Picture Naming by Children with Hearing Loss: I. Effect of Semantically Related Auditory Distractors

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Abstract

Thirty children with hearing loss (HL) and 129 typically developing (TD) children representing comparable ages, vocabulary ability, or phonology skills named pictures while attempting to ignore semantically related or unrelated auditory distractors. The timing relation between the onsets of the distractors and pictures varied. A significant semantic interference effect, that is, slowed naming in the presence of the semantically related distractor, was observed in all groups, suggesting similar categorical knowledge in the HL and TD groups. The time course of semantic interference, however, was protracted in some children with HL, primarily those with unusually slow baseline naming speeds and early ages of identification/amplification of the loss. Thus, children with HL seem to develop normal lexical semantic representations. At the same time, the dynamics of semantic processing appear to be altered by the presence of early childhood HL.

Key Words: Childhood hearing loss, children, language processing, picture-word task, semantic interference

Abbreviations: DPDQ = Denver Prescreening Developmental Questionnaire; HL = hearing loss; HTL = hearing threshold level; LSD = least significant difference; NPVT = Rader Near Point Vision Test; PPVT-III = Peabody Picture Vocabulary Test-III; SOA = stimulus onset asynchrony; TD = typically developing; VMI = Developmental Test of Visual Motor Integration; VOR = voice-operated relay; WIPI = Word Intelligibility by Picture Identification test

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 elementos de distracción con o sin relación semántica. La relación temporal entre el inicio de los elementos de distracción y los dibujos varió. Un efecto de interferencia semántica significativo, esto es, una lentificación en la identificación en presencia de distracciones semánticamente relacionadas, fue observada en todos los grupos, sugiriendo un conocimiento categorizado similar tanto en el grupo con HL como en el TD. El curso temporal de la interferencia semántica, sin embargo, fue prolongado en algunos niños con hipoacusia (HL), principalmente en aquellos con una velocidad de denominación basal inusualmente lenta, y con edad tempranas en el diagnóstico/amplificación de la pérdida. Así, los niños con hipoacusia (HL) parecen desarrollar representaciones léxico-semánticas normales. Al mismo tiempo, la dinámica del procesamiento semántico parece estar alterada por la presencia de una hipoacusia (HL) temprano en la infancia.

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

Abreviaturas: DPDQ = Cuestionario Denver de Pre-Tamizaje en Desarrollo; HL = hipoacusia; HTL = nivel umbral auditivo; LSD = diferencia menos significativa; NPVT = Prueba de Racer de Punto de Visión Cercana; PPVT-III = Prueba de Vocabulario por Dibujos de Peabody III; SOA = asincronía del inicio del estímulo; TD = en desarrollo típico; VMI = Prueba de Desarrollo de Integración Viso-Motora; VOR = dispositivo (relay) activado por la voz; WIPI = Prueba de Inteligibilidad por identificación de Dibujos

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Words are the building blocks of spoken communication. To learn to communicate, children must abstract and store the meanings and names of words. The first stages of vocabulary development typically involve learning the meanings and names of common objects, which requires the integration of cross-modal perceptual information. An important unresolved issue in the literature is how childhood hearing loss (HL) and its perceptual deficits affect the development of word representations and processes. Auditory input dominates word learning in early childhood (Ruffin-Simon, 1983; Tye-Murray, 1992; Tye-Murray et al., 1995; Levelt et al., 1999). To the extent that HL degrades and filters the auditory input, childhood HL may result in impoverished knowledge representations and processes. Auditory input dominates word learning in early childhood (Ruffin-Simon, 1983; Tye-Murray, 1992; Tye-Murray et al., 1995; Levelt et al., 1999). To the extent that HL degrades and filters the auditory input, childhood HL may result in impoverished knowledge representations and processes. Auditory input dominates word learning in early childhood (Ruffin-Simon, 1983; Tye-Murray, 1992; Tye-Murray et al., 1995; Levelt et al., 1999).

