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Improving Initial Sound Segmentation Skills of Preschool Children with Severe to Profound Hearing Loss: An Exploratory Investigation

Krystal L. Werfel, Ph.D., and C. Melanie Schuele, Ph.D.

The purpose of this exploratory study was to evaluate the functional relation between initial sound awareness instruction and increased initial sound segmentation skill in children with hearing loss. Two preschool children with hearing loss participated in this multiple probe design single subject study. The children participated individually in initial sound awareness instruction (37–39 half-hour sessions). Assessment of children's initial sound segmentation skill occurred at the beginning of each session. Initial sound awareness training was associated with an increase in initial sound segmentation skill for the two children with hearing loss but performance did not consistently move to mastery level.

Children with hearing loss show delays in acquiring pre-literacy skills (for a review, see Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007). These delays can profoundly impede reading development and, ultimately, general academic achievement. On average, the reading level of children with severe to profound hearing loss increases at a rate of only one half of a grade each year, before plateauing at the third- or fourth-grade level (e.g., Qi & Mitchell, 2012). Despite technological advances in digital hearing aids and cochlear implants, the average reading level for children with severe to profound hearing loss has not increased in the past several decades (e.g., Qi & Mitchell, 2012; Trybus & Karchmer, 1977). However, there is wide individual

Krystal L. Werfel, Ph.D., is Assistant Professor at the Department of Communication Sciences and Disorders at University of South Carolina in Columbia. C. Melanie Schuele, Ph.D., is Associate Professor at the Department of Hearing and Speech Sciences at Vanderbilt University in Nashville, Tennessee. Correspondence concerning this manuscript may be addressed to Dr. Werfel at werfel@sc.edu.

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variation in reading outcomes of children with hearing loss. Some researchers have reported the reading achievement for many children with cochlear implants to be within the average range (e.g., Geers, 2003; Moog, 2002). The current educational challenge is to optimize literacy outcomes for all children with hearing loss.

Initial proficiency in reading involves skill in the recognition of printed words. The acquisition of an increasingly large word recognition vocabulary relies on the ability to decode words. The National Early Literacy Panel (2008) identified 11 early predictors of later word decoding skills for children with typical hearing, including phonological awareness, alphabet knowledge, and oral language. We follow convention in the contrasting of the terms phonological awareness and phonemic awareness (e.g., Schuele & Boudreau, 2008). Analysis of the sound structure of language, regardless of the analysis task, is referred to as phonological awareness. The term phonemic awareness is reserved for those instances where children have been asked to analyze (e.g., segment) the isolated sounds in a word (e.g., "tell me the first sound in *moon*"). Easterbrooks, Lederberg, Miller, Bergeron, and Connor (2008) reported that within early literacy skills, 3- to 6-year-old children with hearing loss have far greater difficulty with phonological awareness than alphabet knowledge or oral language. More successful readers among children with hearing loss demonstrate better phonological awareness (Spencer & Tomblin, 2009).

Phonological awareness, the ability to analyze the sounds of words in spoken language (Mattingly, 1972; Wagner & Torgesen, 1987), is one important contributor to word decoding skills for children with typical hearing (e.g., Adams, 1990; Stahl & Murray, 1994), and there is evidence that the same may be true for children with hearing loss (Harris & Beech, 1998; for a contrasting viewpoint see Kyle & Harris, 2011). When compared to same-age peers with typical hearing, school-age children with hearing loss, regardless of degree of hearing loss, perform poorly on phonological awareness tasks (Kyle & Harris, 2011; Miller, 1997; Moeller et al., 2007; Most, Aram, & Andorn, 2006; Sterne & Goswami, 2000). It is not the case that these children do not have any phonological awareness, but rather that their development of phonological awareness is delayed (e.g., Harris & Beech, 1998; Miller, 1997; Sterne & Goswami, 2000). Reduced access to sound appears to slow, but not prevent, the acquisition of phonological awareness. Thus, an important intervention question centers around the extent to which explicit intervention can improve the phonological awareness of children with hearing loss, particularly before the onset of formal literacy instruction. Having a stronger foundation of phonological awareness skills could lead children to benefit more from early literacy instruction and improve long-term literacy outcomes for children with hearing loss.

Most studies of phonological awareness in children with hearing loss have not reported results in a manner that allows for the comparison of cochlear implant and hearing aid users. Some researchers have not reported amplification type of participants (e.g., Sterne & Goswami, 2000), some have included only one amplification type (e.g., Spencer & Tomblin, 2009), and others have included both types of amplification in a single analysis group (e.g., Kyle & Harris, 2011). We could find only one study that compared performance across amplification types. James et al. (2005) reported that children with severe hearing loss who wore hearing aids performed better on phonemic awareness tasks than cochlear implant users ($d = 0.71$). Ultimately, it will be critical to differentiate the phonological awareness acquisition trajectories for children with hearing loss based on extent of loss and type of amplification.

Summarizing the extant evidence base on children with typical hearing, the National Reading Panel (National Institute of Child Health and Human Development [NICHD], 2000) identified phonemic awareness instruction as a key component of elementary school literacy instruction. The National Reading Panel's meta-analysis found that teaching children to analyze phonemes is highly effective across many teaching conditions and age levels. Reading instruction with a phonemic awareness component improves overall reading more than instruction without a phonemic awareness component. Effective phonemic awareness instruction (i.e., activities that involve analysis of individual speech sounds) for children with typical hearing is explicit; eventually includes manipulation of letters (i.e., once some segmentation skill is evident); focuses on only one or two types of analysis (i.e., achievement in blending and segmenting is critical); explicitly connects phonemic awareness activities to word recognition and spelling; and takes place in small groups. The extent to which these elements are critical to address the unique instructional needs of children with hearing loss requires empirical investigation.

