Picture Naming by Children with Hearing Loss: II. Effect of Phonologically Related Auditory Distractors

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Abstract

Thirty children with hearing loss (HL) and 129 typically developing (TD) children representing comparable ages, vocabulary abilities, or phonology skills named pictures while attempting to ignore auditory distractors. The picture-distractor pairs were constructed to represent phonologically congruent or conflicting onset relations, for example, the picture “duck” with distractors of /dA/ or /pA/, respectively. In children with good phoneme discrimination, congruent distractors speeded naming and conflicting distractors slowed naming, relative to a control condition. Effects were similar in HL and TD subgroups. In children with poorer phoneme discrimination, conflicting distractors did not influence naming in the HL subgroup, regardless of discrimination status, and consistently slowed naming only for discriminated contrasts in the TD subgroup. Phonologic representations appear suitably fine-grained in HL children with good auditory perceptual abilities but may be less well specified, more holistic, and/or less auditory-linguistically based in HL children with poorer auditory perceptual abilities. Results are discussed in terms of the heterogeneous nature of phonologic processing in children with HL.

Key Words: Childhood hearing impairment, children, language processing, picture-word task, phonologic facilitation, phonologic interference

Abbreviations: LSD = least significant difference test; HL = hearing loss; HTL = hearing threshold level; SOA = stimulus onset asynchrony; TD = typically developing

Sumario

Treinta niños con hipoacusia (HL) y 129 niños en desarrollo típico (TD) mostrando edades, vocabulario y habilidades fonológicas comparables, buscaron identificar dibujos tratando de ignorar sonidos de distracción. Los pares de dibujo-sonido de distracción fueron construidos para representar relaciones iniciales fonológicamente congruentes o conflictivas; por ejemplo, el dibujo “pato” con elementos de distracción /dA/ y /pA/, respectivamente. En niños con buena discriminación fonémica, las distracciones congruentes aceleraron la identificación y las distracciones conflictivas retardaron la identificación, en relación a una condición controlada. Los efectos fueron similares en los sub-grupos HL y TD. En niños con peor discriminación fonémica, las distracciones conflictivas no influenciaron la identificación en el sub-grupo HL, sin importar su condición discriminativa, y, consistentemente redujeron la identificación sólo para los contrastes de discriminación en el sub-grupo TD. Las representaciones fonológicas parecieron ser adecuadamente finas en niños con hipoacusia y con buenas habilidades perceptuales auditivas, pero menos especificadas, más holísticas, y/o menos basadas en aspectos auditivo-lingüísticos en niños hipoacúsicos con menores habilidades perceptuales auditivas. Los resultados se discuten en términos de la naturaleza heterogénea del procesamiento fonológico en niños con hipoacusia.

Palabras Clave: Hipoacusia infantil, niños, procesamiento del lenguaje, tarea dibujo-palabra, facilitación fonológica, interferencia fonológica

Abreviaturas: LSD = prueba de la diferencia menos significativa; HL = hipoacusia; HTL = nivel auditivo umbral; SOA = asincronía del inicio del estímulo; TD = en desarrollo típico

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To communicate, children must learn the meanings and pronunciations of words. Auditory input and feedback provide the foundations for this learning during early childhood (Ruffin-Simon, 1983; Tye-Murray, 1992; Tye-Murray et al, 1995a; Levelt et al, 1999). The dependence of early lexical learning on the auditory modality raises an issue of how childhood hearing loss (HL) may affect the development of word representations and processes. We hypothesize that HL degrades and filters auditory input, resulting in impoverished memory representations, such as less rich semantic knowledge and less well-specified phonologic knowledge. The purpose of this study was to investigate the nature of semantic and phonologic representations during word processing by children with HL who use aural/oral communication. The results are reported in two articles. This article focuses on the nature of phonologic knowledge.

We applied a newly developed children's cross-modal picture-word task to assess the influence of phonologically related auditory distractors on picture naming (Jerger et al, 2002b). The dependent measure is the speed of picture naming. If an auditory distractor speeds up or slows down picture naming relative to a baseline control condition, performance is assumed to reflect cross talk between the production and comprehension systems (Levelt et al, 1991). The patterns of cross talk provide a basis for hypothesizing about the nature of the representations underlying performance (Rayner and Springer, 1986; Glaser, 1992). The basic paradigm is described below, followed by predicted results in children with moderate HL.

Cross-Modal Picture-Word Task: Phonologic Condition

The task requires a participant to name a picture while attempting to ignore a seemingly irrelevant auditory distractor. We selected nonsense syllables, rather than words, as phonologic distractors because we wanted to investigate facilitation and interference without the effects superimposed on the interference effect from word distractors in general (Schriefers et al, 1990). The relation between the distractors and the picture is either phonologically congruent or conflicting, for example, the picture “duck” coupled with /dA/ or /pa/, respectively. Interactions between the picture and the distractor, the production and comprehension systems, are hypothesized to occur when the picture-naming process is occupied with output phonologic, or word form, processing. Congruent distractors, as an example, are assumed to facilitate, or speed, picture-naming responses by activating output phonologic representations shared with the picture, thus allowing these segments to be selected more rapidly during the naming process.

