e.g., Teacher says, "Which word starts with the same sound as dip? Nog, dog, fog."

Student responds, "Dog".)  In segmenting tests, the individual hears a single spoken word and is

asked to say each phoneme in isolation (e.g., Teacher says, "Tell me all the sounds in dog".

Student responds, "/d/ /o/ /g/"). A deletion test requires the individual to say a word without a

specified phoneme (e.g., Teacher says, "Say 'dog' without /d/." Student responds, "og"). Finally,

in blending, the individual says a complete word after hearing phonemes that are spoken

separately (e.g., Teacher says, "Say these sounds together to make a word: /d/ /o/ /g/." Student

responds, "Dog".) Phonological abstraction tests involve larger units of sound (e.g., rhyming

words, syllables), but are conducted similarly. For example, in a rhyming test, the individual says

multiple words that rhyme with a sample (e.g., Teacher says, "Tell me three words that rhyme

with dog." Student responds, "Frog, log, cog."). This PPA skill involves abstraction at the level

of the rime (in this example, /og/) and thus, generalization to other words with the same rime

component.

Limited speech does not preclude assessments of PPA skills, as tests can be conducted

without vocal responses. Segmenting of phonemes or syllables can be tested by requiring the

individual to count or move a block for each phoneme or syllable they hear in a spoken word.

Yes/no gestural responses can be given in categorization tests that ask if a word, for example,

ends with the same sound as another word. Deletion, categorization, and blending can also be

demonstrated by choosing pictures that represent the correct response. Similarly, an individual

can demonstrate an understanding of rhyming words by selecting pictures from an array that

have a common rime. These non-vocal assessments provide an opportunity for individuals with

impaired speech to participate in PPA tests and instruction.

**Importance of PPA to Reading – What is known about Typically Developing Individuals**

PPA skills are not necessary in and of themselves; rather, it is their impact on reading that

makes them important. Along with letter knowledge, PPA skills are the best predictor for early

reading acquisition (Ehri, 2004). Current reading research indicates that, "awareness of the

phonemic structure of speech is among the most difficult and critical steps to becoming a reader"

(Adams, 1994, p. 412). This awareness (or abstraction, as we refer to it) develops gradually with

generalized discrimination of rimes and syllables (i.e., phonological abstraction) occurring prior to generalized discrimination of individual phonemes (i.e., phonemic abstraction) (Ziegler & Goswami, 2005). The inherent difficulty in discriminating individual phonemes in spoken words is that phonemes are not acoustically discrete (Adams, 1994, p.69). Rather, they are co-articulated in a virtually seamless stream of speech and as such, they cannot be heard separately. Despite this, by the time children reach school at age five, many are familiar with the sounds that comprise speech, as well as text, and have learned some PPA skills (Snow et al., 1998, p.51-57).

It should be noted that PPA is different from phonics. Phonics instruction is the system in which letter-sound correspondences (i.e., the relation between phonemes presented in isolation and the letters that represent them) are taught and those correspondences are used to read words. The letter-sound correspondences taught through phonics instruction should, however, be accompanied by PPA skills in order for an individual to skillfully decode words (NRP, 2000; Adams, 1994). PPA is often the missing piece in struggling readers' skill sets and research has shown that readers derive more benefit from phonics instruction when it is delivered with PPA instruction (NRP, 2000).

The effects of PPA on the reading skills of typically developing individuals have been studied extensively, and this literature has been included in comprehensive reviews of reading research conducted by expert authors (see NRP, 2000; Adams, 1994; Snow et al., 1998). The NRP was charged by Congress to report on the status of research-based reading instruction. Phonemic awareness (i.e., PPA) was among the topics selected to be of central importance to learning to read and was included in the NRP analysis. The meta-analysis included 96 PPA-instruction studies and from them the NRP concluded that not only is PPA instruction highly

effective in teaching PPA skills, but also that it improves reading in both the short and long term for typically developing individuals.

Further support of the importance of PPA can be found in Adams' thorough explanation of the process by which individuals learn to read. Adams comprehensively covered over 20 years of basic and applied reading research and placed PPA among the essential features that distinguish skilled readers from those individuals who have reading difficulties. The author also concluded that phonemic awareness should be one of the earliest reading skills taught.

Snow et al. were charged by the U.S. Department of Education and the Department of Health and Human Services with making recommendations about the most effective reading interventions for young children. The authors concluded that PPA activities should be incorporated into reading instruction starting before children reach kindergarten.

Within these comprehensive reviews are individual studies that are representative of a large research base that has provided evidence that reading skills in typically developing individuals are strongly correlated with the PPA skills of rhyme and alliteration (Bryant, MacLean, Bradley, & Crossland, 1990), phoneme segmenting (Muter, Hulme, Snowling, & Taylor, 1998), categorization (Bradley & Bryant, 1983), and blending (Torgesen, Wagner, & Rashotte, 1994), 1994). Based on the accumulated research, the consensus among experts is that due to PPA's strong effects on reading, training in PPA skills should be a part of comprehensive reading curricula (NRP, 2000; Adams, 1994; Snow et al., 1998).

**PPA and Reading Correlations - Research with Individuals with Intellectual Disabilities**

Researchers have recently begun to examine the correlates of reading in individuals with intellectual disabilities. Increasing evidence indicates that PPA skills are indeed correlated with

and predictive of reading skills in this population, but with some differences from typically developing readers.

The majority of studies that have examined the relation between PPA and reading in individuals with intellectual disabilities have been conducted with individuals with Down syndrome. Researchers generally agree that individuals with Down syndrome can acquire literacy skills, but that their sight-word skills far exceed their decoding (Cupples & Iacono, 2002) and PPA skills (Bird, Cleave, & McConnell, 2000; Snowling , Hulme, Mercer, 2002). The extent to which those individuals develop and use PPA to read has been questioned. Cossu, Rossini, and Marshall (1993) examined the correlation between PPA and reading in 10 children with Down syndrome with IQ scores between 40 and 56. Ten typically developing children were matched on reading age and tests of PPA. Single-word reading tests were then delivered to all participants. Although the participants with Down syndrome read words and nonwords (i.e., combinations of letters that conform to regular word structures but do not have meaning) at the same level as the typically developing participants, they performed much less accurately on tests of PPA that included phoneme segmenting, phoneme deletion, and phoneme blending. Based on these results, the authors concluded that individuals with Down syndrome not only do not use PPA to read, they do not acquire PPA skills.

Subsequent studies have challenged the conclusions of Cossu et al. (1993) and have shown strong and significant correlations between PPA skills and reading in individuals with Down syndrome. Gombert (2002) replicated and extended Cossu et al. with 11 children with Down syndrome with a mean IQ of 47 and 11 typically developing children matched on reading age. After measuring the PPA skills of phoneme deletion, phoneme counting, phoneme blending, rime categorization, and onset-phoneme categorization, as well as four reading skills and

spelling, statistical analyses showed that phoneme deletion and phoneme counting were significantly correlated with reading words and nonwords in both groups. A correlation between reading and onset-phoneme categorization was also found in participants with Down syndrome.

Snowling et al., (2002) conducted three studies with 29 children with Down syndrome and 31 typically developing children matched on single-word reading. Practice trials were delivered with models and corrective feedback prior to each PPA test. In addition, tasks were modified to allow non-vocal responses such as picture matching and pointing. Tests of word and nonword reading were delivered along with PPA tests of syllable segmenting, rime categorization, onset-phoneme categorization, and final-phoneme categorization tests. Each PPA skill, with the exception of rime categorization, was correlated with reading in the typically developing and the Down syndrome groups. The correlations found in this study, as compared to other studies with individuals with Down syndrome, may have differed due to the modified PPA tasks. These tasks may have been easier than typical tasks requiring vocal responses, thus tapping the participants' PPA skills more fully.

