Research Article

Developing the Alphabetic Principle to Aid Text-Based Augmentative and Alternative Communication Use by Adults With Low Speech Intelligibility and Intellectual Disabilities

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Purpose: We explored alphabet supplementation as an augmentative and alternative communication strategy for adults with minimal literacy. Study 1's goal was to teach onset-letter selection with spoken words and assess generalization to untaught words, demonstrating the alphabetic principle. Study 2 incorporated alphabet supplementation within a naming task and then assessed effects on speech intelligibility.

Method: Three men with intellectual disabilities (ID) and low speech intelligibility participated. Study 1 used a multiple-probe design, across three 20-word sets, to show that our computer-based training improved onset-letter selection. We also probed generalization to untrained words. Study 2 taught onset-letter selection for 30 new words chosen for

functionality. Five listeners transcribed speech samples of the 30 words in 2 conditions: speech only and speech with alphabet supplementation.

Results: Across studies 1 and 2, participants demonstrated onset-letter selection for at least 90 words. Study 1 showed evidence of the alphabetic principle for some but not all word sets. In study 2, participants readily used alphabet supplementation, enabling listeners to understand twice as many words.

Conclusions: This is the first demonstration of alphabet supplementation in individuals with ID and minimal literacy. The large number of words learned holds promise both for improving communication and providing a foundation for improved literacy.

The communication and language skills of most individuals with intellectual disabilities (ID) lag far behind those of their typically developing peers. (Miller & Chapman, 1984; Rosenberg & Abbeduto, 1993). Many individuals with ID speak, but their speech can be difficult to understand, particularly for unfamiliar listeners (Powell & Clibbens, 1994). Individuals with ID who have low speech intelligibility are increasingly learning to augment their speech through various means, such as using graphic images (Wilkinson & Hennig, 2007). Printed words and letters can also be used to augment speech. Their use, however, requires literacy skills that many individuals with ID may not have acquired.

Speech intelligibility can be defined as the extent to which an individual's speech is understandable to listeners (Hustad, Oakes, & Allison, 2015; Kent, 1993; Kent, Weismer, Kent, & Rosenbeck, 1989; Yorkston, Strand, & Kennedy, 1996). Intelligibility is dependent on many factors, including the context of the communication, the listener's familiarity with the speaker's speech, and the sound quality of the speech (Kent et al., 1989; Yorkston et al., 1996). One way to assess speech intelligibility is to present a recorded sample of an individual's speech to a listener, who transcribes what he or she hears. The number of correctly transcribed words is divided by the total number of words in the speech sample and results in a percentage of intelligibility (see Beliveau, Hodge, & Hagler, 1995; Beukelman & Yorkston, 1977; Dowden, 1997; Hustad, 2001; Hustad & Beukelman, 2001).

Low speech intelligibility can be a significant barrier to effective communication, and thus increasing intelligibility is an important intervention objective (Beliveau et al., 1995;

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Kent, 1993; Kent et al., 1989). Intelligibility can be improved by interventions aimed at improving articulation. In addition, researchers have evaluated the efficacy of augmentative communication strategies such as 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).

Speech-supplementation research has been conducted primarily with literate adults who have motor speech impairments (e.g., dysarthria) due to stroke, traumatic brain injury, Parkinson's disease, or other chronic conditions. Within these populations, the alphabet-supplementation strategy has been shown to be highly effective. In this strategy, the speaker selects the first letter of the word he or she is speaking on an augmentative device. The listener hears the spoken word and also sees the letter cue. The added letter cue increases the probability that the listener will understand the speaker's speech (Beukelman & Yorkston, 1977; Hustad & Garcia, 2005; Hustad, Jones, & Dailey, 2003).

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 and six sentences spoken by the participants. Speech samples 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 effects of slowed speech from effects of the letter cue itself. Results showed that when alphabet cues were visible, intelligibility was substantially higher than in the other conditions for both participants.

Subsequent studies, also with literate adults, have shown similar beneficial effects. Hustad and Lee (2008) found that alphabet supplementation increased levels of intelligibility over that of nonsupplemented speech for each of 12 participants. In multiple studies that compared the effects of supplemental alphabet cues, topic cues, and a combination of alphabet and topic cues, results have shown that the combination was most effective, followed by alphabet cues alone and topic cues alone (Dowden, 1997; Hustad, Auken, Natale, & Carlson, 2003; Hustad & Beukelman, 2001; Hustad, Jones et al., 2003).

To date, participants in published research on alphabet supplementation have had age-appropriate reading and spelling skills. No published research has addressed effects of this augmentative-communication strategy on the speech intelligibility of individuals who have ID or who have very limited reading skills. However, individuals with limited

reading skills could benefit from alphabet supplementation if they could select the first letter of words. Selecting just the first letter of a word, as in Beukelman and Yorkston (1977), can provide a substantial increase in intelligibility. Functional communication could be enhanced for individuals who learn to apply this skill to words most likely to be used in daily life. Thus, a primary goal of the current study was to determine whether we could teach individuals with ID and very limited reading skills to select onset letters (i.e., the letter corresponding to the first sound) for a large number of spoken words.

One strategy would be to teach onset-letter selection through rote memorization—a strategy that has been successful for teaching sight-word reading (for reviews, see Conners, 1992; Browder & Lalli, 1991; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Browder & Xin, 1998). Although memorizing the onset letters of frequently used words might be good for establishing rudimentary alphabet supplementation, this strategy would limit the use of supplementation to words that are taught directly. This constraint, however, would be minimized for individuals who have an understanding of the alphabetic principle.

The term *alphabetic principle* refers to the knowledge that specific units of print map on to specific units of sound (Byrne & Fielding-Barnsley, 1989). Selecting the first letter for spoken words that have not been taught would reflect the alphabetic principle. For example, an individual who has been taught to select the letter F upon hearing “fell” and “family” could also select F when hearing “fish” and “fan” without direct teaching. Note that phonemic awareness is a component of the alphabetic principle. Learners must recognize that fish and fan begin with the same sound as fell and family (i.e., phonemic awareness) in order to select the letter F.

Because acquisition of the alphabetic principle would greatly increase the number of spoken words with which alphabet supplementation could be used, an additional research goal was to explore methods for establishing the alphabetic principle. Research on instruction of the alphabetic principle and phonemic awareness in individuals with ID is limited, despite its well-documented importance for typically developing individuals (National Reading Panel [NRP], 2000) and increasing evidence that these skills are equally important to reading in individuals with ID (e.g., Saunders & DeFulio, 2007; Wise, Sevcik, Ronski & Morris, 2010).