The timing relation between the onsets of the pictures and distractors, termed stimulus onset asynchrony (SOA), also varies in the picture-word task. The classic research in this area used only congruent, phonologically related word distractors (e.g., the picture-distractor pair “bus” and “bug”). Investigators found that manipulating the SOA produced a discrete time course of interaction, that is, facilitation at some SOAs but not others. Recent results with nonsense syllable, rather than word, distractors, however, did not show a discrete time course, noting instead widespread phonologic effects at all SOAs (Starreveld, 2000; Jerger et al, 2002b).

In light of this new evidence, the time course of effects on cross-modal picture-word naming tasks in the presence of phonologic distractors is no longer wholly consistent and may vary as a function of the test materials/task procedures. Jescheniak and Schriefers (2001) noted that the phonologic effects do seem to arise from an automatic preactivation process. The uncertainty, in their view, concerns whether the effects reflect more than just coactivated output phonologic processes. Interestingly, similar debates surround other types of phonologic paradigms (Goldinger et al, 1992; Goldinger, 1999). Despite the current inconsistencies, the cross-modal picture-word task and the other paradigms remain valuable tools for exploring phonologic processes and assessing models of word recognition in normal and clinical populations.
(Goldinger et al, 1992; Hashimoto and Thompson, 2001; Jescheniak et al, 2001). The question addressed by this study is whether normal phonologic facilitation and interference effects will be observed in children with HL.

**Predicted Results in Children with HL**

The development of phonologic representations in typically developing (TD) children is assumed to progress from relatively holistic to more segmentally based (Locke, 1986; Jusczyk, 1995; although see Gerken et al, 1995). Although the age course of the transition from more holistic to more fine-grained may continue into the school-age years, the process has a noticeable degree of refinement by 5 to 7 years of age (Nitrouer et al, 1989; Walley, 1993). To the extent that children with moderate HL may demonstrate abnormally poor phoneme discrimination ability and phonologic awareness (Briscoe et al, 2001), this progression to more segmentally based phonologic representations may not develop normally. Visual speech may also become a more important source of phonologic knowledge, with phonologic representations more tied to articulatory or speechread codes. These points of view suggest that we may not observe normal facilitation and interference effects from phonologically related auditory distractors in children with HL.

In distinction to the above vantage point, however, extensive phoneme repertoires and reasonably normal phonologic processes seem to develop in children with HL, even those with severe prelingual losses, although with significant developmental delay and individual variability (Dodd and Burnham, 1988; Dodd and So, 1994; see Oller and Eilers, 1981, who stress the exceptions rather than the similarities). These latter data suggest that we may find normal phonologic effects in children with HL. This possible outcome may also be promoted by the phoneme onsets of the children's picture-word test, which were limited to speech sounds that represent developmentally early achievements and tend to be produced accurately by both HL and TD young children (Stoel-Gammon and Dunn, 1985; Abraham, 1989; Tye-Murray et al, 1995b).

In short, the aims of this study were to assess phonologic facilitation and interference effects from onset-related distractors representing developmentally early phonemes. In these carefully optimized conditions, any differences between HL and TD children must be attributable to the use of different auditory cues for differentiating phonemes or to phonologic codes that are less fine-grained or more tied to articulatory or speechread codes. These data may thus provide new insights into the phonologic representations underlying the words and phonemes that are mastered early by children, both TD and HL. To our knowledge, these are the first data in young children with HL on a cross-modal picture-word task.

**METHOD**

**Participants and Demographics**

**General**

The participants were divided into a group with HL and several TD comparison groups. They were described in detail in the companion article (Jerger et al, 2002a). In brief, the HL group consisted of 30 children, 16 boys and 14 girls between 5 and 15 years of age. All of the children were considered successful hearing aid users and attended regular classes (mainstreamed). Average unaided hearing sensitivity was approximately 50 to 60 dB hearing threshold level (HTL) bilaterally. The suspected onset of the loss was congenital/at birth or before 2 years of age in most children. The initial identification/amplification of the loss was typically before 3 years of age. The participants were tested while wearing their hearing aids. Average aided speech detection thresholds and word recognition scores were within normal limits. The normal comparison groups consisted of 129 TD children, 71 boys and 58 girls between 3 and 14 years of age. Hearing sensitivity, speech detection thresholds, and word recognition scores were within normal limits in all children.

**Demographic Materials and Instrumentation**

The standard measures of hearing sensitivity, word recognition, visual acuity, oral motor function, gross neurodevelopmental history, and socioeconomic status and the operational definitions for normalcy were detailed in the companion article (Jerger et al, 2002a). Nonverbal abilities were estimated by visual perceptual abilities (Southern California Figure Ground Visual Perception Test [Ayres, 1978] or Block Design subtest of the Wechsler Intelligence Scale for Children-Revised [WISC-R; Wechsler, 1974]), visual simple reaction time, and visual-motor integration (Developmental Test of Visual Motor Integration [VMI; Beery, 1989]). Vocabulary
knowledge was assessed with the Peabody Picture Vocabulary Test-III (PPVT-III; Dunn and Dunn, 1997).