Boudreau (2002) required vocal responses in her assessment of PPA, however, pictures were incorporated to facilitate tests, and training trials similar to that in Snowling et al. (2002) were delivered prior to the assessments. Twenty participants with Down syndrome and 20 typically developing individuals were given rime categorization, word, syllable, and phoneme blending and syllable segmenting tests. Correlational analyses between word and nonword reading and PPA skills showed that phoneme blending alone was significantly correlated with word reading in individuals with Down syndrome. In the typically developing group, phoneme categorization predicted word reading and phoneme blending was predictive of nonword reading.

Pictures were also used to facilitate testing of PPA skills in Roch and Jarrold (2008) and Laws and Gunn (2002). In both studies, participants could respond non-vocally in onset and rime categorization tasks. Roch and Jarrold investigated the relation between onset categorization, phoneme deletion, rime categorization and reading words and nonwords with 12 individuals with Down syndrome and 14 typically developing individuals matched on reading skills. Correlational analyses showed that onset categorization and phoneme deletion were predictive of reading nonwords in both groups. Laws and Gunn, in a study conducted with 30 individuals with Down syndrome, found that word reading and comprehension were both predictors of PPA.

Further studies have shown that not all PPA skills are predictive of reading in individuals with Down syndrome. Verucci, Menghini, and Vicari (2006) compared 17 individuals with Down syndrome to 17 typically developing individuals who were matched on reading accuracy and speed. Multiple tests of PPA were delivered, including syllable blending, syllable segmenting, syllable deletion, rime categorization and first-syllable categorization. Both groups scored close to 100% accuracy in syllable blending and first-syllable categorization tests, but significant differences were observed between the groups on syllable deletion and syllable segmenting. Verucci et al. found only one significant positive correlation between PPA skills and reading in each group. First-syllable deletion was correlated with reading in the Down syndrome group and syllable segmenting was correlated with reading in the typically developing group. The remaining PPA skills were not correlated with reading. Bird et al. (2000) also found only one significant relation in their analysis of reading and PPA in 12 children with Down syndrome. Nonword reading was strongly correlated with phoneme segmenting skills, however, only weak correlations were found between rhyming and syllable segmenting and word and nonword reading.

In sum, the relation between PPA skills and reading seen in typically developing individuals can also be seen in individuals with Down syndrome. Significant positive correlations were shown in seven of the eight studies. It is noteworthy that in contrast to the conclusions of Cossu et al. (1993), clear evidence of PPA skills was shown in individuals with Down syndrome, although these individuals' PPA skills were universally lower than their typically developing controls. This discrepancy might be accounted for by the type of reading instruction that participants had received prior to the studies. Due to the prevalence of sight-word-based instruction for individuals with intellectual disabilities, it is possible that the individuals with Down syndrome received reading instruction that did not emphasize or even include the development of PPA skills. The difficulty of the PPA tests could also account for low PPA scores; however, with the exception of Cossu et al. (1993), the PPA tests in the studies appeared to be within the abilities of the participants with Down syndrome, as evidenced by absence of floor effects. In addition, multiple studies (Snowling et al., 2002; Roch & Jarrold, 2008; Laws & Gunn, 2002; Boudreau, 2002) reduced the demands of the tests by limiting instructions, providing practice trials, and including testing procedures that did not require vocal responses. These modifications may have more adequately assessed the PPA skills of the individuals with Down syndrome and made the examinations of the correlates of reading in these individuals possible.

Further investigations of the correlates of reading in individuals with intellectual disabilities have been conducted with individuals with Williams syndrome. These studies have shown mixed results. Laing, Hulme, Grant, and Karmiloff-Smith (2001) administered a battery of PPA tests which included rime, syllable, and phoneme categorization and deletion tests, along with reading tests, to 15 individuals with Williams syndrome and 15 typically developing

individuals matched on reading age and verbal mental age. Correlations between single-word reading and PPA skills were moderate for the participants with Williams syndrome and strong for the typically developing participants. However, the correlations weakened in the Williams syndrome group when age and general cognitive abilities were controlled for. In contrast, Levy, Smith, and Tager-Flusberg (2003) showed that word and nonword reading were significantly correlated with syllable and phoneme deletion in 17 individuals with Williams syndrome. A significant correlation was also reported between nonword reading and segmenting phonemes. Similar results were reported in a study conducted with 16 individuals with Williams syndrome and 16 typically developing participants (Menghini, Verucci, & Vicari, 2004). Of three PPA skills tested, syllable deletion was the only skill that was strongly correlated with word and nonword reading. Although syllable categorization and syllable blending were not significantly correlated with word or nonword reading, ceiling effects appear to account for that finding.

Only two studies have examined the correlates of reading in individuals with intellectual disabilities of unspecified or mixed etiologies. In these studies, typically developing comparison groups were not included. Thirty adults with IQ scores between 58 and 77 participated in a study by Saunders and DeFulio (2007). Rime, onset-phoneme, final-phoneme, and middle-phoneme categorization tests were delivered, and each was significantly correlated with both word and nonword reading. Wise, Secik, Romski, and Morris (2010) examined the correlation between PPA skills and word and nonword reading in 80 individuals with a mean IQ score of 61. Syllable and phoneme deletion along with syllable and phoneme blending were tested. Highly significant correlations were shown between word and nonword reading and all blending and deletion skills.

Taken as a whole, the results across studies of individuals with intellectual disabilities have shown that PPA and reading skills are often strongly and significantly correlated. There

were, however, negative findings in this literature which may be explained by the differences in participants and procedures. The chronological age of participants varied widely across studies, from those focusing on children aged 5 years (Boudreau, 2002) to adults well past school-age (Saunders & DeFulio, 2007).  IQ scores ranged from 40-70 and the reading skills of participants also varied across and within studies. Multiple studies included participants who were unable to read any words (Boudreau, 2002; Laing et al., 2001; Wise et al., 2010) and over half of the participants in Laws and Gunn (2002) could read only one word. In contrast, participants in Saunders and DeFulio had reading-age equivalence scores from 6 to 10 years. Considering the wide variation in participant ages, IQs, and skills, it is highly probably that participants received different types of reading instruction prior to their participation in the studies discussed here. The prevalence of sight-word instruction for individuals with disabilities might also suggest that for some participants, the PPA tests delivered were their first exposure to PPA skills of any kind. Another factor that could result in negative findings is the range in difficulty of PPA tests from relatively easy (e.g., syllable categorization) to hard (e.g., phoneme deletion). In addition, although many studies tested similar PPA skills (e.g., syllable deletion, phoneme segmenting), the word lists, method of presentation, and response requirements were different in each of the 14 studies. Together, these differences may account for much of the variation in results across and within studies.

Despite the noted variations in findings in this small body of research, the primary finding is that single-word reading and PPA skills are correlated in individuals with intellectual disabilities and those correlations are similar to the correlations found with typically developing individuals. These results have bearing on the expectations for reading development and the type of reading instruction that is delivered to individuals with intellectual disabilities. Further

investigation of procedures shown to be effective to teach reading to typically developing individuals is warranted. As noted previously, the consensus among reading experts is that PPA skills are essential to skilled reading; thereby the training of PPA is an important component of reading instruction. Researchers must now establish the validity of PPA skill instruction for individuals with intellectual disabilities. Evidence of effective procedures for teaching PPA to individuals with intellectual disabilities is a necessary step towards developing effective reading instruction that includes PPA and emphasizes decoding rather than sight-word instruction exclusively.