The purpose of this research was to study the nature of semantic and phonologic processing in children with HL who use aural/oral communication. Two companion articles report the results, with this article focusing on the nature of semantic knowledge and the time course of semantic activation during word processing. We applied a newly developed children's picture-word task to assess the influence of semantically related auditory distractors on picture-naming speed (Jerger et al., 2002). This cross-modal paradigm involves informational cross talk between the comprehension and production processing systems (Levelt et al., 1991). The patterns of this cross talk provide a basis for hypothesizing about the nature of semantic knowledge and the mechanisms underlying language use (Rayner and Springer, 1986; Glaser, 1992). We present a model of performance on the picture-word naming task, followed by predicted results in children with HL.

Cross-Modal Picture-Naming Task: Semantic Condition

The picture-word task is a double-stimulation paradigm. A participant is asked to name a picture while attempting to ignore an auditory distractor. In the semantic condition, the distractor is either categorically related or unrelated to the picture, for example, the picture "apple" coupled with "peach" (related, i.e., food category) and "nickel" (unrelated) (from Damian and Martin, 1999). The dependent measure is the speed of picture naming. Typically, a categorically related distractor increases the latency of picture naming relative to unrelated distractors or to another type of baseline, termed the semantic interference effect. Another important manipulation is that the onset of the distractor is varied to be before, after, or simultaneous with the onset of the picture, termed the stimulus onset asynchrony (SOA). As you will see, both the type of distractor and the SOA are critical determinants of whether a spoken word influences the speed of picture naming (e.g., La Heij et al., 1990; Meyer and Schriefers, 1991).

Several theoretical models of performance on the picture-word naming task have been suggested. In general, the models propose that lexical access is subdivided into semantically and phonologically constrained stages of processing. The relation between the components has been conceptualized as discrete, cascaded, or interactive, a debate that is not critical to the issues investigated here (for further information, see Dell, 1986; Dell and O'Seaghdha, 1991; Levelt et al., 1991; Roelofs, 1992; Jescheniak and Schriefers, 1998; Cutting and Ferreira, 1999; Damian and Martin, 1999). The model of Levelt and his colleagues (1991), depicted in Figure 1, ably conceptualizes our research. The model includes the following stages for picture naming: (1) conceptual processing, (2) activation of a set of meaning-related lexical items, (3) output phonologic processing of the selected item, and (4) naming response. In contrast, processing of the auditory distractor is assumed to consist of the following stages: (1) auditory/phonetic processing, (2) input phonologic processing with activation of a set of phonologically related lexical items, (3) lexical-semantic processing, and (4) conceptual processing.

Figure 1 illustrates the temporal relations, as hypothesized by Levelt and colleagues (1991), among the assumed stages of processing for two
SOA: -150

SOA: +150

Figure 1  Temporal relations, as hypothesized by Levelt et al (1991), among the assumed stages of processing for two stimulus onset asynchronies (SOAs): -150 msec (the auditory distractor leads the picture) and +150 msec (the auditory distractor lags the picture). The shaded areas represent temporal overlap between the stages of picture-distractor processing. Redrawn from Jerger et al, 2002b.

SOAs: -150 msec (the auditory distractor leads the picture) and +150 msec (the auditory distractor lags the picture). The schematic provides a possible explanation for the finding that normal adult and child performance on the picture-word task yields a pattern of semantic interference at -150 msec SOA but not at +150 msec SOA (Schriefers et al, 1990; Damian and Martin, 1999; Jerger et al, 2002b). In other words, the interfering effect of a semantic distractor on picture naming is greater when the distractor is presented before the onset of the picture (-150 msec SOA). Semantic interference is hypothesized to occur when the picture-naming process is occupied with lexical retrieval. A slowed picture-naming response occurs because the distractor's and the picture's lexical semantic representations are coactivated within the same time window. The idea is that the semantically related distractor and the picture share common semantic features as members of the same superordinate category (see Glaser, 1992, for discussion).

Semantic interference occurs because coactivated, meaning-related lexical representations compete for selection and control of the naming response (the lexical competition hypothesis, see Damian et al, 2001, for a discussion).