What is known about phonological awareness in children with hearing loss has been primarily gained in studies that involved school-age children (Kyle & Harris, 2011; Spencer & Tomblin, 2009; Sterne & Goswami, 2000). Thus, an understanding of phonological awareness development in preschool children with hearing loss is absent. Moreover, although there are multiple studies that have demonstrated the effectiveness of phonological awareness training with preschool children with typical hearing, we have not found any published studies in the same age range with children with hearing loss. Given the realization that stronger readers with hearing loss utilize phonemic awareness knowledge when reading, it is essential to explore the benefits of systematic and intensive phonological awareness instruction with children with severe to profound hearing loss. Thus, the purpose of this investigation was to evaluate the functional relation between initial sound awareness instruction and increased initial sound segmentation skill in preschool children with severe to profound hearing loss. The overarching goal of this investigation was to obtain preliminary evidence on the changes in phonemic awareness skill (i.e., in this study, initial sound segmentation) that can be made in a short amount of time so as to inform future intervention studies with preschool children with hearing loss.

We hypothesized that initial experimental control would be established, in that segmentation accuracy would not increase in baseline for any phoneme before an experimental condition was introduced. Three experimental conditions were used; each focused on a different initial phoneme. Once instruction was introduced in the first experimental condition—/m/, three patterns of responses to probe assessments were possible. First, no increase in accuracy would demonstrate no functional relation between instruction and segmentation. Second, an increase in accuracy on the target phoneme /m/ but no increase in the experimental phonemes /d/ or /b/ nor non-taught phonemes would demonstrate a functional relation between instruction and segmentation only for the target phoneme. Third, an increase in accuracy on the target phoneme /m/ accompanied by an increase in the experimental phonemes /d/ and/or /b/ and/or non-taught phonemes would demonstrate a functional relation between instruction and the target phoneme. Such a result would also support the idea that for preschool children with hearing loss segmentation of initial sounds is a metalinguistic skill that applies across sounds in a language and is not restricted to only taught sounds.

Method

The research protocol for this study was approved by the Institutional Review Board at Vanderbilt University.

Participants

The principal of an auditory-oral school in Nashville, Tennessee was given a list of inclusionary/exclusionary criteria for the study (see next paragraph) and asked to send consent forms home with four preschool and kindergarten children that she judged eligible to participate. Three of the four parents gave consent. One preschool child was withdrawn from the study due to inconsistent school attendance. Two preschool children completed the study.

Inclusionary and exclusionary criteria that all consented participants met included (a) use of amplification, (b) native English speaker, (c) no use of manual communication, (d) no cognitive impairment, (e) pass an articulation screening, and (f) score 50% correct or less on the dependent measure during the baseline condition. Both participants had hearing loss in the moderately severe to profound range.

Relevant case history.

Participant 1 (female; aged 4;5 [4 years, 5 months] at study outset) was diagnosed with moderately severe to severe sensorineural hearing loss at 1;9 and fitted with bilateral hearing aids at 1;11. She had unaided pure tone thresholds of 60–75 dB HL in the right ear and 60–80 dB HL in the left ear, and used Phonak behind-the-ear hearing aids per audiological report. Aided thresholds were not reported; a listening check confirmed that her hearing aids were functioning correctly per audiological report. She began early intervention services at 1;11. At the time of the study, she had speech and language delays secondary to hearing loss, was enrolled in an auditory-oral preschool, and received auditory-verbal speech-language intervention one hour per week as part of her academic program.

Participant 2 (male; aged 4;9 at study outset) was diagnosed with bilateral profound sensorineural hearing loss at 2;3, associated with Pendred syndrome, a genetic disorder that causes early hearing loss in children and can affect the thyroid gland as well as balance. He was fitted with bilateral hearing aids at 2;3 but was an inconsistent hearing aid user. He received a cochlear implant in his right ear at 2;6. After implantation, participant 2 began wearing a hearing aid more consistently on his left ear. Subsequently, he received a cochlear implant in his left ear at 4;1. Both his implants were Nucleus Freedoms with Contour Advance electrode arrays. With implant use, participant 2 had aided pure tone thresholds of 20–25 dB HL bilaterally per audiological report. At the time of the study, he had speech and language delays secondary to hearing loss, was enrolled in an auditory-oral preschool, and received speech-language intervention two hours per week as part of his academic program.

Prior to baseline, each child participated in an assessment to describe oral language skills (see Table 1): *Peabody Picture Vocabulary Test-Third Edition* (PPVT-III; Dunn & Dunn, 1997), *Expressive One-Word Picture Vocabulary Test* (EOWPVT; Brownell, 2000), *Phonological Awareness and Literacy Screening-Kindergarten* (PALS-K; Invernizzi, Juel, Swank, & Meier, 2004), *Test of Early Grammatical Impairment* (TEGI; Rice & Wexler, 2001), and a 100-utterance language sample analyzed for utterance length (MLU) and grammatical development (*Index of Productive Syntax* [IPSyn]; Scarborough, 1990). The IPSyn quantifies the emergence of grammatical complexity in young children's spontaneous language in four linguistic areas: nouns, verbs, questions/negations, and sentence structure. The *Leiter International Performance Scale-Revised* (Roid & Miller, 1997) was administered to rule out cognitive impairment. In addition, the most recent (within six months) audiological assessment, *Clinical Evaluation of Language Fundamentals: Preschool-2nd Edition* (CELF-P2; Wiig, Secord, & Semel, 2004), and *Goldman-Fristoe Test of Articulation-2nd Edition* (GFTA-2; Goldman & Fristoe, 2000) or *Arizona Articulation Proficiency Scale-3rd Revision* (Arizona 3; Fudala, 2000) scores were obtained from participants' educational files.

Table 1. *Participant Assessment Scores*

	Participant 1	*Participant* 2
CELF-P	67*	67*
PPVT-III	70*	79*
EOWPVT	82*	84*
TEGI Third Person Singular	1/6	0/5
TEGI Past Tense	3/9	3/6
PALS-K Letter Names	14/26	23/26
PALS-K Letter Sounds	8/26	10/26
PALS-K Rhyme	3/10	5/10
PALS-K Initial Sounds	2/10	5/10
GFTA-2	78*	90*
MLU	2.83	3.12
IPSyn Total	48	58
Noun Phrases	16	16
Verb Phrases	10	20
Questions/Negations	10	8
Sentence Structures	12	14

Note: CELF–P = Clinical Evaluation of Language Fundamentals–Preschool; PPVT–III = Peabody Picture Vocabulary Test–Third Edition; EOWPVT = Expressive One Word Picture Vocabulary Test; TEGI = Test of Early Grammatical Impairment; PALS–K = Phonological Awareness and Literacy Screening–Kindergarten; GFTA-2 = Goldman-Fristoe Test of Articulation–Second Edition; MLU = Mean Length of Utterance in morphemes; IPSyn = Index of Productive Syntax; *Standard Score.