Segmenting—separating a word into its component phonemes—is a phonemic-awareness skill that is especially relevant to the goal of developing the alphabetic principle. That is, one element of learning to select the onset letter that corresponds to the onset sound is separating the onset sound from the rest of the word. A few studies have provided some evidence that individuals with ID can be taught segmenting (e.g., hearing a word and saying each phoneme). Hoogeveen, Birkhoff, Smeets, Lancioni, and Boelens (1989) targeted segmentation of final phonemes in 60 words with 16 children who had moderate ID (etiology unspecified). In training, each target word was spoken by the experimenter

with a pause before the final phoneme. Pause length was decreased gradually until the word was spoken without a pause. Participants were required to speak the word with a pause. All participants were highly accurate with taught words, and 11 participants showed generalization to untrained words.

Kennedy and Flynn (2003) targeted onset-phoneme segmenting for three children with Down syndrome. The experimenter named six pictures in an array and presented a phoneme that matched the onset sound of one of the pictures. The participant's task was to select the correct picture. Training increased segmentation accuracy for all participants. Two between-groups studies, Allor, Mathes, Roberts, Jones, and Champlin (2010) and Allor, Mathes, Roberts, Cheatham, and Champlin (2010), evaluated the effects of a multicomponent reading program on phoneme blending and segmenting with 28 and 59 children, respectively, with mild to moderate ID. Treatment groups received daily direct instruction on segmenting syllables and phonemes; control groups received no explicit segmentation training. In both studies, significant differences were shown between groups, with treatment groups showing significant gains in segmenting words.

Segmenting also underlies the ability to select the onset letter when presented with the entire spoken word. Millar, Light, and McNaughton (2004) demonstrated that this skill can be taught to individuals with ID. Three children with neurological disorders (e.g., cerebral palsy), severely impaired speech, and ID were taught to select five onset letters on an adaptive keyboard in response to spoken words that began with the corresponding letter sounds. Although one participant did not learn to discriminate between target onsets and therefore did not complete the study, two participants learned to select onset letters of spoken words that were directly taught, and one showed generalization to untaught words. Such generalization demonstrates understanding of the alphabetic principle.

A series of studies by Saunders and colleagues devised tasks requiring word segmentation and understanding of the alphabetic principle. The studies operationalized the alphabetic principle similar to the methods used in the seminal studies by Byrne and Fielding-Barnsley (1989). Participants listened to spoken words and either spelled them by touching individual letters in a choice pool (Stewart, Hayashi, & Saunders, 2010) or selected the whole word from a choice pool of similar words (Saunders, 2011; Saunders, O'Donnell, Vaidya, & Williams, 2003). After learning words with elements in common (e.g., pat, mat, mop, mug), participants demonstrated generalization to untaught words that recombined phonemes in taught words (e.g., pop, pug). Although these demonstrations of generalization are promising, this small body of research included only six participants and did not include individuals below the mild to moderate level of ID.

Here, in two studies, we explore the feasibility of alphabet supplementation as an augmentative communication strategy for adults with ID and limited to no reading skills. In study 1, we tested procedures for establishing a repertoire of onset-letter selection for at least 60 spoken

words. In study 2, we integrated onset-letter selection into a naming task and assessed participants' intelligibility with and without alphabet supplementation using listeners who were not familiar with the participants' speech.

Study 1: Establishing Onset-Letter Selection

Study 1 addressed several questions related to the goal of teaching adults with ID and low speech intelligibility to select the onset letter for a large number of spoken words. We sought to teach 60 words with the onsets M, C, T, S, P, and L (10 words per onset letter). The first question was whether teaching participants to select the correct letter when they heard each of the six onset phonemes in isolation (i.e., onset-sound to letter training) would increase accuracy in the spoken-word to onset-letter task. That is, would letter-sound training alone promote generalization to selecting initial letters when corresponding whole spoken words were presented as stimuli?

Our second question was whether the 60 spoken-word to onset-letter relations could be taught directly, if need be. Our third question was whether teaching multiple exemplars of spoken words with the same onsets would lead to generalization to untaught words. The exemplar words were given in minimal pairs differing in onset only (e.g., mall & call, map & cap, etc.). The letter-selection task provided a means of segmenting (and categorizing) the onset sounds (see Ehri, Wilce, & Taylor, 1987). Selecting the correct onset letter via generalization demonstrated the alphabetic principle. Thus, the procedure was designed to teach phonological awareness and the alphabetic principle simultaneously.

A positive outcome would greatly expand the potential contribution of these procedures to communication repertoires. An individual who demonstrates the alphabetic principle could conceivably use alphabet supplementation for any word in his or her communication repertoire (and not just words that had been specifically taught).

Method

Participants

Three men with ID of unknown etiology were nominated by their work supervisors as having difficult-to-understand speech. Aaron, Mark, and Jimmy (pseudonyms) were primarily speech communicators in their daily work environment, and none had been using augmentative communication. Aaron spoke in complete sentences, and Mark and Jimmy spoke in two- to three-word phrases. To assess intelligibility, we modified the Index of Augmented Speech Comprehensibility in Children (Dowden, 1997) for use with adult participants (described in Appendix A). Mean intelligibility for the participants was 28% for Aaron, 14% for Mark, and 10% for Jimmy across two unfamiliar listeners.

In addition to low speech intelligibility, inclusion criteria were (a) hearing within normal range and (b) at

least 90% accuracy on a receptive letter-identification task. To ensure that participants had no difficulty performing the computerized matching-to-sample task and/or discriminating the spoken and printed stimuli to be used in the study, we also presented several practice tasks. See the “Pretraining” section for more detail.

Table 1 shows additional participant characteristics. Peabody Picture Vocabulary Test–Fourth Edition (Dunn & Dunn, 2007) standard scores were 20 for both Mark and Jimmy and 43 for Aaron. Note also Mark’s and Jimmy’s low letter–sound knowledge and scores on the Woodcock Reading Mastery Tests–Revised (Woodcock, 1987), which reflect zero correct responses on the word-attack test (reading nonwords) and five or fewer on the word-identification test (sight words).

Mark and Jimmy participated in all study procedures. Aaron scored at mastery level in the baseline comprehensive test and therefore did not participate in the primary training conditions of study 1. Aaron did experience the two tasks designed to transition to study 2, which will be described in a later section.