Input phonologic knowledge was estimated by onset and rhyme laboratory measures. These skills were chosen because they are usually operational in young children and are assumed to be more independent of reading skill than other phonologic skills (Stanovich et al., 1984; Bird et al., 1995). The onset-segment test consisted of 10 words beginning with the voiced or unvoiced stop consonants of the picture-word test. Each word had a corresponding picture response card with four alternatives. The alternatives represented onsets with (1) correct voicing and correct place of articulation, (2) correct voicing and incorrect place, (3) incorrect voicing and correct place, and (4) incorrect voicing and incorrect place. For example, for the target onset segment /dr/, the pictured alternatives were (1) duck, (2) bus, (3) tongue, and (4) puppy. The rhyme judgment task also consisted of 10 words. Each word had a corresponding picture response card containing four alternatives. The alternatives represented the following relations to the test item (boat): the rhyming word (goat) and words with the test item’s initial consonant (bag), final consonant (kite), and vowel (toad). For both tasks, different response cards varied the position of the alternatives across children.

Output phonologic knowledge was estimated with a test of articulatory proficiency (Goldman-Fristoe Test of Articulation [Goldman and Fristoe, 1986]) and simple naming latency (the instrumentation and procedure are detailed subsequently). Mixed phonologic/semantic ability was estimated with the Expressive Vocabulary Test (EVT) (Williams, 1997).

**Demographic Procedure**

Each of the standardized measures was administered and scored according to the recommended technique. For the laboratory onset-segment and rhyme judgments, a tester asked the child to show her/him “Which one begins with /dr/?” or “Which one rhymes with boat?” To ensure that children understood the concept of onset and rhyme, the tester and the child read pages from Dr. Seuss’ Hop on Pop (New York: Random House, 1963), prior to task administration. The scores for both measures were percentage correct. The individual items comprising the tests were administered randomly in two presentation modes: auditory only and audiovisually. The tester ensured that the child knew the names of the pictured alternatives before administering each item. The child’s responses to the output phonologic tasks, as well as the picture-word task, were digitally recorded and analyzed off-line by two speech pathology students. Dialectal variations were not scored as errors.

**Comparison of Groups**

The groups consisted of children with HL and TD children representing comparable ages and nonverbal skills (n = 60, 5 to 14 years), receptive vocabulary skills (n = 60, 4 to 12 years), and input phonologic skills (n = 30, 3 to 6 years) (see Table 2 of Jerger et al., 2002a, for details). The groups allowed us to compare the performance of HL and TD children of comparable chronic and nonverbal mental ages and knowledge about words in terms of our interest—meanings and sound patterns. Twenty-one of the children participated in two of the comparison groups. In brief, the HL and age comparison groups had statistically equivalent chronicologic ages, visual perceptual abilities, and visual simple reaction times. The average age in each group was 10 years, 6 months. The HL and receptive vocabulary groups had comparable vocabulary knowledge (raw scores of 115 to 116), which corresponded to mental age equivalence scores of approximately 9 to 9½ years. The HL and input phonology groups had comparable onset and rhyme skills, averaging at least 90 percent correct in each group, when the items were presented audiovisually.

In addition to the input phonologic abilities described above, we also obtained some estimates of output phonologic skills. The latter skills, which were not equated between groups, are summarized in Table 1, along with each
Table 1 Performance on Variables That Were Not Equated between HL and Comparison Groups (range in parentheses), along with the Age in Each Group for Comparative Purposes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hearing Loss (n = 30)</th>
<th>Age Comparison (n = 60)</th>
<th>Receptive Vocabulary Comparison (n = 60)</th>
<th>Phonology Comparison (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mo)</td>
<td>128 (64-185)</td>
<td>125 (64-177)</td>
<td>82 (49-150)</td>
<td>63 (47-83)</td>
</tr>
<tr>
<td>Simple naming latency (msec)</td>
<td>428 (269-700)</td>
<td>407 (252-712)</td>
<td>474 (257-727)</td>
<td>552 (327-993)</td>
</tr>
<tr>
<td>Articulation proficiency (raw score)</td>
<td>63 (29-73)</td>
<td>73 (66-73)</td>
<td>72 (50-73)</td>
<td>68 (50-73)</td>
</tr>
<tr>
<td>Expressive vocabulary (raw score)</td>
<td>97 (52-157)</td>
<td>113 (69-188)</td>
<td>87 (44-139)</td>
<td>65 (47-108)</td>
</tr>
</tbody>
</table>

The children were asked to name pictures in the presence of various types of auditory distractors representing either semantic or phonologic relations between the pictures and the words. For the phonology items, naming responses to eight pictures were evaluated in the presence of six types of auditory distractors, for a total of 48 trials. The pictures' names always began with /b/, /p/, /t/, or /d/; coupled with the vowels /i/ or /ʌ/. The distractors were consonant-vowel sequences representing different onset relations between the picture and the distractor, namely congruent, two features conflicting, one feature conflicting, verbal baseline, and nonverbal baseline. The vowel of the nonsense syllable was always congruent. Examples are the picture "teeth" coupled with the distractors /bi/ (congruent, correct voicing, and correct place of articulation), /bi/ (two features conflicting, incorrect voicing, and incorrect place), /pi/ (one feature conflicting, incorrect place only), /di/ (one feature conflicting, incorrect voicing only), /i/ (vowel nucleus verbal baseline), and a drumroll sound (nonverbal baseline).3 The drumroll sound was 425 msec, the average duration of the other