Experimental Design

This study employed a single subject, multiple probe across behaviors (i.e., phonemes) design (see Gast, 2010) exploring the functional relation between initial sound awareness instruction and increased initial sound segmentation skill in preschool children with hearing loss. Importantly, the study design met single case design standards (Kratochwill et al., 2010), with more than three attempts to demonstrate an intervention effect. The study design included three experimental conditions (i.e., intervention) for each participant that differed only in the target phoneme (see 1a in Figure 1). Possible threats to internal validity in multiple probe design include testing effects and maturation effects. Testing effects were addressed by randomizing the order of presentation of the stimulus cards. Maturation effects were addressed by the relatively short duration of the study (approximately three months). Extant research suggested that children with hearing loss would not acquire the skill of initial sound segmentation within the study period simply as a result of maturation (e.g., James et al., 2005). In addition, classroom instruction for the participants did not involve a phonological awareness component.

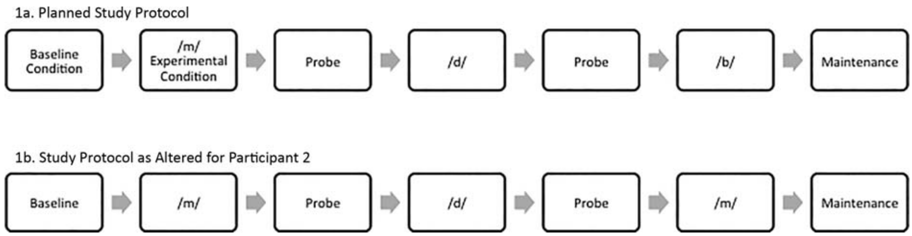

Figure 1. Study protocol illustrated in 1a implemented for participant 1; 1b illustrates study protocol as altered for participant 2.

Research sessions took place in an empty classroom or in a conference room in the school. The first author conducted all assessment and intervention sessions, and children participated individually. All sessions were video and/or audiotaped. Trained lab assistants completed video analysis of 30% of sessions in each condition for each participant to assess inter-observer agreement and procedural fidelity (reported below).

Procedures

Probe assessments.

The probe assessment was a curriculum-based progress monitoring measure developed for this study. It required children to orally segment the first sound of familiar monosyllabic words. Thus, the task tapped the participants' phonemic awareness skills. The examiner presented a colored picture card of each stimulus word (e.g., *ball*). At the beginning of each probe assessment session, the examiner modeled the correct response in three sample items (one for each target phoneme; same items each session). For example, *"Map. Let's think about the first sound in map. I can say it slowly, like mmmmmap. Oh, I hear a /m/ at the beginning of map. The first sound in map is /m/."* Then the examiner elicited an imitation of the correct response (/m/) from the child for each sample item. For administration of each test item, the examiner presented a picture card, said the target word, instructed the child to say the first sound of the word, repeated the target word, and waited for a response. For example, *"Ball. Tell me the first sound in ball. Ball."*

Participants were assessed three times per week. Baseline condition probe assessments consisted of 60 test items (10 items for each of the three phonemes to be targeted in instruction [/m/, /d/, /b/; i.e., target phonemes; 30 items], as well as 10 items each for three phonemes not targeted in the instruction [/n/, /t/, /p/; non-taught phonemes; 30 items]). In contrast, experimental condition probe assessments included only 20 test items (10 items of the target phoneme in that experimental condition; 3 items for each of the two other target phonemes [6 total items], and 4 items of non-taught phonemes [randomly selected from the pool of non-taught phoneme items]). Experimental condition probe assessments were completed at the outset of the session (i.e., prior to any instruction on that day). See Appendix A for the progress monitoring measure word stimuli.

Initial sound awareness instruction in each experimental condition.

The initial sound awareness instruction was adapted from Schuele & Dayton (2004). The curriculum is a standard intervention protocol, comprised of 36 developmentally sequenced lessons (30 minutes each) that target letter-sound knowledge, rhyme knowledge, awareness of initial sounds, awareness of final sounds, and blending and segmenting sounds in words. The curriculum has been successfully implemented in small group kindergarten intervention with children at risk for reading disabilities (Schuele et al., 2008). It has not been evaluated with children with hearing loss but the curriculum may be appropriate for establishing phonemic awareness skills in the population with hearing loss. For this study, only lessons that addressed awareness of initial sounds were used.

The initial sound lessons were modified in two ways: (a) The instruction targeted one sound in each experimental condition (/m/, /d/, /b/) with a defined set of target words (22–29 that began with each target phoneme; see Appendix B) and foils; (b) The first lesson in each experimental condition included an activity that introduced the condition target phoneme, conversation about production of the target phoneme, and introduction of the condition target word set. The lesson sequence was repeated three times; once in each experimental condition.

Children participated in instruction 25 minutes a day, three days per week. Each lesson began with a five-minute letter activity; letter activities were included to reinforce alphabet knowledge and provided limited opportunities to combine alphabet knowledge and phonological awareness knowledge. Two 10-minute initial sound awareness activities followed the letter activity. Consistent with a developmental hierarchy, the lesson activities increased in complexity across the three-week experimental condition: beginning with phonological awareness skills of initial sound judgment and initial sound matching, then progressing to phonemic awareness skills of initial sound segmentation, and initial sound generation. An experimental condition concluded when (a) the three-week lesson sequence was completed, or (b) prior to completion of the lesson sequence if the child achieved at least 80% correct on the target phoneme items for two consecutive probe assessments.