Setting, Apparatus, and Stimuli

Sessions had 30 trials, and between one and five sessions were conducted on weekdays in the participants’ work environment. Because the study was conducted during the participants’ workday, sessions were brief, ranging from 2.4 to 5 min (recorded by the computer from the beginning of the first trial to the end of the last). Mark and Jimmy completed the study in 191 and 206 session days, respectively. Cumulated session time for study 1 was approximately 25 hr. For each day, participants accrued \$1.00 plus \$.05 per correct response. They used this money to purchase items of their choosing at local discount stores approximately once per month throughout the study.

Sessions were presented on a laptop with a touch-sensitive screen. Matching-to-sample software (Dube, 1991) controlled all aspects of sessions and recorded responses. Stimuli were capital letters, used due to their prevalence on keyboards, in 3 cm, black Arial font. Spoken words and letter sounds were recordings in female voice (the first author’s), presented through the computer speakers.

The participants’ work supervisors identified words that they considered to be functional for the participants from

a 744-word vocabulary list (Yorkston, Dowden, Honsinger, Marriner, & Smith, 1988). From the supervisors’ lists, we selected single-syllable words that began with frequently occurring letters and from which minimal pairs of words differing only in onsets could be formed (e.g., mall, call). Although we attempted to maximize the number of real words, our method of promoting the alphabetic principle via minimal pairs necessitated the inclusion of eight non-words, as well as some words that were not on the vocabulary list.

Six onset letters were selected and taught in three pairs: M and C, T and S, and P and L. Pairings consisted of visually dissimilar letters with one continuant and one stop sound. In each word set, the two onset letters were combined with 10 rimes (i.e., vowel and final consonant), resulting in 10 word pairs per set, for a total of 60 words (see Table 2). In training and testing, the onset-letter choices were presented exclusively in these pairs. That is, M was only presented with C, T was only presented with S, and P was only presented with L.

Procedures

Matching-to-Sample Task

For each trial, a spoken-word “sample” was repeated every 1.5 s, and a black square was presented in the screen’s center (see Figure 1). Touching the square removed it from the screen, and “choice” letters appeared, one in each corner. When the procedures included feedback, selecting the correct letter produced chimes and colored stars. Selecting an incorrect letter produced a buzz with a black screen. Feedback was included in training sessions and in comprehensive test sessions. Feedback was omitted from generalization test sessions, because they contained multiple trials of only two different stimuli, and so there was a chance of learning during the test. In each type of session, the experimenter delivered praise for effort (e.g., “Super job working so hard!”) two to four times.

Pretraining. To familiarize participants with the touchscreen and computerized procedures before the baseline comprehensive test was given, we conducted three types of matching-to-sample sessions, all with a four-choice format. Two were identity-matching sessions: picture matching, to introduce participants to the computerized task, and capital-letter matching, because capital letters

Table 1. Participant characteristics.

Participant	Age	Speech intelligibility ^a (%)	PPVT ^b	Word identification ^c	Word attack ^c	Receptive letter identification ^d	Receptive letter–sound identification ^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

^aModified assessment of speech intelligibility. Scores are reported as percentage of speech sample correctly transcribed by listeners.

^bPeabody Picture Vocabulary Test–Fourth Edition (PPVT). Standard scores are reported. ^cWoodcock Reading Mastery Tests–Revised. Scores are reported as grade level:months. ^dFour-choice experimenter-constructed assessment. Scores are reported as total number of letters of the alphabet correctly identified. ^eFour-choice experimenter-constructed assessment. Scores are reported as percentage of correct responses.

Table 2. Study 1 word sets.

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

were used in the study. Trials were as described above, except that instead of a spoken word, a picture or letter was presented in the middle of the screen, and participants selected the matching stimulus from among four choices. The third pretraining session, meant to familiarize participants with procedures that included spoken words, required participants to select pictures of common objects (e.g., scissors, train, baby) when the computer presented the spoken name. All participants met a 90% mastery criterion after three of each pretraining session.

Comprehensive tests. These tested accuracy of onset-letter selection, in a two-choice format, upon hearing each of the 60 spoken words. Each word was presented twice in the baseline comprehensive test and once in all subsequent comprehensive tests. The baseline test was presented after pretraining.

Because we expected accuracy to be low on test trials, two features of the comprehensive test were designed to maintain participation. First, we intermixed 15 known spoken-word to picture trials with the test trials. Second, all responses produced feedback (described in the matching-to-sample section, above). Thus, at least 75% of trials produced positive feedback, all of the picture trials and approximately half of the letter trials (assuming chance performance).

Experimental Questions and Design

Study 1 addressed three questions, all related to establishing onset-letter selection for 60 spoken words.

Question 1: Would Onset-Sound to Letter Training Increase Accuracy in the Spoken-Word to Onset-Letter Selection Task?

After the baseline comprehensive test, we taught all six onset sounds targeted in the study (/m/, /k/, /t/, /s/, /p/, /l/). In this task, the isolated onset sound was presented as the sample stimulus (e.g., /m/), and the participant selected between the pair of printed letters (e.g., M and C) on the computer screen. Once all three pairs of onsets had been taught (using the full training procedures described below), the comprehensive test was presented to determine whether training increased accuracy of selecting the onset letters of the 60 spoken words. If accuracy was less than 90%, we initiated the procedures for question 2.

Question 2: Could Our Multiple-Exemplar Teaching Procedures Establish Highly Accurate Performance and Maintenance of the 60 Targeted Spoken-Word to Onset-Letter Relations?

We used a multiple-probe design (cf. Horner & Baer, 1978) across the three word sets to determine whether our teaching procedures were responsible for increases in accuracy. A comprehensive test was presented each time all word pairs in a set had been taught. Increases in accuracy for a word set when and only when that set had been taught would support the conclusion that our procedures produced the increase. The order in which the three word sets were trained was individualized on the basis of the accuracy in the baseline comprehensive test. For each participant, the highest-accuracy set was taught first and the lowest set was taught last, because lower-accuracy sets provided the best baseline against which to assess effects of training.

Question 3: Would Multiple-Exemplar Training Result in Generalization to Other Words With the Same Onsets as Taught Words?

This question was addressed in conjunction with question 1. The procedures were replicated across the three word sets. Within each word set, word pairs were taught one at a time. Each time a word pair was mastered, a test for generalization to the next word pair was given before that pair was directly taught. Thus, the procedures allowed up to nine generalization tests per word set (i.e., the second word pair was tested after the first word pair was taught, the third word pair was tested after the second pair was

Figure 1. Computer screen displays for one trial of onset-letter selection training.

taught, and so on). Figure 2 shows the training and testing sequence within a word set. When the participant mastered all word pairs in a set, the comprehensive test was presented again. This sequence was replicated for each word set.