The pronunciation of the picture-name onsets (initial consonant-vowel sequence) was accurate in all children, both HL and TD. This finding agrees with previous observations (Stoel-Gammon, 1983; Stoel-Gammon and Dunn, 1985; Abraham, 1989; Dodd and So, 1994). The pronunciation of the offsets (all succeeding sounds) was also accurate in 112 of the TD children and 12 of the HL children. The remaining 17 TD children mispronounced from 1 to 3 offsets during speeded naming, and the remaining 18 HL children mispronounced from 2 to 8 offsets. Common mispronunciations in both groups were the /r/ in deer, the /s/ in pizza and bus, and the /θ/ in teeth.

Experimental Task

Instrumentation/Materials

The instrumentation, test items, and conditions comprising the Children's Picture-Word Test have been detailed previously (Jerger et al, 2002a, 2002b). In brief, colored pictures were presented via a computer monitor, and auditory distractors were presented via a speech audiometer and associated loudspeaker. Both the computer monitor and the loudspeaker were mounted on an adjustable height table directly in front of the child at a distance of approximately 90 cm. Naming latencies to the onset of a picture were obtained with 1 msec resolution using a computer counter/timer and voice-operated relay.

3Some of the onsets coupled with the /i/ vowel formed words; we demonstrated previously that the vowel nucleus /i/ vs /ʌ/ did not differentially affect performance (Jerger et al, 2002b). One of the distractors also did not have a pure phonologic relation with two of the pictures. Specifically, the distractor /bi/ was phonologically, semantically, and morphologically related to the pictures "bees" and phonologically and semantically related to the picture "deer." We demonstrated previously that the two items with both semantic and phonologic relationships produced both congruency and interference effects. The effects on naming by these distractors with multiple relations were either smaller or comparable to the effect produced by the "pure" distractors. Our findings are consistent with Damian and Martin's (1999) observation that the congruency effect produced by semantically and phonologically related word distractors is comparable to the one produced by pure phonologically related distractors.
distractors. A rationale for the one feature conflicting distractors was the previous observation of an interaction between the perception and production of voicing features but not of place of articulation features (Gordon and Meyer, 1984).

In addition to the picture-word task, a same-different task assessed the children's phoneme discrimination ability. Test stimuli were the stop consonants /p/, /b/, /t/, and /d/ coupled with the vowels /i/ and /A/. The items were recorded by the same male talker and played back as above. The a priori probabilities were 40 percent same responses (pa-pa, pa-pa) and 60 percent different responses (pa-ba, pa-ta, pa-da). The intersignal interval from the onset of the first syllable to the onset of the second syllable was 750 msec. The test was composed of 40 trials, in which each of the four consonants was presented five times (as illustrated) with each vowel. The "same" stimuli were composed of two different utterances; thus, the "same" pairs had phonemic constancy with acoustic variability. The response board contained two keys labeled "same" and "different." The labels were two circles (or two blocks for younger children) of the same color or of different colors (and shapes). A blue star approximately 3 cm to the outside of each key designated the "start" position for each hand assumed before each trial.

**Procedure**

In brief, the participant sat at a child-sized table in a double-walled sound-treated booth. A cotester sat alongside the child, keeping him/her focused on the task. All trials judged to be flawed (e.g., the child said "a" before the name) were deleted on-line and readministered after intervening items. The child was instructed to name each picture as quickly and as accurately as possible and to ignore the auditory distractor. The intensity level of the distractors was approximately 70 dB SPL, as measured at the imagined center of the participant's head with a sound level meter. The picture-word task was administered in a practice session prior to the primary experimental procedure. During the practice run, each picture of both the semantic and phonologic conditions was presented once, coupled with one of its auditory distractors selected at random. At the end of these trials, the tester showed each picture on a 5 × 5" card to the child, teaching him/her the target names of any pictures named incorrectly. During the primary run, each picture was presented with each of its auditory distractors at each of three SOAs: -150 msec, 0 msec, and +150 msec. The test items and the SOAs were presented randomly within one unblocked condition (see Starreveld and La Heij, 1996, for a discussion).

Immediately prior to and after the picture-word task, the child completed a simple naming task, without any auditory distractors, to a predetermined picture, lamp. The task quantified the child's ability to detect and name a predetermined target. Each presentation consisted of 2 practice trials and 10 test trials.

For the phoneme discrimination task, a stimulus pair was presented, and the child was instructed to push the correct response key as quickly and as accurately as possible. The child was informed that about half of the trials would be the same and about half would be different. The scores were the percentage correct for the different trials and the overall distribution of same/different responses.

**Data Analysis**

Picture-word results were analyzed by subjects (F₁) and by items (F₂) with a mixed-design analysis of variance (Pedhazur, 1982), with one exception. Data in the small subgroups of children with chance performance on the phoneme discrimination task for at least one contrast were analyzed separately with t-tests. The total number of excluded, missing, and deleted (with replacement) trials was detailed in the companion article (Jerger et al, 2002a).