In the first experimental condition, lessons focused on analysis of /m/ in the initial position of words. This bilabial nasal phoneme was selected for the first experimental condition because it is low in frequency and high in amplitude, making it one of the easiest phonemes for children with hearing loss to hear. In addition, /m/ is produced at the front of the mouth and thus, visual cues are high. In the second experimental condition, lessons focused on analysis of /d/ in the initial position of words. This voiced alveolar stop phoneme is also low in frequency, high in amplitude, and produced near the front of the mouth. In the third experimental condition, lessons focused on analysis of /b/ in the initial position of words. This voiced bilabial stop phoneme is also low in frequency, high in amplitude, and produced at the front of the mouth.

Response Definitions and Measurement System

Assessment.

Child responses to the probe assessment were recorded in real time. After the session, each response was categorized as correct or incorrect. Total correct and total incorrect scores were tallied. A correct response was defined as an isolated production of the initial phoneme for each stimulus word. An incorrect response was defined as (a) responding with a phoneme other than the initial phoneme of the stimulus word, (b) any other verbal response (e.g., repeating the word, saying "I don't know," responding with letter name), or (c) not responding within four seconds.

Inter-observer agreement (IOA).

To calculate IOA, two lab assistants were trained to give the assessment. Lab assistants simultaneously recorded responses of the first author's live administration of the probe assessment with the participants until 90% agreement was attained for three consecutive administrations. Agreement was calculated for both correct and incorrect responses using the point-by-point method (i.e., divide number of agreements by number of agreements plus number of disagreements and multiply by 100). IOA was collected on each participant in 30% of sessions in each condition. A lab assistant viewed video recordings of the probe assessment and recorded child responses on a data collection sheet. The lab assistants' data collection sheets were compared to the first author's data collection sheets. Agreement was calculated collectively and individually for each participant. Overall agreement was 98.8% (90 - 100). Agreement for participant 1 was 99.6% (97 - 100). Agreement for participant 2 was 98.1% (90 - 100).

Procedural fidelity.

Procedural fidelity (e.g., correct materials for lessons, activities executed, time length of activities) was measured in 30% of sessions in each experimental condition. Percentage of compliance with the experimental condition protocol (total number of instances of compliance divided by number of instances of compliance plus number of instances of noncompliance, multiplied by 100) was calculated collectively and individually for each participant. Overall procedural fidelity was 96.1% (87 - 100). Procedural fidelity for participant 1 was 94.3% (87 - 100). Procedural fidelity for participant 2 was 98% (93 - 100).

Results

Participant 1

Participant 1's responses across all probe assessments are displayed in Figure 2. Initial experimental control was established with virtually no change in performance (0% correct) across sessions 1 through 3 for all phonemes. Experimental condition /m/ was initiated in session 4 and accuracy continued at 0% for /m/ through session 8 (and other phonemes as well). A sharp increase in accuracy to 70% correct for the target phoneme /m/ was observed in session 9; experimental condition /m/ was discontinued after session 11 when criterion was reached (80% for two sessions). The remaining probe assessments for /m/ (sessions 12 through 39) were obtained under maintenance (i.e., no /m/ instruction) with accuracy varying between 68% and 100%. Importantly, when /m/ instruction was withdrawn (session 12 and thereafter), participant 1's accuracy on /m/ did not return to baseline level and instead far exceeded baseline accuracy of 0%.

Experimental condition /m/ appeared to influence the segmentation accuracy on other phonemes. Probe assessment accuracy for /d/, /b/, and non-taught phonemes (through session 12) indicates increased accuracy for all phonemes (behaviors), though accuracy never exceeded 50%. These changes, observed after 2.5 hours of instruction (experimental condition /m/) and concurrent with increased accuracy on /m/, lend some support to initial sound segmentation as a generalized behavior rather than a phoneme-specific behavior for children with hearing loss.

Experimental condition /d/ was initiated in session 15 after experimental control for /d/ was observed in sessions 12 to 14. Under circumstances of no instruction, accuracy on /d/ was at 20% or below. In experimental condition /d/ an immediate and sharp increase on /d/ was observed; the experimental condition /d/ was withdrawn after session 16 (only two instruction sessions) because criterion was reached. The remaining probe assessments for /d/ administered under maintenance primarily varied between 30% and 80% with no consistent increasing or decreasing trend. Notably, after experimental condition /d/ was withdrawn there was an immediate drop in accuracy on /d/ and accuracy on /d/ in maintenance was less consistent than for /m/ in maintenance. There were eight instruction sessions for /m/ but only two for /d/.