Generalization tests. Sessions contained five trials of each word in the new untrained pair intermixed with 20 trials of the most recently trained word pair. There was no feedback delivered. We defined generalization as 90% accuracy. If accuracy was less than 90%, we initiated spoken-word to onset-letter training.

Spoken-word to onset-letter training. Depending on the outcome of the generalization test for a new word pair, participants received either full or abbreviated training procedures that differed in intensity and duration (procedures available from the authors upon request). Full training was delivered if accuracy was below 80% in a generalization test. Designed to minimize errors, these sessions began with trials that had the correct onset letter displayed in the center of the screen (as a visual prompt). The prompt was removed after several correct responses. This sequence was first conducted with the same spoken word presented in all trials and then with the second spoken word in the pair. After criterion was met for each of the two words, they were intermixed across trials. This training required a minimum of

three sessions, two with feedback and one without feedback. The sessions without feedback were presented to ensure that accuracy remained high without feedback, as would be the procedure in generalization tests.

If generalization-test accuracy was 80% or greater, an abbreviated form of training was delivered. The purpose was to provide additional practice with the new word pair, because the generalization test contained only 10 trials with the pair and no feedback. This training required only two sessions (one with feedback and one without) and had no prompting. When a 90% accuracy criterion on each word was met in either the full or abbreviated training sessions, maintenance sessions were conducted.

Maintenance sessions. These were presented after the first three word pairs in a set had been trained and again after each subsequent pair. Sessions included all previously mastered words in the set, and they served two purposes. First, they provided concentrated practice in selecting the same onset letter for multiple exemplars of words with the two onset letters in the set. Second, they demonstrated and promoted maintenance of taught words over time. If a 90% accuracy criterion was not met, training was repeated for words on which errors had been made. The maintenance session was then redelivered.

Figure 2. Flowchart of training and testing sequence within a single word set.

Transition to Study 2

After the final comprehensive test, we presented two conditions designed to facilitate the transition from selecting between unchanging pairs of letters presented on a computer screen (e.g., M always paired with C) to selecting from six letters on a QWERTY keyboard. These procedures are described in Appendix B.

Results

Questions 1 and 2

Data that address the effects of onset-sound to letter training (question 1), and the question of whether our multiple-exemplar teaching procedures produced high accuracy of onset-letter selection with spoken words (question 2), are shown in Figure 3. The figure shows results for all five presentations of the comprehensive test for Mark (left) and Jimmy (right). Each horizontal panel shows accuracy for one of the three word sets, with the set taught first at the top. The leftmost bars in each panel show accuracy in the baseline comprehensive test. For both participants, accuracy was above chance levels for the set taught first. Accuracy on other sets ranged from 55% to 70% across participants.

The first phase-change line indicates the completion of onset-sound to letter training. Mark and Jimmy completed training in 11 and 14 sessions, respectively. In the subsequent comprehensive test, neither participant showed increased onset-selection accuracy.

The second phase-change line indicates the completion of spoken-word to onset-letter training for all words in each of the three individual word sets. For both participants,

Figure 3. The 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. The first phase line indicates the completion of sound to letter training. The second phase line indicates the completion of spoken-word to onset-letter training.

accuracy of onset-letter selection increased markedly above baseline levels when and only when training was completed for a given word set. Thus, in six opportunities to demonstrate that our teaching procedures produced high accuracy, the study showed six positive outcomes.

Question 3

Figure 4 shows the extent to which the multiple-exemplar teaching procedures led to the demonstration of the alphabetic principle, which we defined as achieving 90% accuracy in the final three consecutive generalization tests within a word set. We always completed the testing/teaching cycle for all 10 pretested word pairs in each set (shown as striped bars on the figure). If a participant did not meet the generalization criterion within the 10 pretested word pairs, we continued the teaching and testing sequence with added word pairs that had not been pretested (shown as solid bars). We discontinued training words within a set either when accuracy was 90% correct for three consecutive tests or after a maximum of nine additional pairs had been tested.

The order in which word pairs were tested, and then taught, is shown along the *x*-axis. Bars show accuracy on each generalization test (i.e., for each word pair). For comparison purposes, triangles show accuracy on each word pair in the baseline comprehensive test. Note that we placed word pairs that were least accurate on the baseline test at the end of the testing sequence.

Mark met the generalization criterion within the first 10 word pairs in the first word set (T/S onsets; top panel

of Figure 4). He achieved three consecutive generalization tests with 90% accuracy after three added word pairs in his second word set (M/C; second panel). For his final word set (P/L; bottom panel), accuracy was highly variable and markedly lower than in the first two word sets. We speculated that motivational factors played a role. To explore this possibility, we added feedback to the tests for the final five added word pairs. If high accuracy was shown with feedback, we repeated the test for that word pair under typical procedures, without feedback. The black bars show that, with feedback, test accuracy increased immediately and was virtually perfect across all five of the word pairs. Accuracy remained high when feedback was removed for four of these five word pairs (the gray bars after each black bar). This concluded the predetermined maximum of nine added pairs.

Jimmy achieved three consecutive tests with 90% accuracy in the first two word sets, M/C and T/S, but with three and seven added word pairs, respectively. Jimmy did not meet this criterion in the P/L set, and training was discontinued when nine additional word pairs had been trained.

In summary, across participants, we obtained three consecutive generalization tests with accuracy of at least 90% in five of six opportunities. In all but one, however, participants reached this level with word pairs that were not pretested.

Discussion: Study 1

The overarching goal of study 1 was to establish a large number of spoken-word to onset-letter relations. Mark's 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. Both participants learned to select the onset of the 60 original study words and maintained high accuracy with taught onset letters across subsequent comprehensive tests. By the study's end, the two participants selected onset letters for 78 and 92 words, respectively.

Our goals also included exploring procedures for establishing the alphabetic principle. To that end, we asked whether teaching target letter sounds (receptively) and multiple exemplars of word pairs with target letter sounds would promote the development of the alphabetic principle (albeit limited to onset letters). Prior to any training, accuracy on receptive letter-sound knowledge was low for Mark and Jimmy. During onset-sound to letter training, both participants made very few errors and completed training in close to the minimum number of sessions possible. In the comprehensive tests that immediately followed, however, there was no evidence that onset-sound to letter training alone increased onset-letter selection with spoken words.