**RESULTS**

**Baseline Condition**

Figure 1 shows average naming latencies in the groups for the verbal (vowel) and nonverbal (drumroll) baseline distractors. Results were collapsed across the /i/ and /A/ vowel distractors because naming times were statistically equivalent. Three statistical analyses by subjects and by items included the between factor of group (HL vs age, HL vs vocabulary, HL vs input phonology) and type (vowel and drumroll). Each analysis contained the same within factors, namely SOA (-150, 0, and +150 msec) and type (vowel and drumroll). Average overall naming latencies differed significantly between the HL and comparison groups, although the analyses by subjects for the HL versus age comparison groups did not achieve significance: HL-age: F₁ = 3.41, df = 1, 88, p = .07; F₂ = 29.08, df = 1, 14, p = .0001; HL-vocabulary: F₁ = 9.32, df = 1, 88, p = .003; F₂ = 54.70, df = 1, 14,
Figure 1 Average naming latencies in the groups for the verbal (vowel) and nonverbal (drumroll) baseline distractors. Results were collapsed across the /i/ and /a/ vowel distractors because naming times were statistically equivalent.

**Phonology Comparison**

**Age Comparison**

**Hearing Impairment**

**Receptive Vocabulary Comparison**

**Stimulus Onset Asynchrony (msec)**

Prior to analyzing results, children were grouped into pass versus no-pass subgroups based on discrimination accuracy on the phoneme discrimination task. The pass subgroup consisted of children who discriminated all contrasts accurately; the no-pass subgroup contained children who showed chance performance for at least one contrast. Preliminary
statistical analyses indicated that naming performance differed significantly in the pass versus no-pass subgroups. Thus, the data for these subgroups are presented separately.

**Pass Phoneme Discrimination Subgroups**

Phoneme discrimination was accurate, at least 75 percent correct, for all contrasts in 115 TD children and 16 HL children. Statistical analyses by subjects and by items included the between factor of subgroup (HL vs age, HL vs vocabulary, or HL vs input phonology) and the within factors of SOA and type (congruent, two features conflicting, one feature voice conflicting, and one feature place conflicting). Figure 2 shows average adjusted naming latencies for the phonologic distracters in the pass discrimination subgroups collapsed across SOA. The SOA did not significantly affect performance in any subgroup.

Naming latencies were significantly influenced by the type of distracter in all subgroups: HL-age: $F_1 = 21.67$, $df = 3, 210$, $p = .0001$; $F_2 = 18.80$, $df = 3, 42$, $p = .0001$; HL-vocabulary: $F_1 = 13.01$, $df = 3, 186$, $p = .0001$; $F_2 = 14.32$, $df = 3, 42$, $p = .0001$. Performance was consistently faster for congruent onsets than for conflicting onsets. No other significant effects or interactions were observed, with one exception. The pattern of results differed significantly in the HL and input phonology comparison subgroups, with a significant type x subgroup interaction: $F_1 = 3.23$, $df = 3, 114$, $p = .02$; $F_2 = 2.58$, $df = 3, 42$, $p = .06$ (elaborated subsequently).

To assess whether each type of distractor significantly facilitated or disrupted performance, we determined whether the unadjusted naming latencies for each condition differed from the vowel baseline. Statistical analyses by subjects and by items included the between factor of subgroup (HL and TD) and the within factor of type (baseline and distracter). Unadjusted naming latencies for the congruent type of distracters were significantly faster than the vowel baseline in all subgroups: HL-age: $F_1 = 13.45$, $df = 1, 70$, $p = .0005$; $F_2 = 4.23$, $df = 1, 14$, $p = .05$; HL-vocabulary: $F_1 = 4.73$, $df = 1, 62$, $p = .03$; $F_2 = 4.55$, $df = 1, 14$, $p = .05$; HL-phonology: $F_1 = 15.10$, $df = 1, 38$, $p = .0004$; $F_2 = 7.12$, $df = 1, 14$, $p = .02$.

Figure 2 Average adjusted naming latencies in the presence of the phonologic distracters in the hearing loss and typically developing pass subgroups. The baseline condition was composed of the vowels /i/ and /æ/. Results are collapsed across stimulus onset asynchrony, which did not significantly affect performance.
There were no significant subgroup × type interactions, indicating that the degree of facilitation was statistically equivalent in the HL and TD subgroups.