**PPA Instruction in Individuals with Intellectual Disabilities**

Although it is a firmly established finding in the mainstream reading literature that PPA instruction is highly effective in teaching PPA skills to typically developing individuals (NRP, 2000), the literature addressing PPA instruction with individuals with intellectual disabilities remains small. The aim of following review is to describe and critically analyze the current state of research in this area and offer suggestions for future research.

**Literature Search Procedures and Inclusion and Exclusion Criteria**

For this review, articles published in peer-reviewed, English-language journals through the year 2011 were identified through PsycInfo using the following terms: *phonological awareness, phonemic awareness, phoneme* or *sound categorization, phoneme* or *sound segmenting, phoneme* or *sound blending, phoneme* or *sound deletion,* and *phoneme* or *sound identity*. Each term was entered in combination with the following terms*: intellectual disability, developmental disability, mental retardation, autism, Down syndrome*, and *Williams syndrome*. In addition, articles with the keywords *phonics, word-attack,* and *decoding*, that included

participants with intellectual disabilities, were hand searched to determine if PPA skills were included in the experimental analysis.

Articles identified through the search procedures were included in our analysis if at least two participants were clearly identified as having an intellectual disability as evidenced by a diagnosis of mental retardation, developmental or intellectual disability, or an IQ score of 70 or below. IQ scores must have been acquired through a standard IQ test, from scores on a test from which the mental age could be divided by the chronological age and multiplied by 100 to calculate IQ, or from a test in which the standard score was comparable to IQ test scores (e.g., PPVT-R). Because diagnostic labels such as autism, cerebral palsy, and Down syndrome do not necessarily indicate IQ scores at or below 70, articles that reported those diagnostic labels only were excluded (e.g., Kennedy & Flynn, 2003).

To be included in this review, the identified studies must have measured the effects of a PPA instructional intervention on the acquisition of at least one PPA skill. Studies that measured PPA skills but whose instruction did not directly teach PPA were excluded (e.g., Joseph & McCachran, 2003), as were studies that taught PPA skills but did not measure PPA outcomes (e.g., Conners, Rosenquist, Sligh, Atwell, & Kiser, 2006). Articles were also excluded if the results for the participants with disabilities could not be separated from the results of the participants with IQ scores above 70 (e.g., Hoogeveen, Birkhoff, Smeets, Lancioni, & Boelens, 1989; O'Connor, Notari-Syverson, & Vadasy, 1996; Richardson, Oestereicher, Bialer, & Winsberg, 1975).

## Results

**Participant Characteristics**

Ten articles were identified that met our criteria. Table 1 displays those articles and the descriptive characteristics of the participants in each study. The heterogeneity of individuals with intellectual disabilities as a group is evident in these results. A total of 170 individuals with IQ scores between 30 and 69 participated in 10 individual studies in which the effects of PPA training on PPA skill acquisition were evaluated. Participant age ranged from 2.11 to 19.5, with the majority of participants younger than age 12 at the time of study onset. Three studies included participants with a range of diagnosed disabilities (e.g., Williams syndrome, autism, cerebral palsy), two studies included participants with Down syndrome exclusively, and one study included only participants with congenital cerebral palsy. The remaining four studies did not specify the participants' disabilities.

Even within groups of individuals with similar IQs, reading skills often vary widely. The inclusion of descriptive measures of reading skills is especially important for interpreting the results of PPA interventions and for the replication of the research. Three studies provided only narrative descriptions of reading skills, noting that participants were unable to read words by decoding (Bracey, Maggs, & Morath, 1975), or that the participants were non-readers (Hoogeveen, Kouwenhoven, & Smeets, 1989; Hoogeveen & Smeets, 1988). The remaining seven studies included a variety of standardized tests and experimenter designed assessments that measured reading skills including letter identification, letter-sound correspondences, word and nonword reading, fluency, and comprehension.

**PPA Skills – Dependent Variables**

The dependent variables in each study fell primarily into the PPA skills of segmenting and blending, although the unit of sound measured (e.g., syllable, phoneme) varied across studies, as shown in Table 2. Effects of the instructional interventions were evaluated on

segmenting (a) words into individual syllables (Blackman, Burger, Tan, & Weiner, 1982), (b) words into onset phoneme and rime (Millar, Light, & McNaughton, 2004; Truxler & O'Keefe, 2007), (c) words into individual phonemes (Allor, Mathes, Roberts, Cheatham, & Champlin, 2010; Allor, Mathes, Roberts, Jones, & Champlin, 2010; Bracey et al., 1975; Cologon, Cupples, & Wyver, 2011; Cupples & Iacono, 2002) and (d) nonwords into individual phonemes (Cologon et al., 2011; Cupples & Iacono, 2002). A vocal response was required for the demonstration of segmenting in six studies (Allor, Mathes, Roberts, Cheatham et al., 2010; Allor, Mathes, Roberts, Jones et al., 2010; Blackman et al., 1982; Bracey et al., 1975; Cologon et al., 2011; Cupples & Iacono, 2002). To accommodate the needs of participants with speech impairments, one study required picture selection only (Truxler & O'Keefe, 2007) and one study required letter selection on an adaptive keyboard (Millar et al., 2004).

Multiple studies evaluated the effects of instruction on different blending skills, including blending (a) separate words into compound words (Hoogeveen & Smeets, 1988), (b) separate syllables into whole words (Blackman et al., 1982; Hoogeveen & Smeets, 1988), (c) onset phoneme and rime into whole words (Hoogeveen et al., 1989), and (d) final phoneme and the remainder of the word or nonword into words (Hoogeveen & Smeets, 1988). However, the majority of studies that evaluated the acquisition of blending skills assessed participants' accuracy with blending individual phonemes into whole words (Allor, Mathes, Roberts, Cheatham et al., 2010; Allor, Mathes, Roberts, Jones et al., 2010; Blackman et al., 1982; Bracey et al., 1975; Cologon et al., 2011; Cupples & Iacono, 2002; Hoogeveen & Smeets, 1988) or whole nonwords (Allor, Mathes, Roberts, Cheatham et al., 2010; Allor, Mathes, Roberts, Jones et al., 2010; Cologon et al., 2011; Cupples & Iacono, 2002; Hoogeveen & Smeets, 1988). Studies

primarily required vocal responses to demonstrate blending skills; however, two studies

combined picture selection and vocal responses (Cologon et al., 2011; Cupples & Iacono, 2002).

**PPA Training – Independent Variables**

Instructional approaches varied widely across studies, as shown in Table 2. Direct

Instruction-based methods that included highly structured lessons, frequent opportunities for

participant responses, corrective feedback, praise for correct responses, and training skills to

mastery were used in three studies.

Bracey et al. (1975) implemented a phonics program that also emphasized segmenting

and blending skills, along with rhyming, and reading words. In addition to direct instruction

components, reinforcement was delivered for individual and group responses with a token

economy and backup reinforcers that included food, toys, and books. Allor, Mathes, Roberts,

Jones et al. (2010) and Allor, Mathes, Roberts, Cheatham et al. (2010) implemented a

comprehensive reading program that taught skills explicitly and sequentially through scripted

lessons. Blending and segmenting instruction was delivered along with instruction in letter

identification, sight words reading, reading fluency, reading comprehension, and story retell. In

both studies, the effects of the comprehensive direct instruction program was compared to the

effects of the ongoing eclectic reading instruction in the special education classrooms of control

group participants.