These results are consistent with the current consensus that letter-sound knowledge alone is not sufficient for establishing the alphabetic principle (Byrne & Fielding-Barnsley, 1989; NRP, 2000). In addition to letter-sound knowledge, learners must develop phonological awareness (Byrne &

Figure 4. The percentage of correct onset-letter selections in generalization tests for Mark and Jimmy. Rimes within the word pairs are shown along the x-axis, and the onsets are shown within the field of each graph. For example, Mark's first word pair was sip/tip. White triangles show pretest data, and bars show generalization (untrained word pairs). Solid gray bars represent added word pairs (not pretested). For Mark's final five word pairs, we tested first without feedback (black bars), and then without feedback on every test trial.

Fielding-Barnsley, 1989; NRP, 2000). Our letter-selection task was designed to teach phonemic awareness by providing a means of segmenting (and categorizing) the onset sounds (see Ehri et al., 1987). Selecting the correct onset letter via generalization demonstrated phonemic awareness and the alphabetic principle.

Although our multiple-exemplar procedures effectively taught Mark and Jimmy to select the onset letters of spoken words, generalization tests following training showed equivocal results. For most word sets, achieving three consecutive generalization tests with accuracy of at least 90% required more than the original 10 word pairs that had been pretested. Because we did not have baseline data for the additional words, we cannot be certain that high accuracy reflected generalization rather than preexisting skills. It is worth noting, however, that many of the added words were either nonwords or very low-frequency words. It is generally accepted that testing nonwords rules out previous learning (in tests of decoding, for example). Further, for the word sets to which this concern most applies (the second sets for both participants and the third set for Mark), there was no more than one word pair with 90% accuracy in the pretest. In future work, it may be important to pretest more word pairs.

In considering the potential for demonstrating the alphabetic principle in individuals with ID and this level of literacy, the results encourage further study. Both participants showed higher pretest accuracy with one onset pair (i.e., one word set). Although we do not know why accuracy was higher for some onset pairs in the pretest, it is possible that participants had more experience with these sounds. If so, additional teaching of letter pairs with lower pretest accuracy might produce generalization.

In addition, our teaching procedures can no doubt be improved. For example, we could integrate the onset-sound to letter training with the multiple-exemplar training, perhaps by initially presenting exemplars with the initial phoneme elongated/exaggerated (i.e., it would sound more like the isolated phoneme). Another option is to focus initially on the larger, consonant-vowel portion of a syllable and require discrimination of words on the basis of units of two phonemes rather than just one (e.g., cat/mut, can/mun, cab/mub). This strategy is based on research showing that phonological awareness for larger linguistic units develops before awareness of individual phonemes (Lieberman, Shankweiler, Fischer, & Carter, 1974).

Generalization outcomes might also be improved if test trials incorporated feedback. Although we do not have

definitive evidence that feedback was responsible for the high accuracy shown when feedback was added in Mark's P/L word set, the immediate large increases in accuracy and the consistency across tests suggest that feedback was helpful. There was a single error in 50 test trials across five word pairs. In research, however, it is traditional to test without feedback, with the rationale that high accuracy could result from learning rather than via generalization. Future work should devise ways of resolving the interpretation issue without eliminating feedback. One solution might be to provide feedback but evaluate generalization in the first few trials only. The logic is that feedback would not affect accuracy in the first trials. It is worth noting that feedback creates an interpretation problem only when accuracy is high (Sidman, 1981). Low accuracy with feedback strengthens the conclusion that participants lack the skill.

Last, we used a minimal-pairs procedure to force attention to the onset letters. High accuracy in a two-choice task can be misleading, however, as to whether both sound-letter relations have been learned (Sidman, 1987). For example, with S and T always presented together, a participant might learn to select S upon hearing /s/ and to exclude S when the onset phoneme is /t/ (i.e., not /s/). Thus, high accuracy could be achieved by learning one relation (/s/ = S). If so, transition to the six-choice task would not be successful. Thus, in preparing for this transition, we first ensured that high accuracy was maintained when letters were presented in differing pairs. This ensured that participants learned all six onset-letter relations and did not simply "respond away" from some letters.

Study 2: Speech With Alphabet Supplementation

The onset-letter selection skill established in study 1 is one of several component skills comprising alphabet-supplemented speech. In study 2, we sought to establish the remaining skills that would enable participants to demonstrate alphabet supplementation with a keyboard.

Method

Participants

Two categories of participants were involved in study 2: speakers and listeners. Speakers were the three men who had participated in study 1. The listeners were five adults who were native English speakers and who reported having no hearing difficulties and only incidental experience communicating with individuals with severe speech impairments or ID. All listeners were college graduates, and their mean age was 39. The speakers were unknown to the listeners.

Apparatus and Materials

The laptop described in study 1 was used for computerized tasks. Printed color pictures, 7.6 cm × 12.7 cm,

represented each study word. To serve as the augmentative communication device (i.e., alphabet-supplementation board), a stand-alone QWERTY keyboard was covered with a metal keyguard that allowed only the six capital letters targeted in the current studies to be shown.

Participants' vocal and letter-selection responses were recorded with a JVC GZ-MG130U camcorder in a quiet room; background noise was negligible. Videos were presented to listeners on a 76-cm liquid crystal display computer monitor using Apple QuickTime player and added speakers. Audio levels were approximately 60 dB SPL.

Word Sets

For each of the onset letters used in study 1 (/m/, /k/, /t/, /s/, /p/, /l/), we chose five easily pictured nouns (see Table 3). To include words that might be familiar to the participants, and potentially functional in their daily lives, some were multisyllable nouns (e.g., medicine).

Procedure for Establishing Supplemented Speech

Training and testing were broken into five steps for research purposes. When participants passed step 5, indicating that they performed the supplemented-speech task with high accuracy, their speech intelligibility was assessed by unfamiliar listeners. We will describe each step's procedures and results together.

Step 1: Pretraining—Picture Naming

Before pretesting performance of the supplemented-speech task, we ensured that participants' names for the pictures were the same as we assumed (because names had to begin with the target onsets). We assessed naming accuracy and then remediated errors (description available from the authors). Aaron, Mark, and Jimmy initially correctly named 87%, 79%, and 73%, respectively. After training, they all scored 100%.

Step 2: Pretest—Speech With Alphabet Supplementation

This step determined whether participants performed the terminal communication act—naming pictures and selecting the onset letter on the QWERTY keyboard—given only verbal instructions. If not, we taught component skills in steps 3 and 4.