For the two features conflicting onsets, unadjusted naming times were significantly slower than the vowel baseline in all subgroups: HL-age: $F_1 = 11.25, df = 1, 70, p = .001; F_2 = 7.99, df = 1, 14, p = .01$; HL-vocabulary: $F_1 = 4.92, df = 1, 62, p = .03; F_2 = 6.27, df = 1, 14, p = .02$; HL-phonology: $F_1 = 8.60, df = 1, 38, p = .005; F_2 = 8.61, df = 1, 14, p = .01$. There were no significant subgroup × type interactions, indicating that the degree of interference for the two features conflicting onsets was statistically equivalent in the HL and TD subgroups. Unadjusted naming latencies for the one feature conflicting distractors were also significantly slower than the vowel baseline in all subgroups: HL-age: $F_1 = 7.33, df = 1, 70, p = .008; F_2 = 18.34, df = 1, 14, p = .003$; HL-vocabulary: $F_1 = 7.93, df = 1, 62, p = .006; F_2 = 12.17, df = 1, 14, p = .003$; HL-phonology: $F_1 = 29.54, df = 1, 38, p = .0001; F_2 = 19.91, df = 1, 14, p = .0005$. Place-conflicting onsets: HL-age: $F_1 = 13.99, df = 1, 70, p = .0004; F_2 = 14.32, df = 1, 14, p = .002$; HL-vocabulary: $F_1 = 5.88, df = 1, 62, p = .02; F_2 = 13.88, df = 1, 14, p = .002$; HL-phonology: $F_1 = 30.25, df = 1, 38, p = .0001; F_2 = 28.16, df = 1, 14, p = .0001$. The degree of interference produced by the one feature conflicting distractors was significantly less in the HL subgroup than in the input phonology subgroup, with a significant subgroup × type interaction in the analysis by subjects for both voice-conflicting onsets: HL-age: $F_1 = 18.34, df = 1, 70, p = .001; F_2 = 13.23, df = 1, 14, p = .003$; HL-vocabulary: $F_1 = 7.93, df = 1, 62, p = .006; F_2 = 12.17, df = 1, 14, p = .003$; HL-phonology: $F_1 = 29.54, df = 1, 38, p = .0001; F_2 = 19.91, df = 1, 14, p = .0005$. Place-conflicting onsets: HL-age: $F_1 = 13.99, df = 1, 70, p = .0004; F_2 = 14.32, df = 1, 14, p = .002$; HL-vocabulary: $F_1 = 5.88, df = 1, 62, p = .02; F_2 = 13.88, df = 1, 14, p = .002$; HL-phonology: $F_1 = 30.25, df = 1, 38, p = .0001; F_2 = 28.16, df = 1, 14, p = .0001$. The degree of interference produced by the one feature conflicting distractors was significantly less in the HL subgroup than in the input phonology subgroup, with a significant subgroup × type interaction in the analysis by subjects for both voice-conflicting onsets and place-conflicting onsets, respectively: HL-phonology: $F_1 = 4.46, df = 1, 38, p = .04$; HL-phonology: $F_1 = 5.34, df = 1, 38, p = .03$. The subgroup × type interaction did not consistently achieve significance, however, in the analysis by items for voice-conflicting type and place-conflicting type, respectively: HL-phonology: $F_1 = 2.13, df = 1, 38, p = .16$; HL-phonology: $F_2 = 4.29, df = 1, 38, p = .05$. The degree of interference for the one feature conflicting distractors was approximately 45 to 60 msec in the HL subgroup and 110 to 125 msec in the input phonology subgroup.

The overall pattern of results characterizing the HL and input phonology subgroups, namely no significant difference in the degree of facilitation and interference from congruent and two features conflicting onsets coupled with a significant difference in the degree of interference from one feature conflicting onsets, clarifies the subgroup × type interaction in the initial analysis. There were no other significant interactions, indicating that the interference effect from one feature conflicting distractors was statistically equivalent in the HL subgroup and the age and vocabulary subgroups. The difference in naming latencies between the two features versus each of the one feature conflicting distractors exceeded Fisher's least significant difference (LSD) test (Keppel, 1973) in the input phonology subgroup. None of the other differences achieved the LSD in any subgroup.

To summarize, for the pass subgroups, the congruent distractors significantly facilitated performance and the conflicting distractors significantly disrupted performance. The degree of facilitation and interference was similar in the HL and TD comparison subgroups, with one exception. The HL subgroup showed significantly less interference from the one feature conflicting distractors than the input phonology TD subgroup. The type of conflicting onset did not differentially affect the degree of interference, again, with one exception. The input phonology subgroup showed significantly more interference for the one feature conflicting distractors than for the two features conflicting distractors, suggesting that distractors that are more similar to the target are more disruptive to the naming process. This pattern of results was observed in our previous project (Jerger et al., 2002b).

**No-Pass Phoneme Discrimination Subgroups**

Phoneme discrimination showed chance performance for at least one contrast in 14 TD children and 14 HL children. Phoneme discrimination difficulties, particularly for one feature contrasts, have been observed previously in both TD and HL children within this age range (Graham and House, 1970; Briscoe et al., 2001). Data were analyzed separately for picture-word pairs representing a phoneme contrast that could versus could not be discriminated. Results in the TD children were examined as a whole, regardless of the original comparison group assignment. Results for the different types of one feature conflicting distractors were combined because there were no significant differences in the separate data.

Figure 3 shows average adjusted naming latencies in the HL and TD subgroups for picture-word pairs representing a one feature or two features conflicting phoneme contrast that could
Comparison of Pass and No-Pass Phoneme Discrimination Subgroups

In the HL group, performance on the demographic variables indicated that the pass subgroup was about 2 years older than the no-pass subgroup, with average ages of 138 versus 117 months, respectively. The two HL subgroups had (1) comparable nonverbal skills, about the 53rd percentile; (2) comparable input phonologic processing abilities when items were presented audiovisually, about 97 percent for onset judgments and 93 percent for rhyme judgments; and (3) similar distributions with regard to the suspected age of onset, age of identification, and etiology of the hearing loss. In contrast to these commonalities, however, the pass HL subgroup, relative to the no-pass subgroup, exhibited (1) more advanced vocabulary and articulatory abilities, approximately the 55th versus 23rd percentiles, respectively; (2) stronger input phonologic processing abilities for items presented auditorily, 91 percent versus 80 percent for onset judgments and 95 percent versus 77 percent for rhyme judgments; (3) better unaided hearing sensitivity, 44 dB versus 58 dB HTL; and (4) better aided word recognition, 98 percent versus 80 percent correct.