A multi-component reading program which incorporated worksheets, games, and

repeated practice of segmenting, blending, and word decoding was delivered to two groups of

participants in Blackman et al. (1982). PPA skills were taught sequentially, with segmenting or

"isolation" of onset phonemes, final phonemes, and phonemes in the middle position of words

taught first, followed by blending training. Letter-sound correspondence instruction was then

delivered and finally, decoding words was taught. The treatment group also received training in phoneme recall, sorting words with similar phonemes, and picture puzzle completion with words made of trained phonemes.

Graduated prompting was used to teach blending skills in Hoogeveen et al. (1989) and Hoogeveen and Smeets (1988). A delay of increasing duration (up to 1.5 sec) was inserted between each sound unit in a spoken word. Instructors delivered praise for correct blending responses and modeled the correct responses when errors occurred. Hoogeveen and Smeets presented pictures which corresponded to the training words in initial steps, and as correct responding increased, picture prompts were removed. Hoogeveen et al. compared the effects of the graduated prompting procedures with and without the picture prompts. In both studies, participants moved to the next training step after mastery criterion on the previous step was met. After blending training was complete, Hoogeveen and Smeets also delivered reading training for two and three-letter words.

Cologon et al. (2011) taught blending skills along with word reading and basic comprehension using modeling, corrective feedback, and prompting. Instruction was delivered in seven training tasks per session, three of which addressed blending skills. First, onset and rime blending was targeted. Then participants were taught to blend individual phonemes into words while moving letters together for each phoneme within the word. Participants also selected a picture that represented the word they had blended. In the final training step participants blended words and selected pictures, but did not use letters. Five new words were introduced each session, although a mastery criterion was not in place for training.

Using differential reinforcement procedures, Cupples and Iacono (2002) delivered blending and segmenting instruction via computer. In the four training tasks in each session,

participants were taught to select pictures that had common rimes, spell words that had target sounds throughout the word, segment onsets of spoken words and select the appropriate matching picture, and provide vocal blending responses. Paper and pencil homework was also given each week and participants' parents were asked to deliver instruction at home.

Miller et al. (2004) used three training tasks to teach onset-phoneme segmenting skills. In the first task, letter-sound correspondences were taught with differential reinforcement. Onset-phoneme segmenting was then taught with a graduated prompting procedure in which the onset phoneme was elongated and separated by a pause from the remainder of the word. Finally, instructors spoke three words associated with each of four pictures. Participants were instructed to select the onset letter (and remainder of the word, if possible) on an adaptive keyboard that corresponded to the onset phoneme for at least one word for each picture. Prompts were not provided, but models of correct responses were delivered at the end of the task.

Onset-phoneme segmenting and letter-sound correspondence were trained in a story-based, read-aloud context in Truxler and O'Keefe (2007). Instructors delivered models of segmenting responses while reading a story and identified letters corresponding to phonemes. Participants were instructed to identify letters and phonemes on a QWERTY keyboard following the model. Training trials were then delivered in which three pictures were presented and labeled by the instructor, followed by a spoken target phoneme or letter name. Participants were instructed to select the picture whose label began with the spoken target. Additional training sessions were delivered if response accuracy fell below an 80% accuracy criterion. In these sessions, selection responses were taught outside of the story-based context.

In addition to directly teaching PPA skills, all studies in the current review, with the exception of Hoogeveen et al. (1989), taught one or more reading skills (see Table 2). These

skills included identifying letters, identifying letter-sound correspondences, reading words and nonwords, improving reading fluency and comprehension, and story retell. Instruction in these skills was not expected to improve PPA skill outcomes; rather, they were included as part of combined reading curricula and most were measured as additional dependent variables. The results of those measures are not reported here.

**PPA Skill Instruction Outcomes**

Outcomes for a given targeted skill can be viewed as having two components: the acquisition of directly trained exemplars meant to promote PPA, and generalization to spoken words that have not been taught as exemplars. However, in multiple studies (Allor, Mathes, Roberts, Cheatham et al., 2010; Allor, Mathes, Roberts, Jones et al., 2010; Blackman et al., 1982; Bracey et al., 1975; Cologon et al., 2011; Cupples & Iacono, 2002; Truxler & O'Keefe, 2007), measures of the dependent variable (e.g., standardized tests) did not directly assess a specific set of trained words. Because the authors expected to see changes in those measures as a result of the PPA-skill training they delivered, those results will be reported here as primary outcomes. Outcomes of specific assessments of generalization will be reported separately.

Improvements in trained PPA skills were reported in nine of the 10 studies (see Table 2). In both Allor, Mathes, Roberts, Cheatham et al. (2010) and Allor, Mathes, Roberts, Jones et al. (2010) significant post-training differences were shown between the treatment and control groups on measures of blending phonemes into nonwords and segmenting words into individual phonemes. Although significant differences between groups were not shown on blending words, the effect sizes on all measures of PPA were moderate to strong. In addition to the between-groups analyses, individual participant data were reported for segmenting pre and post-tests in

Allor, Mathes, Roberts, Cheatham et al. These data revealed highly variable results, with 12 of 34 participants in the treatment group showing no improvement in segmenting skills.

Although Blackman et al. (1982) evaluated between group differences for reading skills, they evaluated only within group changes on PPA skills. Participants in both the treatment and control groups showed significant gains on blending and segmenting words. Significant gains were also seen in syllable segmenting for the control group. However, due to ceiling effects, significant gains were not evident for syllable blending in either group or in syllable segmenting for the treatment group. Cupples and Iacono (2002) also did not use statistical analyses to evaluate the differences between intervention groups in PPA skill acquisition. They did, however, report changes in pre and post-test PPA-skill scores. Only one participant achieved over 50% accuracy in nonword blending on the post-test, although five of seven participants' scores did improve to some degree. Post-tests also showed that only one participant accurately segmented more than one word and one nonword, while all but one participant blended phonemes into words with 80% or greater accuracy.

In their analysis of pre and post-test group means, Bracey et al. (1975) showed significant differences on word-blending in one test and on word-segmenting in one out of three tests. Cologon et al. (2011) showed significant differences between pre and post-test scores across all PPA skills; however, individual data revealed low levels of accurate responding for multiple participants. Three of five participants scored above 80% accuracy on post-test measures of blending words. In nonword blending, only one participant scored above 80%, while the remaining four participants scored below 50% accuracy. Similarly, two participants scored above 80% accuracy on segmenting words and nonwords, and three scored between 8% and 50%.

Hoogeveen et al. (1989) found that both instructional programs were effective in teaching PPA exemplars. Nine of 10 participants in the picture-prompt group and seven of 10 participants in the no-picture prompt group completed training and met the 90% accuracy criterion on blending onset and rime on all trained words. Although fewer participants completed training in the no-picture prompt group, results of post-tests that included 30 trained words showed the no-picture prompt group scored more accurately than the picture-prompt group, with 86% of participants scoring above 80%, versus only 44% of participants in the picture-prompt group. In Hoogeveen and Smeets (1988), all seven participants completed training and met the 90% mastery criterion for the three targeted blending skills.