Procedure. The participant sat at a table in front of the keyboard fitted with a keyguard. Gesturing to the

Table 3. Study 2 words.

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

keyboard, the experimenter said, "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 and asked, "What is it?" If no response was made, the next trial was initiated. If the participant named the picture within 5 s, 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. There was no feedback related to performance, but participants were praised for effort approximately every five trials. Accuracy of picture naming and letter selection was recorded separately. Procedures for assessing interobserver agreement in scoring vocal responses and letter selection on the keyboard are described in Appendix C.

Results. None of the participants made more than one picture-naming error. Aaron selected the corresponding onset letter for 27 of 30 words and received one training session (described in step 5) to meet the 100% mastery criterion for the task. Mark made no letter selections. Although Jimmy selected a letter on 24 trials, accuracy was close to chance levels (23%).

Step 3: Spoken-Word to Onset-Letter Task—Pretest, Training, and Posttest

The goal was to ensure that participants selected the correct onset letter when they heard each word. Using the touchscreen, we assessed all words, and then we provided training for words on which participants made errors.

Procedure. We used matching-to-sample procedures such as those described in study 1, except within a six-choice task. In the pretest, the 30 words were presented once each as a spoken sample. Thirty known spoken-word to onset-letter trials from study 1 were intermixed. The 60 trials were divided into two sessions.

Words on which participants made errors in the pretest were trained in pairs with different onsets. Unlike study 1, however, words in a pair did not have identical rimes. We used a condensed version of the study 1 training procedures (available from the authors upon request). After all words were taught, sessions included a mixture of all taught words. Accuracy of at least 90% overall, with no more than one error on a specific word, was required to move to the posttest.

Results. In the pretest, Mark and Jimmy selected the correct onset letter for 21 and 12 of the 30 study 2 words, respectively. In a six-choice task, we would expect five correct selections by chance; thus, both performed above chance levels. Sessions were 2.4 to 5 min in duration, and teaching was completed in 20 and 18 days, respectively. After teaching, accuracy was 97% and 100%, respectively.

Step 4: Communication Practice Task—Pretest, Training, and Posttest

At this point, participants had learned to select letters when they heard a spoken word. In our alphabet-supplementation task, however, spoken words were not presented. Instead, participants were required to name a

picture and point to its onset letter. To avoid changing two skill components at once, we designed an intermediate practice step that was the same as the alphabet-supplementation task in that participants named pictures and selected onset letters, but it was conducted on the familiar computer screen.

Procedure. For each trial, one of the 30 pictures was presented in the screen's center. The experimenter asked, "What is it?" After the participant named the picture, he touched the screen, and the six onset-letter choices appeared. The participant then selected the letter that corresponded to the onset sound of the picture name.

If accuracy in this pretest was less than 100% for both naming the picture and selecting the onset letter, we taught the words on which the participant had erred. Training sessions consisted of 15 picture to onset-letter trials, with picture naming required (described above). If the participant named the picture incorrectly or did not provide a response within 5 s, the experimenter named the picture and required the participant to repeat the name before touching the picture to continue the trial. The computer delivered differential feedback for onset-letter selection, and 15 familiar spoken-word to picture trials were interspersed in the session to ensure some positive feedback. When the 100% accuracy criterion for trials requiring picture naming was met, a posttest of the practice task was delivered.

Results. Both Mark and Jimmy accurately named all 30 pictures in the practice task. For onset-letter selection, they scored 83% and 90%, respectively. After additional training for the error words, which required 4 and 2 days, respectively, they both achieved 100% accuracy on naming and letter-selection responses.

Step 5: Posttest—Speech With Alphabet Supplementation

This test was delivered after all necessary training steps were completed.

Procedure. The posttest differed from step 4 in that pictures were presented by the experimenter and letters were selected on the keyboard rather than the computer screen. This posttest was procedurally identical to the pretest. If 100% accuracy was not met, participants received training sessions in which the experimenter modeled naming the picture or correct letter selection, depending on the type of error. The posttest was then repeated.

Results. Jimmy responded with 100% accuracy on both picture-naming and onset-letter selection tasks. 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 listeners' transcription of the participants' speech, we made video recordings of participants saying the 30 study 2 words before and after they began using the augmentative keyboard. Words were presented in a different order across tests and participants. Listeners could see the keyboard, which was present in all recordings, but not the participants' faces.

Procedure

In individual sessions, five listeners transcribed each participant's speech from the video recordings. A minimum of 1 week and maximum of 2 weeks separated listeners' transcription of speech without alphabet supplementation (presented first) and with supplementation (presented second). Listeners were seated 1 m from a computer monitor, and recordings were played at audio levels equivalent to conversational speech. For the tests without alphabet supplementation, instructions were (a) listen to each word spoken by the participant and (b) write each word to the best of your ability. For the tests with alphabet supplementation, listeners were additionally instructed to watch the participant's letter selection. Listeners were given as much time as they needed to transcribe a participant response, and they were allowed to listen to a second presentation if they requested. Listeners were not given a context for the participants' speech.

A correct transcription was defined as a phonemic match to the target word. Words transcribed with a plural /s/ at the end were scored as correct whether or not the test word ended in /s/. For each participant, the percentage of words that each listener transcribed correctly was calculated.

Results

Figure 5 shows mean overall intelligibility percentage, across the 5 listeners, for each participant without and with the augmentative keyboard. Intelligibility increased substantially across participants.

Table 4 shows intelligibility results without and with alphabet supplementation for one-syllable and multisyllable words. There were 17 one-syllable words, 11 two-syllable words, and 2 three-syllable words. Across participants, intelligibility of one-syllable words approximately doubled with alphabet supplementation. For multisyllable words, intelligibility without supplementation varied widely across participants. For Mark and Jimmy, listeners understood few to no words without alphabet supplementation; the percentage increased to 23% for both participants with supplementation. For Aaron, listeners understood more than half of the words without alphabet supplementation and 85% with supplementation.

Figure 5. Mean overall speech-intelligibility percentages for Aaron, Mark, and Jimmy in the speech-only condition and in the speech-with-alphabet-supplementation condition.

Table 4. Speech intelligibility without and with alphabet supplementation (AS) across participants.