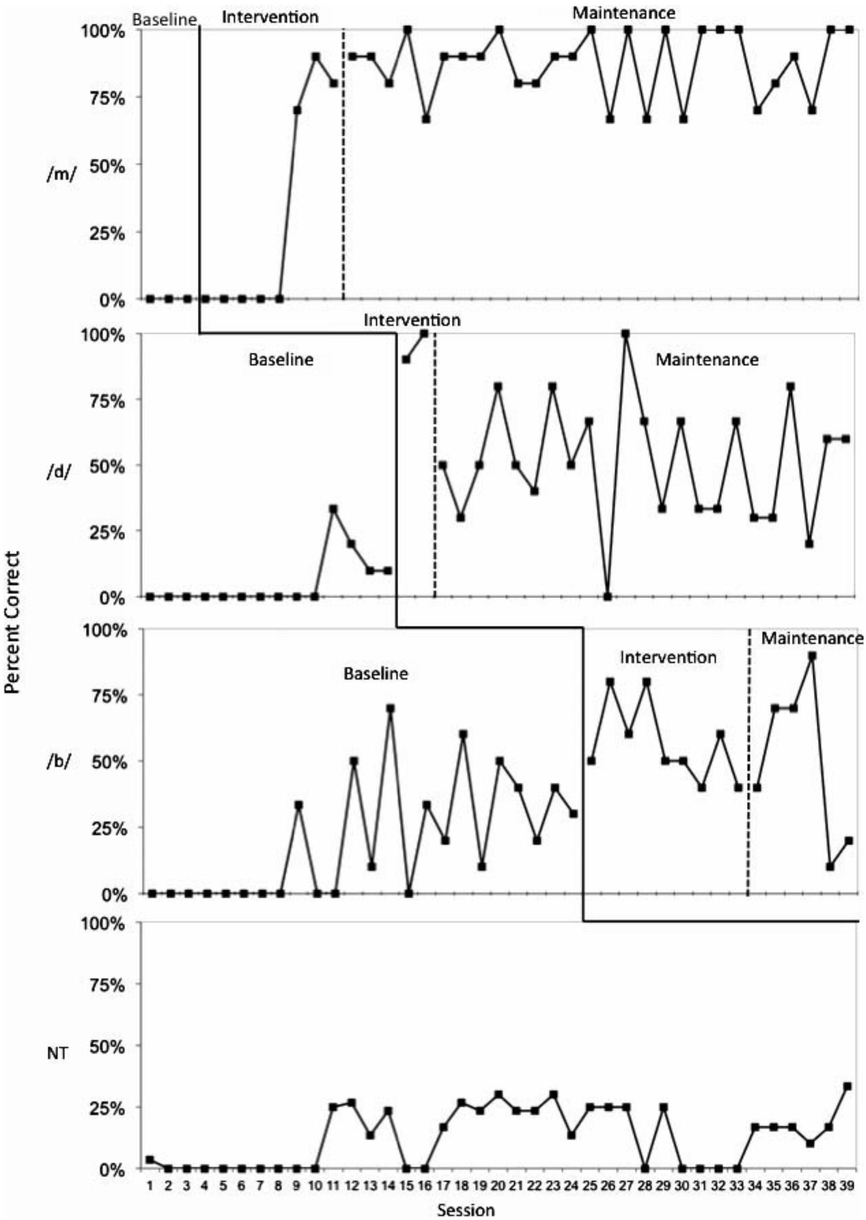

Figure 2. Participant 1′s performance on the initial sound segmentation progress monitoring measure. Solid lines indicate introduction of intervention. Dashed lines indicate conclusion of intervention on sound. NT = sounds not taught in intervention.

It is likely that the instruction for /d/ was not long enough to influence /b/ or the non-taught phonemes. However, because participant 1's accuracy on /b/ segmentation appeared to have been influenced by experimental condition /m/, the introduction of experimental condition /b/ was delayed until a stable baseline was observed. From session 21 to session 24, variation was minimal and accuracy was low.

After experimental condition /b/ was introduced (session 25), improved accuracy was observed on /b/ segmentation (40 – 80%) but criterion was not achieved within the nine planned instructional sessions. Six probe assessments were administered under maintenance. The initial four maintenance probe assessments yielded accuracy on /b/ segmentation consistent with accuracy within experimental condition /b/ (40 – 90%). However, accuracy on the last two probe assessments fell to the level of baseline performance (20% or less). Any influence of /b/ instruction on segmentation of non-taught phonemes (sessions 25 – 33) appears questionable given that five of nine probes in this period were at 0% accuracy. Experimental condition /b/ did not appear to influence performance on either /m/ or /d/, as performance in sessions 25 – 33 was as variable as other maintenance assessments.

The ultimate influence of segmentation instruction on initial sound segmentation for participant 1 can be assessed with probe assessments in sessions 34 – 39 administered under circumstance of no instruction. Three experimental conditions had been implemented for a total of 19 instructional sessions. Performance on the target phonemes varied from 70 – 100% for /m/ with an average of 85%, from 30 – 80% for /d/ with an average of 47%, from 20% – 90% for /b/ with an average of 50%, and from 10 – 33% for non-taught phonemes with an average of 18%. Although accuracy varied widely, it is remarkable that participant 1's segmentation accuracy consistently exceeded the initial baseline of 0% across all behaviors (/m/, /d/, /b/, and non-taught).

Participant 2

Participant 2's responses for all probe assessments are displayed in Figure 3. Initial experimental control was established with no change in performance (0% correct) across sessions 1 through 3 for all phonemes. Experimental condition /m/ was initiated in session 4 and accuracy continued at 0% for /m/ through session 10 (and other phonemes as well). A sharp increase in accuracy to 100% correct for /m/ was observed in session 11; however, criterion was not achieved within the nine planned experimental conditions. The probe assessments for /m/ in sessions 13 through 27 were obtained under maintenance with accuracy varying between 0% and 100%. When /m/ instruction was withdrawn and /d/ baseline commenced (sessions 13 to 16), there was an immediate drop in accuracy to below 40%.