Lesser effects were shown in the two studies that included participants with severe speech impairments. One of two participants in Millar et al. (2004) met the 80% mastery criterion for onset segmenting and maintained those skills over one month. The second participant achieved only 20% accuracy. In Truxler and O'Keefe (2007), neither participant met the 80% mastery criterion for the trained onset-segmenting skill. However, although both participants scored at chance levels in baseline, large increases in accuracy were shown at the completion of training and throughout the maintenance phase. It should be noted that due to the way in which results were reported, the accuracy of onset segmenting cannot be separated from letter-sound correspondence accuracy. Thus, it is impossible to determine the exact accuracy for the PPA skill.

**Generalization Measures and Outcomes**

Measurement of the generalization of skills taught in a PPA instructional program is important not only because it allows for some indication of the functionality of the skills, but also because it is necessary to assess if abstraction has occurred. Generalization tests can be

conducted by assessing a participant's accuracy on a trained skill (e.g., segmenting words) with a novel set of stimuli (e.g., new words). Only three studies in the current review systematically assessed the generalization of trained PPA skills.

Table 2 shows the studies in which systematic tests of generalization were conducted. Hoogeveen et al. (1989) assessed onset and rime blending with 30 untrained words after participants met the mastery criterion for onset and rime blending with trained words. Results showed a significant difference between treatment groups. The mean accuracy for participants in the no-picture prompt group was 70%, while mean accuracy in the picture-prompt group was only 49%.

Millar et al. (2004) delivered two generalization tests to the one participant who completed onset-segmenting training. In these tests, 25 pictures that did not correspond to trained words were presented, and participants were required to look at the picture and select the letter that corresponded to the onset phoneme of the pictured item. The participant's mean accuracy of 42% on the tests indicated low levels of generalization. It should be noted that although the response required in this task was topographically identical to that of the trained task (i.e., selection of letters on the adaptive keyboard) the procedures were different than those used in training. Participants had been taught to select onset letters upon hearing spoken words. Spoken labels were not delivered by instructors when pictures were presented in the generalization test and this procedural difference may have led to errors. Participants may not have understood the task, or they may have labeled the pictures as something different than the instructor intended and selected a different letter. Thus, this was a poor test of generalization of the trained skill.

Finally, two generalization measures of onset segmenting, demonstrated by picture selection, were assessed in Truxler and O'Keefe (2007). One test assessed segmenting of trained

phonemes which occurred in the middle and last position of spoken words and the second test assessed segmenting of untrained phonemes in the onset position of spoken words. Both participants scored close to 50% accuracy on the first generalization test and at 60% on the second test. As noted previously with respect to the primary results presented in this study, due to the grouping of the segmenting skills and letter-sound correspondence results, it is not possible to determine the exact accuracy on the segmenting tests.

**Methodology**

Table 3 shows aspects of the methodology used in each study. Four studies evaluated the effects of PPA instruction on the acquisition of PPA skills using group designs. In two longitudinal studies, Allor, Mathes, Roberts, Cheatham et al. (2010) and Allor, Mathes, Robers, Jones et al. (2010) randomly assigned participants to either an experimental or control group within their school. Statistical analyses were conducted to reveal differences between the groups and also within each group. Blackman et al. (1982) created experimental and control groups by matching participants on chronological age and measures of IQ, mental age, and standardized achievement tests. Results were analyzed within and between groups. Hoogeven et al. (1989)

Single-subject, multiple-baseline designs were used in three studies. Hoogeveen and Smeets (1988) evaluated the effects of instruction across successively more difficult blending skills using a multiple-probe design. Visual analyses of each participant's results were conducted to assess the change in all skills prior to and after each training step. Millar et al. (2004) evaluated the effects of segmenting training using a multiple-probe across participants design. Aspects of the multiple-probe design were the tests that were delivered for all training words prior to the training of each individual word set. This allowed for analysis of the effect of training any particular word set on all other sets prior to their training. As in a traditional

multiple baseline design, some participants were also held in baseline until the effects of the intervention were observed in the prior participant receiving instruction. Truxler and O'Keefe (2007) used visual analysis to interpret the effects of segmenting-skill training shown in a multiple-baseline-across-participants-design.

AB (pretest/post-test) designs were used in three studies. Bracey et al. (1975) analyzed group means on pre and post-test measures of PPA skills. Cupples et al. (2002) assessed individual pre and post-test scores and looked for statistically significant changes in each dependent measure for which there were enough items to run analyses. Cologon et al. (2011) used statistical analyses to determine change in group means from pretests to post-test. The pretest was delivered twice prior to intervention, separated by 10 weeks, to increase the strength of the design by establishing a long baseline.

Interobserver agreement (IOA) was reported in only half of the studies (Cologon et al., 2011; Hoogeveen et al., 1989; Hoogeveen & Smeets, 1988; Millar et al., 2004; Truxler & O'Keefe, 2007). The range of reported means was 96-99% and agreement was assessed in a minimum of 20% of sessions in each of these studies. With the exception of Cologon et al. who collected agreement data for only a sample of their participants, the other four studies obtained IOA data across all participants.

Measurement of the fidelity of intervention implementation was assessed in four studies. Allor, Mathes, Roberts, Cheatham, et al. (2010) and Allor, Mathes, Roberts, Jones et al. (2010) assessed procedural fidelity with each teacher two and three times per year, respectively. Multiple aspects of classroom instruction (e.g., use of error correction, lesson pacing) were rated on a 3 point scale. Mean procedural fidelity of 92% (Allor, Mathes, Roberts, Cheatham et al., 2010) and 91% (Allor, Mathes, Roberts, Jones et al., 2010) was reported across teachers. Millar

et al. (2004) assessed procedural fidelity in 30% of intervention sessions with each participant. The fidelity measure assessed accurate implementation of all instruction steps, as well as individualized prompting procedures developed to accommodate each participant's disability. Mean fidelity was reported at 95%. Truxler and O'Keefe (2007) reported a mean of 100% procedural fidelity using a measure of eight instructional components in 20% of each participant's sessions.

**NRP – Important Properties of PPA Instruction**

The NRP (2000) meta-analysis of PPA instructional studies conducted with typically developing individuals evaluated effect sizes associated with different characteristics of PPA training. Training properties that resulted in significantly higher effect sizes for PPA acquisition were: (a) training conducted in small groups, (b) training no more than two PPA skills, (c) training PPA skills with letters, (d) training length of 5 to 18 hours, and (e) training delivered by instructors (versus solely by computers).

Table 4 shows how the ten studies in the current review align with the properties associated with large effects sizes identified by the NRP. Although half of the studies were published prior to the NRP analysis, many of the characteristics associated with large effect sizes were found in each study. Two studies delivered training in small groups (Blackman et al., 1982; Bracey et al., 1975), while in two additional studies (Allor, Mathes, Roberts, Cheatham et al., 2010; Allor, Mathes, Roberts, Jones et al., 2010) the teaching-group size ranged from one to four participants. All PPA instruction was delivered individually in the remaining six studies. In line with studies showing large effects sizes identified in the NRP analysis, nine studies focused on delivering instruction for only one or two PPA skills. The exception to this was Bracey et al. who taught three skills. Letters were incorporated into the PPA training in all studies with the

exception of Hoogeveen et al. (1989). Some measure of training length was reported in each study; however, no study reported the amount of training time for PPA skill acquisition separately from training in other reading skills. Hoogeveen et al. (1989) only taught PPA skills, but because they did not report the total number of training sessions delivered, the number of hours of PPA training could not be determined. Only one study (Cupples & Iacono, 2002) used computers exclusively for PPA instruction; in the remaining nine studies, training was delivered by human instructors.