In the TD children, the pass subgroup was approximately 3 years older than the no-pass subgroup, with average ages of 101 versus 64 months, respectively. The TD subgroups had comparable (1) nonverbal skills, about the 70th percentile; (2) vocabulary and articulatory skills, about the 78th percentile; (3) phonologic processing abilities for onset judgments in both the auditory-only mode, about 95 percent correct, and the audiovisual mode, 97 percent correct; (4) hearing sensitivity, about 6 dB HTL; and (5) word recognition, 99 percent correct. Phonologic processing abilities for rhyme judgments, however, differed in the subgroups, with the pass TD subgroup having better performance in both presentation modes, 97 percent versus 68 percent correct for the auditory-only items and 98 percent versus 83 percent correct for the audiovisual items.

Overall, when the HL subgroups were compared, the no-pass subgroup consisted of younger children with a greater degree of hearing loss, poorer word recognition, poorer overall verbal abilities, and a greater reliance on visual speech for phonologic processing. When the TD subgroups were compared, the no-pass subgroup again consisted of younger children. Unlike the HL subgroup, however, performance was poorer.
for these children only on the rhyming tasks, regardless of mode of presentation. Although average performance between the subgroups differed noticeably on these indices, we should caution that the range of scores in both the HL and TD subgroups overlapped. Thus, data on a larger number of children are necessary to unequivocally discern the relation among phonologic picture-word effects, phoneme discrimination abilities, and related demographic factors.

DISCUSSION

This research examined the influence of phonologically related auditory distractors on picture naming by TD children and children with HL, with a new cross-modal picture-word test. Results in the baseline condition showed a slight but significant difference in naming times for vowel versus drumroll distractors, agreeing with the more pronounced difference observed for word versus drumroll distractors in the companion article (Jerger et al, 2002a). Apparently, speech input was more compelling and harder to ignore than nonspeech input. This finding agrees with previous observations in adults (Martin et al, 1988; LeCompte et al, 1997). Results indicate that the children, even those with HL, processed input as speech or nonspeech, signifying that this critical dimension of processing was normal (de Gelder and Morais, 1995).

In addition to the above on-line processing task, the current study also assessed children's ability to discriminate phoneme contrasts using an off-line technique. The purpose of this assessment was to ensure that all children, including those with HL, could accurately discriminate the onsets used in the picture-word task. In the pass subgroups of children, congruent distractors significantly speeded up naming and conflicting distractors significantly slowed naming. The degree of facilitation and interference was reasonably similar in the HL and TD subgroups. Apparently, both TD and HL children with better phoneme discrimination were sensitive to the phonologic relations between the distractor and the picture. A trend in the data, which achieved statistical significance only in the younger, input phonology comparison group, was for the one feature conflicting distractors to disrupt naming more than the two features conflicting distractors. This pattern of results was observed in our preceding project (Jerger et al, 2002b).

The latter outcome may seem surprising at first glance as one might have expected less interference from distractors that are more similar to the target. Some researchers have suggested, however, that there are inhibitory connections between activated phonologic representations and that the degree of inhibition increases as the similarity between the activated representations increases (Slowiaczek and Hamburger, 1992; Dell and O'Seaghdha, 1994). If so, then the one feature, relative to the two features, conflicting distractors would activate a cohort of representations with more similar phonologic onsets, which would produce greater inhibition of the target word's onset. Further research is needed to determine the generality of this finding and contributing factors.

In the no-pass TD subgroup, prominent interference effects were observed for discriminated contrasts. For nondiscriminated contrasts, the conflicting distractors also produced significant interference for the two features conflicting onsets but not for the one feature conflicting onsets. Thus, for nondiscriminated contrasts, the one feature conflicting onsets appeared to be less disruptive to naming than the two features conflicting onsets, opposite to the trend that was observed in the pass subgroups (see Fig. 2). Several possible explanations should be considered. First, it is known that consonants differing in two features, relative to one feature, are more easily discriminated by children (Graham and House, 1970). This suggests that, even though the onsets were not discriminated above chance in these children, the two features conflicting contrasts may nonetheless have been more perceptually salient and hence more effective in disrupting naming than the one feature conflicting onsets. Note that this explanation cannot account for the trend in Figure 2. We can speculate that the pass TD subgroup with accurate perception of all contrasts is revealing an interference pattern consistent with higher-level inhibitory processes, whereas the no-pass TD subgroup with poorer perception of contrasts is revealing an interference pattern consistent with lower-level perceptual processes. An assumption is that the higher-level inhibitory pattern cannot be seen in the presence of phoneme discrimination problems.