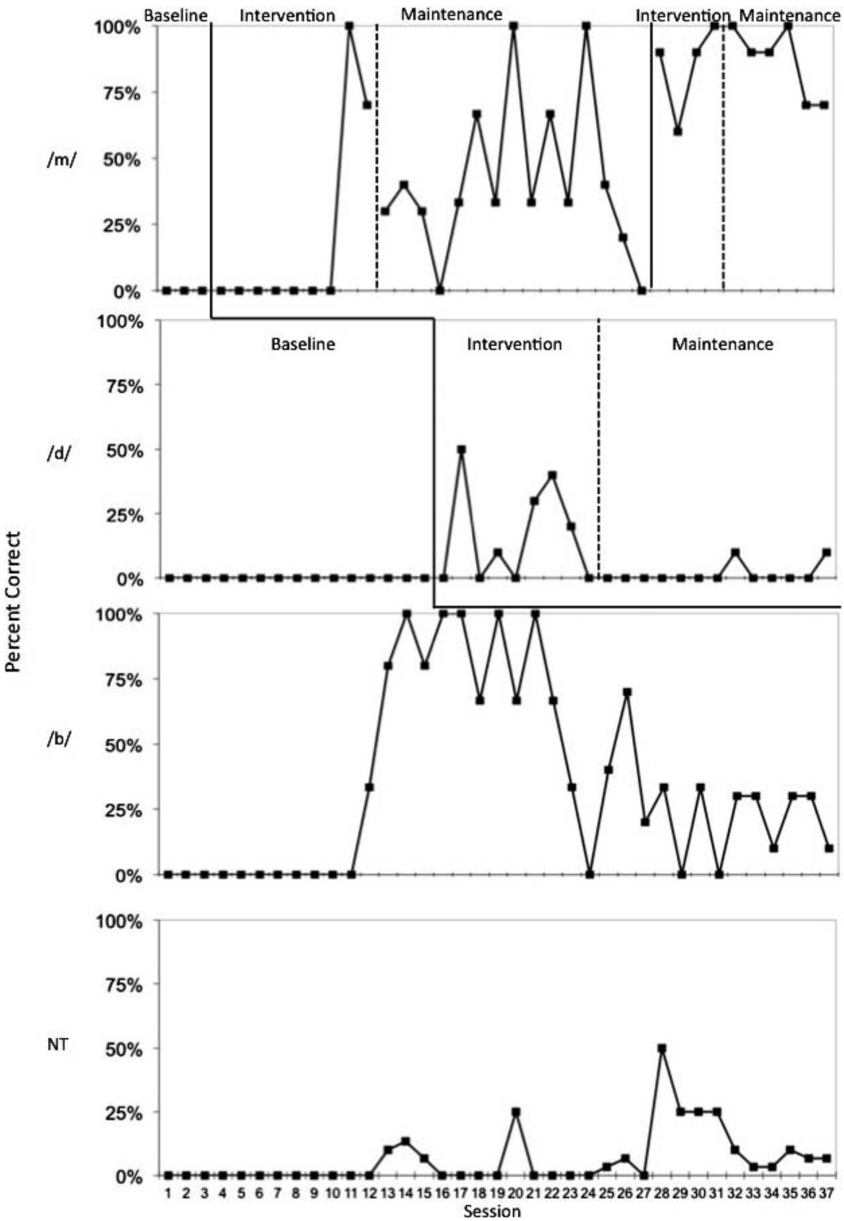

Figure 3. Participant 2's performance on the initial sound segmentation progress monitoring measure. Solid lines indicate introduction of intervention. Dashed lines indicate conclusion of intervention on sound. NT = sounds not taught in intervention.

Experimental condition /d/ was initiated in session 16 after experimental control for /d/ was observed in sessions 13 to 15 (0% accuracy). In experimental condition /d/, nine lessons were administered. An increase of accuracy was observed; however, accuracy on /d/ did not exceed 50% at any point during the experimental condition and criterion was not reached. In fact, participant 2 had 0% accuracy on four of nine probe assessments during the experimental condition. After the experimental condition was withdrawn, the remainder of probe assessments administered under maintenance indicated performance more consistent with baseline than experimental condition /d/ performance, varying between 0 and 10% accuracy (11 of 13 at 0%).

In contrast to participant 1, experimental condition /m/ did not appear to influence the segmentation accuracy on /d/ or non-taught phonemes, but it did appear to influence /b/. Probe assessment accuracy for /d/ and non-taught phonemes (through session 12) indicated no increased accuracy for any phoneme (behavior). For /b/, performance began to increase at session 12 (the last session of experimental condition /m/) and remained at high accuracy through the /d/ baseline period (session 15). In experimental condition /d/, /b/ segmentation remained at about 60% accuracy for seven sessions. Interestingly, accuracy on /b/ exceeded /d/ during experimental condition /d/. There also appeared to be an influence of experimental condition /d/ on /m/ segmentation; accuracy on /m/ increased (33 – 100% accuracy). These findings, as with participant 1, lend support to initial sound segmentation as a generalized behavior rather than a phoneme-specific behavior for children with hearing loss.

Given that participant 2's performance on /b/ segmentation increased to 100% accuracy during instruction from the other experimental conditions, we could have continued with maintenance for /b/. However, we noticed that /m/ accuracy had decreased and decided to veer from the planned design. We reintroduced /m/ instruction, because it would be informative to planning future studies. Therefore, the third experimental condition for participant 2 consisted of /m/ intervention instead of /b/ (see 1b in Figure 1). From session 25 to 27, performance on the /m/ probe assessment steadily decreased from 40% to 0% accuracy. After the second experimental condition of /m/ was introduced, improved accuracy was observed on /b/ segmentation (60 – 100%) and criterion was achieved after four instructional sessions. After the third experimental condition, six maintenance probe assessments yielded accuracy on /b/ segmentation consistent with accuracy within experimental condition /b/ (70 – 100%).

The ultimate influence of segmentation instruction on initial sound segmentation for participant 2 can be assessed with probe assessments in sessions 32 – 37 administered under circumstance of no instruction. Three experimental conditions had been implemented for a total of 22 instructional sessions. Performance on the target phonemes varied from 70 – 100% for /m/ with an average of 87%, from 0 – 10% for /d/ with an average of 3%, from 10 – 30% for /b/ with an average of 23%, and from 3 – 10% for non-taught phonemes with an average of 7%. Although accuracy still varied widely for participant 2 in this last period, segmentation accuracy consistently exceeded the initial baseline of 0% across all behaviors (/m/, /d/, /b/, and non-taught). However, only the /m/ increase was clinically significant.

Discussion

The purpose of this exploratory investigation was to evaluate the functional relation between initial sound awareness instruction and increased initial sound segmentation skill in preschool children with hearing loss. Intensive individual initial sound awareness instruction was associated with an increase in initial sound segmentation skill after a period of no change for these two children with hearing loss. Both participants made gains within each experimental condition. In addition, the performance of both participants on the phonemes not targeted in each experimental condition lends some support to initial sound segmentation as a generalized behavior rather than a phoneme-specific skill for preschool children with hearing loss. The instruction used in this study was modified from a published curriculum developed to address phonological awareness deficits in children with language impairment. Thus, it appears that instruction that is effective for children with language impairment can be modified to improve skills for children with hearing loss. However, the participants' performance did not always increase to criterion levels (i.e., 80% accuracy within the instruction condition). Thus, instruction for children with hearing loss may require different instructional components than those required for children who have typical auditory access to sounds.