Participants	One-syllable words (%)		Multisyllable words (%)	
	Without AS	With AS	Without AS	With AS
Mark	24	41	8	23
Jimmy	24	47	0	23
Aaron	28	51	54	85

Discussion: Study 2

We taught participants to use a keyboard to supplement speech in a naming task using three steps. These steps were (a) naming pictures, (b) selecting the onset letter corresponding to the onset phoneme of spoken words, and (c) selecting the correct onset letter when shown a picture—without hearing a spoken word—in combination with naming the picture themselves. We taught steps b and c using the laptop, and then we demonstrated generalization to the augmentative keyboard.

All three participants required training to name some of the pictures accurately. This teaching step presumably would not be necessary in practice, because the speaker would be speaking about familiar objects. Once reliable picture naming was established, Aaron performed the naming task—including the selection of onset letters on the keyboard—after he was given verbal instructions. For Mark and Jimmy, components of the skill were taught in two steps using the familiar touchscreen. After component skills were established, highly accurate responses transferred to alphabet supplementation with a modified QWERTY keyboard.

Although all three of our participants ultimately demonstrated the alphabet-supplementation skill, the generality of these outcomes to similar participants remains to be determined. At the least, this initial small-scale demonstration suggests the potential of this communication approach for this population. In particular, Aaron's increase from 44% to 73% intelligibility represents a meaningful increase in his ability to communicate verbally. Although increases by the other two participants were more modest, it should be remembered that listeners were not familiar with the participants or other individuals with ID, and they were not provided any contextual support. Under more favorable listening conditions, results may have shown a larger effect of supplementation (Hustad et al., 2015). Moreover, this study contributes a task analysis of the necessary skills and the procedures needed to develop these skills, which will provide a strong foundation for future work in this area.

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 who had motor speech impairments: 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 listeners knew the first letter of words spoken by participants, they correctly transcribed, on average, more than twice the number of words compared with words transcribed when speech was not supplemented.

A potential limitation of the intelligibility findings is that single words were used for the speech sample, and most of those spoken words were only one or two syllables in length. It is unknown whether supplementation would have similar effects for longer utterances.

General Discussion

Because alphabet supplementation has shown beneficial effects on the speech intelligibility of literate individuals without ID, we explored the feasibility of this augmentative communication strategy for individuals who differed from previous participants in potentially critical ways. In addition to low speech intelligibility, our participants had ID, severely impaired receptive language, and minimal to no reading skills.

Taking a task-analysis approach, we built the alphabet-supplementation skill component by component. In study 1, we established onset-letter selection with a large number of spoken words, and we also evaluated generalization to untrained spoken words. The latter would demonstrate acquisition of the alphabetic principle. In study 2, we trained the additional component skills needed for participants to incorporate onset-letter selection into a naming task and assessed effects of alphabet supplementation on speech intelligibility.

The onset-letter selection skill established with Mark and Jimmy in study 1 provides evidence that some individuals with ID and impaired receptive language can learn to select onset letters for a large number of spoken words when each spoken word is taught directly. At the completion of both studies, Mark and Jimmy selected the onset letter for a total of 108 and 128 spoken words, respectively, which included six different onset sounds. Given the sparse literature on early literacy skills in individuals with ID and speech impairments, this is a notable contribution.

Although encouraging, this demonstration of onset-letter selection has the limitation of involving only two participants. Replication to determine generality is essential. Achieving similar learning outcomes with other individuals may depend on whether or not prerequisite skills are in those individuals' repertoires. The current participants' preexisting high accuracy on a receptive letter-naming task was probably critical to their success. That is, we selected participants who were already skilled at looking at an array of letters and selecting one on the basis of the spoken letter name—a large component of the spoken-word to onset-letter task. It would be important to test for these skills, and if necessary teach them, before beginning instruction on letter selection when spoken words are presented. Moreover, letter naming is an excellent predictor of reading achievement (Adams, 1994; NRP, 2000).

Although neither Mark nor Jimmy showed strong evidence of the alphabetic principle, this finding is consistent with their very low reading skills. On standardized measures, both read fewer than five real words and no nonwords. Thus, these participants may not have had sufficient experience with many skills that typically developing individuals have in place before instruction in the alphabetic principle occurs. They did not demonstrate letter-sound knowledge, for example, before we taught it. Moreover, letter-sound instruction did not improve performance on the spoken-word to onset-letter task. This finding is consistent with contemporary research showing that the benefits of letter-sound knowledge are not shown in the absence of phonemic-awareness skills (Byrne, 1998; NRP, 2000). In evaluating the progress these individuals made toward demonstrating the alphabetic principle, it is important to remember that they were well beyond school age and were unfortunately not receiving additional literacy instruction outside of this study. The procedures should be explored with school-age children with ID whose daily environments support literacy acquisition.

The procedures used enabled individuals to demonstrate the alphabetic principle (and its component, phonemic awareness) nonvocally. A means of demonstrating skills without speech is essential for individuals with low intelligibility. Most existing tests of phonemic awareness, however, require a vocal response. For example, in a traditional onset-segmenting assessment, the student says the first sound of a whole spoken word. Our onset-letter selection task eliminated the vocal response, as well as the difficulty of scoring the vocal response of an individual whose speech is difficult to understand.

Although previous studies have demonstrated phonemic-awareness skills via selection responses (Millar et al., 2004; Truxler & O'Keefe, 2007), our study extended the use of computerized phonemic awareness instruction and nonvocal responses to individuals with severely impaired receptive language and speech impairments. In related work, we have applied these nonvocal techniques to developing an assessment of phonemic awareness and the alphabetic principle (Barker, Bridges, & Saunders, 2014). With a greater emphasis on reading instruction for all individuals, procedural adaptations for foundational skills will be critical to meet the needs of individuals who also have speech impairments (Barker, Saunders, & Brady, 2012; Barker et al., 2014; Hesketh, Dima, & Nelson, 2007; Iacono & Cupples, 2004; Laing & Espeland, 2005; Vandervelden & Siegel, 1999, 2001).

Much of our teaching was computerized. Thus, our training was not compromised by procedural-fidelity concerns, which can arise when teachers have to manage all aspects of teaching (e.g., delivering instructions, presenting spoken-word stimuli, arranging choice stimuli, randomizing trial presentation, recording the individual's response). Other benefits of computerized training sessions include their brevity (approximately 3–5 min) and the large number of opportunities to practice the desired response in each session. The National Reading Panel (2000) recommended

additional research to determine how computers might be used to teach phonemic awareness more effectively. This study is an important step in that direction.