## Conclusion

Analysis of this small body of research primarily calls attention to what must be determined experimentally before sound recommendations can be made about procedures that promote acquisition of PPA in individuals with intellectual disabilities. Before extending research to determine the generality of the findings, studies that have a high degree of internal validity must be conducted.

Multiple methodological flaws weakened the internal validity of the studies in the current review. Three studies used A-B (pretest-posttest) designs and although posttests showed increases in PPA skill accuracy in each of these studies, it is not possible to rule out the effects of external variables. This threat is even more likely with the school-aged participants in these studies where it is more difficult to control for the effects of a language and literature-rich environment.

The absence of inter-observer agreement data in five studies also calls into question the believability of reported results. These data are standard for both group and single-subject research (Horner, Carr, Halle, McGee et al., 2005; Troia, 1999); thus, the omissions of IOA data weaken the validity of these studies. Procedural fidelity data were obtained in four studies.

However, in two of those studies the data were collected only two or three times per year; a frequency which is insufficient to determine if the interventions were implemented as they were designed. The absence of fidelity data in the remaining six studies presents an even greater concern. Multiple studies reported wide variation in the post-intervention levels of PPA skill accuracy. Without fidelity data, it is impossible to determine if inadequate implementation of the independent variables account for those differences or if they are attributable to the independent variables themselves.

Another methodological concern is that several studies included insufficiently technological descriptions of the dependent and independent variables. This presents a difficulty in that the generality of the studies cannot be determined through further research if the procedures are not replicable. Given the numerous ways to teach a given PPA skill (e.g., using picture cues, letter manipulatives, delayed prompting) or demonstrate a PPA exemplar (e.g., vocal or selection response) it is inadequate to simply state that a given skill was taught systematically or shown. Further detail about the independent variable should also include the amount of time spent engaging in PPA instruction and practice. This information would be especially useful for practitioners who will be designing instruction and setting goals for acquisition. In sum, although the studies in the current review may represent the best evidence available, due to these methodological flaws the results should be interpreted cautiously.

Interpretation of results and replication of research relies upon clear descriptions of participants (Horner et al., 2005). The studies in the current review included descriptive data about participants; however, there was great variability in the particular characteristics that were reported and the way in which they were reported. Of particular interest in this literature are the basic reading skills that participants have prior to intervention. Future research should consider

reporting on common measures of reading using common scores (e.g., raw scores). Knowledge of the prerequisite skills of participants would allow for better interpretation of the effects of a given intervention and accurate replication or extension of the research.

It is difficult to determine from the small number of studies reviewed here what the best procedures are for teaching PPA skills to individuals with intellectual disabilities. However, the studies that showed the strongest evidence of the positive effects of PPA training included prompt fading and error correction. This is consistent with instructional procedures that have been shown to be effective in teaching phonics and sight words to individuals with intellectual disabilities (Conners, 1992; Machalicek et al., 2010). For typically developing individuals, the most effective PPA instruction incorporates printed letters in its training. All studies in the current review, with the exception of Hoogeveen et al. (1989), included letters in some aspect of PPA skill training. Although it is not possible to determine the effect this had on PPA acquisition, it does conform to best practice for instruction with typically developing individuals (Adams, 1994; NRP, 2000; Snow et al., 1998).

As researchers and practitioners develop procedures to teach PPA skills to individuals with intellectual disabilities, it may be advisable to look to the findings of the NRP (2000) to determine what has been shown to be effective with individuals without disabilities. In the current review, we found that the majority of studies included at least two of the five properties associated with large effect sizes found in the NRP meta-analysis. A property on which studies in the current review differed from the NRP findings was in training-group size. The majority of studies delivered individual instruction in PPA skills. This may be a function of the participants' individual learning styles or it may have been necessitated by the instructional procedures in the studies. In either case, individual training is not inconsistent with the instruction many

individuals with intellectual disabilities receive in school settings. Future research should evaluate to what degree procedures designed to promote acquisition of PPA in typically developing individuals may need to be tailored to accommodate the specific needs of individuals with intellectual disabilities.

It was difficult to determine the amount of time dedicated to teaching PPA skills in the majority of studies included in this review, primarily because multiple reading skills were taught and instructional time was not reported skill-by-skill. However, based on the information that was provided, it is likely that the majority of studies exceeded the 5-18 hours of instruction time found by the NRP to be associated with the largest effect sizes. It is probable that due to the learning deficits of individuals with intellectual disabilities a greater amount of instruction time was necessary to master PPA skills. The evaluation of the instructional time needed to reap the greatest benefits of PPA instruction may be an area of analysis in future research with individuals with intellectual disabilities. This information could assist teachers in creating instructional programming that best fits the students with whom they work.

The assessment of generalization to untaught words is necessary to determine if PPA has occurred, as abstraction is "generalization among all stimuli with [a given] property" (Catania, 1998). Without a demonstration of generalization, it can only be said that multiple exemplars of words containing a target phoneme have been taught. Although it is no small feat for individuals with intellectual disabilities to learn, for example, to segment or blend phonemes in a large number of words, it is of more importance that they can do this with words that have never been trained. The majority of studies in the current review fell short of demonstrating PPA (i.e., abstraction). Only three studies assessed generalization following PPA skill instruction and of those, only participants in Hoogeveen et al. (1989) responded with high accuracy, thereby

showing an educationally significant level of generalization. Although generalization tests were delivered in Millar et al. (2004) and in Truxler and O'Keefe (2007), three of the tests were significantly dissimilar from the PPA skills that were trained. Thus, they did not represent good tests of generalization because high accuracy on PPA tasks that have not been trained would not be expected. For example, after onset segmenting training it would not necessarily be expected for participants to segment phonemes in the middle of words (see Generalization Probe 1, Truxler & O'Keefe, 2006). A better assessment of generalization would be to test the trained PPA skill (e.g., onset segmenting) with a novel set of words (see Generalization Probe 2, Truxler & O'Keefe, 2006). Future research in PPA instruction with individuals with disabilities must move beyond teaching only PPA exemplars and evaluate if the skills taught are generalized to untrained words. Without this assessment, it is not possible to know if the trained skills will be useful to individuals outside the training environment or if further instruction is needed.

The profound effect of PPA instruction on reading in individuals *without* intellect disabilities warrants further pursuit of this area for individuals *with* intellectual disabilities. The growing consensus among researchers is that individuals with intellectual disabilities should have the opportunity to become fluent, independent readers and PPA instruction and acquisition is an essential part of that process (Allor, Mathes, Champlin, & Cheatham, 2009; Browder et al., 2008; Katims, 2001; Machalicek et al., 2010; Saunders, 2007). This may necessitate moving away from sight-word instruction, or at a minimum, adding to it. In addition, if instructional practices for individuals with intellectual disabilities are to change, future research must determine not only the most effective procedures for teaching PPA, but also how to then apply those skills to reading.