Another possible explanation to be considered concerns the definition of accurate discrimination that we applied in the off-line assessment. We defined the threshold for accuracy as 75 percent correct, the traditional definition on a two-alternative forced-choice task. It may be that children who achieved just under threshold for the two features conflicting di-
tractors were nonetheless receiving some meaningful auditory input. Thus, some interference was observed.

Finally, it is possible that the presence of significant interference for the nondiscriminated two features conflicting distractors in the no-pass TD subgroup is related to varying task demands. The cross-modal picture-word task assesses how the manipulation of a seemingly to-be-ignored variable affects performance, without the participants' consciously trying to respond to the manipulation. The approach may be viewed as an “implicit,” rather than “explicit,” behavioral measure. Previous evidence has suggested that implicit measures may reveal evidence supporting substantive phonologic knowledge in individuals who are less able to use the knowledge explicitly (Hanson and Fowler, 1987; Campbell and Wright, 1988; see Schacter et al, 1995, and Fleischman et al, 1997, for evidence supporting dissociable effects of other implicit and explicit measures). Thus, it may not be surprising that performance on an explicit discrimination task might underestimate phonologic processing abilities in some children. A contrary finding, however, is that the no-pass subgroup performed accurately when asked to make explicit onset judgments on the laboratory procedure. Thus, the explicit nature of the task per se does not appear to be adequate to fully explain these results.

Clearly, further data are needed to penetrate the complicated array of findings in the TD subgroups. Perhaps, as some previous investigators have emphasized, phonologic processes may represent a heterogeneous set of abilities, and performance on phonologic tasks tapping these abilities may vary significantly depending on nontargeted variables, such as the cognitive demands of the task and the linguistic complexity of the stimuli (Lenel and Cantor, 1981; Treiman and Zukowski, 1996; Treiman et al, 1998).

Relative to overall results in the no-pass TD subgroup, effects in the no-pass HL subgroup seemed more coherent. A striking finding was that the conflicting distractors did not significantly influence naming, regardless of discrimination status in these children. This pattern may be related to several observations. First, the no-pass HL subgroup may have less well-specified phonologic knowledge, as previously hypothesized, owing to their greater auditory perceptual deficits. This subgroup may also require more acoustic information to process linguistic input owing to their younger ages and auditory perceptual difficulties (Elliott et al, 1987; Walley, 1988). Finally, the HL subgroup may process linguistic input more asymmetrically, disproportionately relying on auditory speech for vowel content and on visual speech for consonantal content. This might result in phonologic representations that are encoded more diversely or perhaps disproportionately in terms of visual speech gestural and/or motoric/articulatory codes. Previous research has clearly established that vowels in auditory speech, relative to consonants, are more easily identified by children in degraded listening situations (Johnson, 2000). Vowel identification also remains more robust across decreases in loudness.

A possible overall result of these influences is that HL children with poorer phoneme discrimination may not accord a special status to word initial segments. Thus, interference effects are not observed on the picture-word task, even for discriminated contrasts. Children in the no-pass HL subgroup also might not be able to employ their phoneme discrimination abilities when processing more complicated linguistic input. Their impoverished discrimination abilities might be adequate for an auditory discrimination task but not adequate to produce interference when naming picture stimuli.

In our companion article on semantically related distractors (Jerger et al, 2002a), we reported that the time course of semantic activation appeared abnormally prolonged in some children with HL, primarily those with unusually slow baseline naming speeds and early ages of identification/amplification of the loss. One of the hypotheses we proposed to account for this finding was unusually poor lexical semantic skills. To the extent that children's phonologic abilities may influence lexical knowledge (Stoel-Gammon, 1998), one might query whether the abnormal semantic time course was confined to HL children in the no-pass subgroup. To address this possibility, we re-evaluated the semantically related and unrelated naming curves, separating the children in the pass and no-pass subgroups. Results did not change. Thus, the abnormal time course of semantic processing that was reported in Jerger and colleagues (2002a) was not attributable to the fact that some of the children had poorer phoneme discrimination skills.

Finally, all of the TD and HL children in the no-pass subgroups were able to accurately produce all phoneme contrasts, including those they could not discriminate auditorily. Although
speech perception generally outpaces speech production in children, the reverse pattern has been reported in both TD and HL populations (Locke and Goldstein, 1971; Osberger, 1983; Subtelny, 1983). This further supports the idea that phonologic knowledge may be established in both auditory and nonauditory ways (Dodd and Hermelin, 1977; Hanson and Fowler, 1987; Campbell, 1988). Perhaps the children who could not discriminate a contrast auditorily nonetheless had some phonologic knowledge of the contrast from nonauditory (e.g., articulatory) information.

In short, results of this research suggest that some children with HL display good phonologic discrimination abilities and demonstrate phonologic effects during real-time language use that appear to be strikingly similar to those of TD peers. Thus, these children do appear to develop fine-grained phonologic representations in spite of their limited auditory experiences. Other children with HL, however, do not demonstrate these skills to the same degree and may develop phonologic representations that are less well specified, more holistic, and/or less structured in terms of auditorily based linguistic information. Children with HL clearly represent a heterogeneous set. Further studies are necessary to more completely specify the important effects of a broad range of perceptual experiences and linguistic skills.

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