In study 2, our participants learned the skills needed to use alphabet supplementation in a naming task. Teaching each element of the task has not been necessary in other studies of speech intelligibility, because participants generated speech samples from printed text and followed spoken directions for using the augmentative communication device (Hustad & Garcia, 2005). In clinical practice, another augmentative and alternative communication strategy, such as graphic symbols with voice output, might be more quickly learned or more effective for individuals with skill sets similar to Mark and Jimmy. Our aim, however, was to explore the viability of alphabet supplementation, which potentially would expand the user's communication repertoire beyond preprogrammed graphic stimuli. We thus demonstrated a means of establishing the skill in participants for whom alphabet supplementation might not have previously been considered.

The results for one of our participants may have more immediate applied implications. Aaron's first-grade-level reading skills were well below those of participants in previous studies with literate adults. His high accuracy in the study 1 comprehensive test, however, shows that he began the study already having some knowledge of the alphabetic principle. This knowledge supported his rapid learning of alphabet supplementation—at least within the naming task we devised. Here again, replication is needed to determine the prerequisite skills that supported Aaron's usage of alphabet supplementation with little more than verbal instructions. Practitioners may consider evaluating letter-based augmentative communication strategies for individuals with similar skills for whom these strategies have not historically been recommended (Beukelman & Mirenda, 2005; Mirenda & Mathy-Laikko, 1989).

In terms of percentage increase, the effects of alphabet supplementation on speech intelligibility were substantial. With supplementation, unfamiliar listeners understood more than twice the number of words spoken by Mark and Jimmy. Aaron's intelligibility increased by over two thirds. These results support previous research showing positive effects of alphabet supplementation. They also provide some support for extending the alphabet-supplementation strategy to a population with whom it had not previously been evaluated. It should be noted, however, that there was substantial room for improvement in the intelligibility percentages of Mark and Jimmy, particularly with two-syllable words. That said, inclusion of other characteristics present in typical communication, such as seeing the speaker's face, knowing the context of the speech, and greater familiarity between the speaker and listener, might improve these intelligibility scores.

Study 2 has limitations beyond the small number of participants. Alphabet supplementation was only demonstrated within a contrived context and only within a single-word naming task. It is a long way from this simple demonstration to teaching individuals when and how to

use alphabet supplementation in the natural environment. That is, the procedures for establishing functional use are not yet in the literature. In addition, the method for assessing intelligibility was rudimentary (for a detailed discussion of intelligibility assessment strategies, see Miller, 2013). For example, we selected the words used on the basis of functionality, and thus we did not sample a comprehensive range of speech sounds. In addition, intelligibility was tested under laboratory conditions and not in an environment with background noise. Investigating the utility of alphabet supplementation for enhancing communication in natural settings is warranted, because the effects of this strategy on the quality of life of individuals with both ID and difficult-to-understand speech could be substantial.

Summary and Future Directions

The overall outcome of this study was to demonstrate that individuals with ID and limited to no reading skills can learn to identify letters representing onset sounds in spoken words. This skill allows individuals whose speech is difficult to understand to use alphabet supplementation to improve intelligibility. Thus, the skill is highly relevant to communication interventions for individuals who have low speech intelligibility. In addition, learning letter-sound relations is essential for spelling and reading—skills that increase independence and quality of life for individuals with ID.

This initial demonstration requires replication as well as additional research aimed at improved communication and literacy in everyday contexts. For example, studies aimed at maximizing intelligibility should address the pragmatic aspects of communication along with letter-selection skills. Individuals using the supplementation strategy must learn to recognize when and how to use it in conversation. In addition, communication partners will need training in how to request supplementation of speech. The ultimate goal would be to improve communication through increased intelligibility and literacy skills.

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Appendix A

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 nonstandardized measure was used as a screening tool for potential participants' inclusion in the study.

Eighty-two nouns 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). Words were represented by color pictures on 8-in. × 10-in. (20-cm × 25-cm) cards and 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 recorded 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") and then again asked, "What is this?"

Recordings were edited to include only participants' spoken responses (vocal prompts from the experimenter were deleted). Two native English-speaking adults, who reported having no hearing difficulties and moderate experience communicating with individuals with severe speech impairments and ID, served as listeners. Both were college graduates, and their mean age was 27. The speakers were unknown to the listeners. Listeners transcribed each word they heard or wrote a dash if they could not determine what the speaker said. 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 averaged.

Appendix B

Transition to Study 2

The augmented communication task to be taught in study 2 would require selecting from among six letters on a QWERTY keyboard. In study 1, however, we used a minimal-pairs teaching procedure, and onset-letter choices were always presented in the same pairs (e.g., S always paired with T, etc.). To facilitate transition from the two-choice task to the keyboard, we presented two intermediate conditions, still using the touchscreen and the matching-to-sample procedures described earlier.

Varied Letter Pairings

Mark and Jimmy received tests with letter pairs that were not used in training (e.g., M with S, C with T) with a subset of the taught words. These tests were conducted after the next-to-last and last comprehensive tests. Tests had no feedback. Had accuracy fallen below 90% for any letter, we would have taught the novel pair. Test accuracy ranged from 97% to 100%. That is, accuracy for all six letters was high regardless of which letter was presented as the incorrect choice.

Six-Choice Task

We assessed, and trained if necessary, onset-letter selection with all six letters (M, C, T, S, P, L) simultaneously presented as choices. Each of the 60 spoken words was presented as the sample once. Letters appeared in varying locations around the edge of the computer screen. Feedback was delivered. Participants scoring less than 90% on any letter received training specific to their errors, and the six-choice test was repeated. Training and testing continued until the mastery criterion of at least 90% accuracy on each letter was met.

All three participants received these tests. Jimmy and Mark met the criterion of at least 90% for all onset letters, with the exception that Mark's accuracy with the onset L was 40%. After remedial training specific to errors, Mark met the 90% accuracy criterion in the six-choice test. For Aaron, who had not participated in study 1 (because of his high accuracy in the baseline comprehensive test), accuracy was 82% overall, and it was below 90% on spoken words beginning with P, M, and S. Following targeted remediation, he achieved the 90% accuracy criterion on the six-choice test.

Appendix C

Scoring and Interobserver Agreement

This section describes procedures for establishing interobserver agreement for the scoring of participants' picture-naming and letter-selection responses. In sessions with picture naming, 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 the 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 naming and selection responses in 100% of test sessions and in 20% of training sessions that included either or both of those responses. The two observers' 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. The percentage of trials in which observers agreed was calculated for vocal and selection responses separately. Mean agreement across the three participants was 99% (range 97% to 100%) for both naming and letter selection across training and testing sessions.