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Table 1

*Participant Characteristics*

| Reference | Participants | | | | Descriptive Reading Measures |
|---|---|---|---|---|---|
| | Number | Age | IQ | Disability | |
| Allor, Mathes, Roberts, Cheatham et al. 2010 | 34 Treatment 25 Control | M = 7.94 | Range = 40-69 | Mixed; Down syndrome, autism, Williams syndrome, unspecified | Letter identification Word and non-word reading Fluency Comprehension |
| Allor, Mathes, Roberts, Jones et al. 2010 | 16 Treatment 12 Control | M = 9.36 | Range = 40-55 | Mixed; Down syndrome, autism, Williams syndrome, unspecified | Letter identification Word and non-word reading Fluency Comprehension |
| Blackman et al. 1982 | 17 Treatment 17 Control | M = 11.82 | M = 60 | Unspecified | Letter-sound correspondence Word and non-word reading |
| Bracey et al. 1975 | 6 | Range = 7-14 | Range = 30-40 | Unspecified | No word decoding |
| Cologon et al. 2011 | 5 | Range = 2.11-10.8 | Range = <40-69 | Down syndrome | Letter-sound correspondence Word and non-word reading Comprehension |
| Cupples et al. 2002 | 7 | Range = 8.6-11.1 | Range = <40-67 | Down syndrome | Word and non-word reading |
| Hoogeveen et al. 1989 | 20 | M = 6.3 Range = 7-16.9 | M =51.7 Range = 40-67 | Unspecified | Non-readers |
| Hoogeveen et al. 1988 | 7 | M =12.6 Range = 8.8-17.9 | M = 43 Range = 30-51 | Unspecified | Non-readers |
| Millar et al. 2004 | 2 | Range = 6-11 | Range = 40-51 | Mixed; Cerebral palsy, alternating hemiplegia | Letter identification Word decoding |
| Truxler et al. 2007 | 2 | Range = 8-9 | Range = 59-63 | Congenital cerebral palsy | Letter identification Letter-sound correspondence Word and non-word reading |

*Note.* M = mean.

Table 2

*Dependent and Independent Variables and Outcomes*

| Reference | PPA Skills Tested and Response Topography (DV) | PPA Skills Taught and Instruction Components (IV) | Reading Skills Taught | Outcomes | Generalization Measures and Outcomes |
|---|---|---|---|---|---|
| Allor, Mathes, Roberts, Cheatham et al. 2010 | Blending words, non-words <br><br> Segmenting words <br><br> Vocal response | Blending <br><br> Segmenting <br><br> "Early Interventions in Reading" <br><br> Direct instruction based: systematic and sequenced instruction, skills taught to mastery, frequent opportunities to respond, feedback | Letter identification, sight words, fluency, comprehension, retell | Treatment and control groups showed significant increases in PPA skills. <br><br> Significant differences between treatment and control groups were shown on measures of blending non-words and segmenting words. <br><br> Individual participant data showed 12 of 34 participants in treatment group showed no improvement in word segmenting. | Not assessed |
| Allor, Mathes, Roberts, Jones et al. 2010 | Blending words, non-words <br><br> Segmenting words <br><br> Vocal response | Blending <br><br> Segmenting <br><br> "Early Interventions in Reading" <br><br> Direct instruction based: systematic and sequenced instruction, skills taught to mastery, frequent opportunities to respond, feedback | Letter identification, sight words, fluency, comprehension, retell | Significant differences between treatment and control groups were shown on measures of blending non-words and segmenting words. | Not assessed |

Table 2 (continued)

| Reference | PPA Skills Tested and Response Topography (DV) | PPA Skills Taught and Instruction Components (IV) | Reading Skills Taught | Outcomes | Generalization Measures and Outcomes |
|---|---|---|---|---|---|
| Blackman et al. 1982 | Blending syllables, words Segmenting syllables<br><br>Vocal response | Blending Segmenting onset, middle, and final phonemes<br><br>"ABD's of Reading" Systematic instruction, worksheets, and games (treatment and control groups). Treatment group also received "strategy training" involving memory and sorting by phonemes. | Letter-sound correspondence Reading words | Significant gains on blending words and segmenting words (treatment and control groups) and on segmenting syllables (control group).<br><br>No gains were shown on blending syllables (treatment and control groups) and segmenting syllable (treatment group). | Not assessed |
| Bracey et al. 1975 | Blending words Segmenting words<br><br>Vocal response | Blending words Segmenting words Rhyming words<br><br>"Distar Level 1" Systematic and sequenced instruction, skills taught to mastery, token economy. | Reading words | Significant gains on blending words (1 of 1 test). Significant gains on segmenting words (1 of 3 tests). | Not assessed |
| Cologon et al. 2011 | Blending words, non-words Segmenting words, non-words<br><br>Vocal response, picture selection | Blending onset and rhyme, words<br><br>Feedback, prompting, letter and picture selection, homework | Reading words, sentence completion | Group data showed significant gains on all skills - blending words and non-words, and segmenting words and non-words.<br><br>Individual post-test data ranges: Blending words – 50-100%, (chance 33%) Blending non-words – 17-91% Segmenting words and non-words – 12-95% | Not assessed |

Table 2 (continued)

| Reference | PPA Skills Tested and Response Topography (DV) | PPA Skills Taught and Instruction Components (IV) | Reading Skills Taught | Outcomes | Generalization Measures and Outcomes |
|---|---|---|---|---|---|
| Cupples et al. 2002 | Blending words, non-words<br><br>Segmenting words, non-words<br><br>Vocal response, picture selection | Blending onset and rhyme<br><br>Segmenting onsets<br><br>Computer-delivered, feedback, letter and picture selection, homework | Reading words, sentence completion | Post-tests showed increased accuracy for 5 of 7 participants in blending non-words (range = 17-58%).<br><br>Little or no change in accuracy for segmenting words and non-words (range = 0-40%) or blending words (range = 83-100%). | Not assessed |
| Hoogeveen et al. 1989 | Blending onset phoneme and rhyme<br><br>Vocal response | Blending onset and rhyme<br><br>Skills taught sequentially and to mastery, feedback, modeling, graduated prompting. Pictures used with one group. | None | 7 of 10 participants in no-picture prompt group and 9 of 10 participants in picture-prompt group met mastery criterion on trained words. | Blending onset and rhyme of 30 untrained words.<br><br>70% mean accuracy for participants in no-picture prompt group and 49% in picture-prompt group. |
| Hoogeveen et al. 1988 | Blending compound words, syllables, rhyme and final phonemes in words and non-words<br><br>Vocal response | Blending compound words, syllables, rhyme and final phonemes in words and non-words, words, non-words.<br><br>Skills taught sequentially and to mastery, feedback, modeling, graduated prompting and pictures. | Reading words, non-words | 7 of 7 participants met mastery criterion on trained words. | Not assessed |

Table 2 (continued)

| Reference | PPA Skills Tested and Response Topography (DV) | PPA Skills Taught and Instruction Components (IV) | Reading Skills Taught | Outcomes | Generalization Measures and Outcomes |
|---|---|---|---|---|---|
| Millar et al. 2004 | Segmenting onset phoneme<br><br>Letter selection on modified keyboard | Segmenting onsets<br><br>Graduated prompting, modeling | Letter-sound correspondences | 1 of 2 participants met 80% mastery criterion on trained words | Segment onsets of novel words represented by pictures without oral label given by instructor. 1 of 2 participants tested. Mean of 2 tests = 42% |
| Truxler et al. 2007 | Segmenting onset phoneme<br><br>Picture selection | Segmenting onsets<br><br>Story-based context, modeling, booster training without story context | Letter-sound correspondences | 0 of 2 participants met 80% mastery criterion on trained words | Segment trained phoneme in middle and final position of 12 spoken words. Range 50-54%.<br><br>Segment untrained phonemes in onset position of 10 spoken words. Range 60%. |