Instruction Needed for Gains

Fewer sessions were required for both participants to exhibit growth in initial sound segmentation skill in subsequent experimental conditions. Participant 1 demonstrated growth during /m/ instruction after five sessions; growth was seen immediately for /d/ and /b/. Participant 2 demonstrated growth during /m/ instruction after seven sessions, growth during /d/ instruction after one session, and immediate growth when /m/ instruction was reintroduced. With each experimental condition, children seemed to move closer to a general awareness of initial sounds. Participant 1 in particular was able to apply the general skill of initial sound segmentation to newly taught sounds with relative ease.

As shown in Figures 2 and 3, generalization to criterion performance (i.e., 80% accuracy) on non-taught sounds was not observed. Neither participant 1 nor participant 2 showed much improvement on segmenting initial sounds that were not taught. Although initial sound segmentation appears to be a generalized behavior for children with hearing loss, it may be necessary to explicitly teach many sounds individually before children are able to generalize adequately from phoneme-specific awareness to general awareness of initial sounds.

Consideration of Phoneme Properties

In most published phonological awareness curricula, including the curriculum modified for this study, target words for teaching analysis of initial sounds are not separated by target phonemes. When teaching initial sound analysis to children with hearing loss, interventionists may need to carefully consider the properties of the target phonemes. The target phonemes in this study were chosen based on the acoustic and visual properties of the sounds. Children with hearing loss may not have adequate auditory access to sounds that are high in frequency (i.e., /s/ or /f/) and/or low in amplitude (i.e., voiceless sounds such as /k/ or /p/), as well as sounds that are produced with minimal visual cues (i.e., velar sounds such as /k/ and /g/). The goal of instruction should be to ensure success for children. Thus, instruction should begin with sounds that are easier for children to successfully analyze. We chose to target one phoneme at a time in order to decrease the difficulty level of the task as compared to introducing multiple phonemes simultaneously thus ensuring optimal opportunity for successful acquisition of initial segmentation skill.

Both participants had relative ease segmenting words that began with /m/, as compared to other sounds assessed. We targeted /m/ first because we judged /m/ to be the easiest sound for children with hearing loss to segment from the beginning of words. The /m/ phoneme is high in amplitude and low in frequency (Kent & Read, 2002), placing it within the range of sounds to which children with hearing loss typically have the most access. In addition, /m/ is a bilabial nasal sound. Bilabial sounds are produced with the lips thus providing visual cues for identification, and nasal sounds can be produced continuously, which can aid in auditory detection. Acoustically, nasal sounds have a nasal murmur, which provides additional cues to its identification (Kent & Read, 2002). The results of this study suggest that teaching should begin with sounds that are easiest for children with hearing loss to hear and identify.

Alternately, children with hearing loss might benefit from grouping phonemes that share acoustic and/or visual properties for instruction. Both participants demonstrated simultaneous growth in /b/ segmentation during /m/ instruction. These two sounds are very similar, differing only in manner of production. There is a need to explore in more detail the specific components of phonological awareness instruction required to move children with hearing loss to successful segmentation of individual phonemes.

Maintaining Gains after Instruction

In addition to demonstrating learning of the skills taught in this study, the two participants demonstrated some maintenance of skills learned. However, this maintenance of skills was not complete. Participant 1 maintained mastery performance in identifying the initial sound of words that began with /m/, but did not maintain mastery performance for /d/ or /b/. Importantly, participant 1′s performance did not revert to baseline performance for any taught sound. Participant 2 demonstrated some maintenance above baseline performance for /m/ but did not maintain performance above baseline for /d/. When /m/ instruction was reintroduced, participant 2′s performance increased to mastery almost immediately and was maintained at 70% or above after instruction was discontinued. Thus, in general some degree of skill was maintained but this maintenance was not typically at criterion levels. Perhaps reintroducing sounds for a few lessons when maintenance falls below mastery or mixing sounds together in subsequent intervention conditions would help ensure maintenance of skill for children with hearing loss.

Future Directions

The results of this study provide preliminary evidence that phonological awareness training is effective for preschool children with hearing loss. Additional work is needed to determine the most appropriate method of phonological awareness instruction for preschool children with hearing loss, including necessary modifications to existing programs, most effective instructional group size (i.e., individual versus small group versus classroom), and the amount of instructional time needed. It is critical that instruction ultimately lead children with hearing loss to successful segmentation and blending of all sounds in words as these are the skills critical to building word decoding and spelling. This study provides evidence that children with hearing loss can begin to develop segmentation skill in the preschool years though we suspect that proficient segmentation and blending skill will not be achieved until school-age, as is true for most children with typical hearing. For children with typical hearing, phonological awareness is taught as a general skill. However, there is evidence that particular sound features are harder than others. For example, stops are harder than continuants (e.g., Marsh & Mineo, 1977) and consonant blends are harder than singletons (e.g., Bruck & Treiman, 1990) to segment. These differences are likely more pronounced for children with hearing loss, who have limited access to sounds. Future work should explore these potential differences in performance for children with hearing loss.

In addition, it is not enough to increase phonemic awareness skills in children with hearing loss. Children need to learn and retain phonemic awareness skills so they can apply these skills to word decoding and spelling. In the scope of the present study, we did not follow children's performance to elementary grades to determine the effects of training on word decoding or spelling skills. It is vital that future studies explore the effects of instruction on immediate as well as later reading outcomes.

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References

Adams, M. (1990). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.

Brownell, R. (2000). *Expressive One-Word Picture Vocabulary Test*. Novato, CA: Academic Therapy Publications.

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. *Journal of Experimental Psychology, 50,* 156–178.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test-Third Edition*. Circle Pines, MN: American Guidance Service.

Easterbrooks, S., Lederberg, A., Miller, E., Bergeron, J., & Connor, C. (2008). Emergent literacy skills during early childhood in children with hearing loss: Strengths and weaknesses. *The Volta Review, 108*(2), 91–114.

Fudala, J. B. (2000). *Arizona Articulation Proficiency Scale* (3rd rev.). Los Angeles, CA: Western Psychological Services.

Gast, D. (2010). *Single subject research methodology in behavioral sciences*. New York, NY: Routledge.

Geers, A. (2003). Predictors of reading skill development in children with early cochlear implantation. *Ear & Hearing, 24,* 59S–68S.

Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation* (2nd ed.). Bloomington, MN: Pearson Assessments.

Harris, M., & Beech, J. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf Studies and Deaf Education, 3*, 205–216.

Invernizzi, M., Juel, C., Swank, L., & Meier, C. (2004). *PALS: Phonological Awareness Literacy Screening-Kindergarten*. Charlottesville, VA: University of Virginia.

James, D., Rajput, K., Brown, T., Sirimanna, T., Brinton, J., & Goswami, U. (2005). Phonological awareness in deaf children who use cochlear implants. *Journal of Speech, Language, and Hearing Research, 48*, 1511–1528.

Kent, C., & Read, C. (2002). *The acoustic analysis of speech*. San Diego, CA: Singular Publishing Group.

Kratochwill, T. R., Hitchcock, J., Horner, R. H., Levin, J. R., Odom, S. L., Rindskopf, D. M., & Shadish, W. R. (2010). *Single-case designs technical documentation*. Retrieved from http://ies.ed.gov/ncee/wwc/pdf/wwc_scd.pdf

Kyle, F., & Harris, M. (2011). Longitudinal patterns of emerging literacy in beginning deaf and hearing readers. *Journal of Deaf Studies and Deaf Education, 16*, 289–304.

Marsh, G., & Mineo, R. (1977). Training preschool children to recognize phonemes in words. *Journal of Educational Psychology, 69*, 748–753.

Mattingly, I. (1972). Reading, the linguistic process, and linguistic awareness. In J. Kavanagh & I. Mattingly (Eds.), *Language by ear and by eye: The relationships between speech and reading* (pp. 133–147). Cambridge, MA: MIT Press.

Miller, P. (1997). The effect of communication mode on the development of phonological awareness in prelingually deaf students. *Journal of Speech, Language, and Hearing Research, 40*, 1151–1163.

Moeller, M. P., Tomblin, J. B., Yoshinaga-Itano, C., Connor, C., & Jerger, S. (2007). Current state of knowledge: Language and literacy of children with hearing impairment. *Ear & Hearing, 28*, 740–753.

Moog, J. (2002). Changing expectations for children with cochlear implants. *The Annals of Otology, Rhinology, & Laryngology, 111*, 138–142.

Most, T., Aram, D., & Andorn, T. (2006). Early literacy in children with hearing loss: A comparison between two educational systems. *The Volta Review, 106*(1), 5–28.

National Early Literacy Panel (2008). *Developing early literacy: Report of the National Early Literacy Panel*. Washington, DC: National Institute for Literacy.

National Institute of Child Health and Human Development (NICHD) (2000). *Report of the National Reading Panel. Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Report of the Subgroups (NIH Publication No. 00–4754)*. Washington, DC: U.S. Government Printing Office.

Qi, S., & Mitchell, R. (2012). Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Journal of Deaf Studies and Deaf Education, 17*, 1–18. doi: 10.1093/deafed/enr028

Rice, M., & Wexler, K. (2001). *Rice/Wexler Test of Early Grammatical Impairment*. Austin, TX: PsychCorp.

Roid, G., & Miller, L. (1997). *Leiter International Performance Scale - Revised*. Wood Dale, IL: Stoelting.

Scarborough, H. (1990). Index of Productive Syntax. *Applied Psycholinguistics*, *11*, 1–22.

Schuele, C. M., & Boudreau, D. (2008). Phonological awareness intervention: Beyond the basics. *Language, Speech, & Hearing Services in Schools, 39*, 3–20. doi: 0161–1461/08/3901-0003

Schuele, C. M., & Dayton, N. D. (2004). *Intensive phonological awareness program*. Nashville, TN.

Schuele, C. M., Justice, L., Cabell, S., Knighton, K., Kingery, B., & Lee, M. (2008). Field-based evaluation of two-tiered instruction for enhancing kindergarten phonological awareness. *Early Education and Development, 19*, 726–752.

Spencer, L., & Tomblin, J. B. (2009). Evaluating phonological processing skills in children with prelingual deafness who use cochlear implants. *Journal of Deaf Studies and Deaf Education, 14,* 1–21.

Stahl, S. A., & Murray, B. A. (1994). Defining phonological awareness and its relationship to early reading. *Journal of Educational Psychology, 86,* 221–234.

Sterne, A., & Goswami, U. (2000). Phonological awareness of syllables, rhymes, and phonemes in deaf children. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *41,* 609–625.

Trybus, R., & Karchmer, M. (1977). School achievement scores of hearing-impaired children: National data on achievement status and growth patterns. *American Annals of the Deaf, 122*, 62–69.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*, 192–212.

Wiig, E., Secord, W., & Semel, E. (2004). *Clinical Evaluation of Language Fundamentals-Preschool* (2nd ed.). Austin, TX: PsychCorp.

Appendix A

Words Used in Assessment

/b/	/d/	/m/	/n/	/p/	/t/
ball	dad	mad	nail	paint	tail
bath	dance	man	nap	pants	tall
bear	dark	me	neck	park	teeth
bed	day	mess	neigh	pie	ten
big	dig	milk	nest	pig	toe
boat	dirt	mom	night	point	tongue
book	dog	moo	nine	pool	top
boy	doll	moon	nose	pot	toy
bus	door	mouse	nurse	pour	tub
bye	duck	mouth	nut	purse	two

Appendix B

Words Used in Teaching

/m/	/d/	/b/
maid	**dark**	bag
mail	dart	bake
make	**day**	**ball**
man	deck	band
mane	deer	bat
mask	desk	bead
mat	dew	**bear**
match	dice	bee
math	**dig**	beg
meal	**dirt**	bell
meat	disc	**big**
meet	dish	bike
melt	dive	bill
mess	dock	bone
mic	**doll**	**book**
mice	dome	boss
mime	dots	bow
mint	dove	bowl
mitt	down	bug
mix	dump	bull
mole	dunk	bun
mom	dust	burn
moo		**bus**
moose		bush
mop		
moth		
mouse		
mow		
mug		

Note: Words in bold also used in assessment.