Table 3

*Methodology*

| Reference | Design | Data Analysis | Inter-observer Agreement | Procedural Fidelity |
|---|---|---|---|---|
| Allor, Mathes, Roberts, Cheatham et al. 2010 | Group - Random assignment | Statistical within groups and between experimental and control groups | Not reported | 92% Assessed approximately two times per year with each teacher |
| Allor, Mathes, Roberts, Jones et al. 2010 | Group - Random assignment | Statistical within groups and between experimental and control groups | Not reported | 91% Assessed three times per year with each teacher |
| Blackman et al. 1982 | Group – matched | Statistical between experimental and control groups | Not reported | Not reported |
| Bracey et al. 1975 | AB | Statistical using group means | Not reported | Not reported |
| Cologon et al. 2011 | AB * | Statistical using group means  Visual inspection of individual results | M = 99% Assessed in pre and post-tests for 2 participants | Not reported |
| Cupples et al. 2002 | AB | Statistical with individual results | Not reported | Not reported |
| Hoogeveen et al. 1989 | Group - matched with random assignment | Statistical between groups  Visual inspection of individual results | M = 98% Assessed in minimum of 24% of training and test trials across participants | Not reported |
| Hoogeveen et al. 1988 | Multiple-probe across skills | Visual inspection of individual results | M = 99% Assessed in minimum of 59% of training and test trials across participants | Not reported |

*Note.* * Two pretests delivered separated by 10 weeks. M = mean.

Table 3 (continued)

| Reference | Design | Data Analysis | Inter-observer Agreement | Procedural Fidelity |
|---|---|---|---|---|
| Millar et al. 2004 | Multiple-probe across participants | Visual inspection of individual results | Mean 96%<br>Assessed in 30% of sessions across participants | M = 95%<br>Assessed in 30% of instructional sessions across participants |
| Truxler et al. 2007 | Multiple-baseline across participants | Visual inspection of individual results | Range 96-100%<br>Assessed in 20% of probes in each phase for each participant | M = 100%<br>Assessed in 20% of instruction sessions with each participant |

*Note.* * Two pretests delivered separated by 10 weeks. M = mean.

Table 4

*NRP Identified Properties of PPA Instruction Associated with Greatest Effect Sizes*

| Reference | Training-Group Size | Number of PPA Skills Trained | PPA Training delivered with Letters | Training Length | Trainer Type |
|---|---|---|---|---|---|
| Allor, Mathes, Roberts, Cheatham et al. 2010 | 1-4 | 2 | Yes | 40-50 min per day 105 weeks * | Instructor |
| Allor, Mathes, Roberts, Jones et al. 2010 | 1-4 | 2 | Yes | 40-50 min per day 30-53 weeks * | Instructor |
| Blackman et al. 1982 | 3 | 2 | Yes | 1 hr per week 25 weeks Total = 25 hr* | Instructor |
| Bracey et al. 1975 | 6 | 3 | Yes | 15-30 min per school day 1-2 school years* | Instructor |
| Cologon et al. 2011 | 1 | 2 | Yes | 60 min sessions 10 sessions Total = 6 hr* | Instructor |
| Cupples et al. 2002 | 1 | 2 | Yes | 45-60 min sessions 6 sessions | Computer |
| Hoogeveen et al. 1989 | 1 | 1 | No | 25 min sessions 2 sessions per week | Instructor |
| Hoogeveen et al. 1988 | 1 | 1 | Yes | 20 min sessions 3-4 session per week* | Instructor |
| Millar et al. 2004 | 1 | 1 | Yes | 30-45 min 2-3 sessions per week* | Instructor |
| Truxler et al. 2007 | 1 | 1 | Yes | 30 min per day Total = 6-12.5 hr* | Instructor |

*Note.* *PPA training time not reported separately from other reading training time.

Appendix B

**Modified Assessment of Speech Intelligibility**

The Index of Augmented Speech Comprehensibility in Children (I-ASCC) (Dowden, 1997) was modified for use with adult participants by the first author. The modified assessment was conducted as described by Dowden, except where noted. This non-standardized measure of intelligibility was administered to potential study participants and the results of the assessment were a basis for participant inclusion.

A list of the 82 nouns used in the assessment of intelligibility is shown in Table B1. Words were selected from the original I-ASCC categories and word pool. The pool was modified in the current study by eliminating verbs and words that were likely to be less relevant to adults (e.g. jungle gym). All words were represented by color pictures on 8" x 10" cards. Words were placed into categories that served as contextual cues for participants and listeners.

To collect a speech sample, the experimenter sat at a table adjacent to the participant. A digital voice recorder was placed near the participant to record all vocal responses. The experimenter presented each picture card individually and implemented a three-level prompting procedure to increase the probability of a spoken response. First, the experimenter asked, "What is this?" If the participant did not respond, the experimenter delivered a prompt that included the category to which the item belonged (e.g., "This is a type of clothing.") If the participant did not respond or responded with an incorrect name, the experimenter said the name of the item in a carrier phrase (e.g., "This is a coat") then again asked, "What is this?"

The recordings were edited to include only participants' spoken responses. All vocal prompts from the experimenter were deleted to prevent listeners from hearing cues that might affect their transcription of the speech sample. Two listeners who were unfamiliar with the

participants scored the recordings in three presentation conditions. In each condition, the listeners transcribed each word they heard or a dash if they could not determine what the speaker had said. In the initial presentation of a participant's recorded speech, the listener heard each word but was given no cues to aid in transcription. In the second presentation of the recording, the listeners were given a contextual cue (i.e., the category to which the word belonged) before they heard each response. In the final presentation, the experimenter specified the first letter of the word that the participant was speaking. This condition differed from the third condition in Dowden (1997) in which listeners were given both the context and the letter prior to transcribing each word.

Intelligibility was calculated for each condition. That is, the percentage of words a listener correctly transcribed was calculated when the spoken response was presented (a) without cues, (b) with a contextual cue, and (c) with a letter cue. In each condition, the number of words that a listener correctly transcribed was divided by the total number of words and multiplied by 100. Scores from the two listeners were added and then divided by two for a mean percentage intelligibility for each participant in each condition. The intelligibility score from the condition without contextual or letter cues was the basis for participant inclusion.

References

Dowden, P. A. (1997). Augmentative and alternative communication decision making for

children with severely unintelligible speech. *Augmentative and Alternative*

*Communication, 13,* 48-58.

Table B1

*Modified I-ASCC Word List by Category*

| Category | Words | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Five | Two | Six | One | Nine | Seven | Four | Eight | Three | Ten |
| Numbers less than 11 | | | | | | | | | | |
| Fruits and vegetables | Grapes | Banana | Carrots | Apple | Orange | Beans | Cherries | Corn | Watermelon | |
| People at work | Nurse | Policeman | Teacher | Mailman | Doctor | Clown | Fireman | | | |
| Things kids play with | Blocks | Balls | Wagon | Bicycle | Balloon | | | | | |
| Zoo animals | Lion | Tiger | Monkey | Zebra | Giraffe | Owl | Bear | | | |
| Vehicles | Airplane | Car | Ship | Bus | Train | Helicopter | Boat | | | |
| Farm animals | Cow | Pig | Horse | Sheep | Chicken | Dog | Cat | Rabbit | Mouse | |
| Colors | Green | Purple | Red | White | Yellow | Brown | Orange | Black | Blue | |
| Clothing | Shoes | Dress | Shirt | Boots | Mittens | Pants | Hat | Coat | Shorts | |
| Food | Noodles | Hotdog | Eggs | Pancakes | Fish | Meat | Potato | Sandwich | Soup | Bread |