In short, the basis of semantic interference is temporal overlap between the picture's and the distractor's lexical semantic representations, which is greater at -150 msec than at +150 msec SOA, as depicted in Figure 1. When the categorically related distractor lags the onset of the picture (+150 msec SOA), the picture's word entry is assumed to be selected prior to the distractor's complete lexical semantic activation, and no interference is observed. A question is whether this normal pattern of results will be observed in children with moderate HL, which is hypothesized to limit the abstraction and storage of some word meanings in semantic memory.

Predicted Results in Children with HL

Semantic interference is determined by both word meaning and categorical knowledge.
With regard to word meaning, children with a moderate degree of HL show a reasonably normal pattern of vocabulary development, although the rate is slowed and individual variability is pronounced (Blair et al, 1985; Osberger and Hesketh, 1988; Gilbertson and Kamhi, 1995; Briscoe et al, 2001). Word-learning ability, and measures of language ability in general, is not readily predicted from the degree of HL. This counterintuitive finding may be related to important differences in factors such as the age of onset of the loss (Davis et al, 1986; Gilbertson and Kamhi, 1995). With regard to the organization of semantic categories in children with HL, categorical knowledge appears normal for categories that are easily perceived visually (Osberger and Hesketh, 1988). Individuals with HL also show normal proactive interference when recalling categorically related pictures and normal release from proactive interference when the final to-be-recalled picture is changed to a different semantic category (Hoemann et al, 1974). Individuals with even severe to profound HL can make efficient use of semantic relations to boost performance on a paired associate memory test, learning “fork-knife” better than “bell-leaf” (Campbell and Wright, 1990). Finally, children with a mild to moderate degree of HL demonstrate the auditory Stroop effect, another form of semantic interference (Jerger et al, 1988, 1997). Reaction times to talker gender are consistently slower and less accurate for speech targets with a semantically conflicting relation between stimulus dimensions (e.g., a male talker saying “Mommy”) than with a semantically congruent dimensional relation (e.g., a male talker saying “Daddy”).

This review overall predicts semantic interference effects on the picture-word naming task in children with HL owing to the reasonably normal semantic knowledge demonstrated in this population. For this study, we ensured the familiarity of picture-word pairs by selecting words that represented an early age of acquisition, high familiarity, high concreteness, and high imageability (Paivio et al, 1968; Carroll and White, 1973a, 1973b; Gilhooly and Logie, 1980; Snodgrass and Vanderwart, 1980; Francis and Kucera, 1982; Nusbaum et al, 1984; MacWhinney, 1993). With regard to the dynamics of the information processing system in children with HL, predictions are difficult to derive from the currently available literature. Our results will provide new information about the nature of semantic representations and the time course of lexical semantic processing in children with HL.

METHOD

Participants and Demographics

General

The participants, who were recruited from cooperating educational programs, were divided into a group with HL and several typically developing (TD) comparison groups. The criteria for participation were English as the native language and no diagnosed or suspected disabilities (excepting, in the HL group, the speech and language problems that accompany childhood HL). All of the children had normal visual acuity, gross neurodevelopmental history, visual-motor integration, and oral-motor function. The average Hollingshead Social Strata Score (1.6) was consistent with a major business and professional socioeconomic status.

HL Group

The group consisted of 16 boys and 14 girls between 5 and 15 years of age. The racial/ethnic distribution was 74 percent Whites, 13 percent Hispanics, and 13 percent Blacks. All of the children were considered successful hearing aid users and attended regular classes (mainstreamed), with support from a speech-language pathologist or special education teacher. Table 1 details the audiologic characteristics. The participants were tested while wearing their hearing aids. A technician routinely inserted new batteries into the aids and ensured that they were functioning properly prior to testing.

Comparison Groups

One hundred twenty-nine TD children were divided into groups representing comparable ages, receptive vocabulary skills, or input phonology skills. The racial/ethnic distribution was 80 percent Whites, 8 percent Asians, 7 percent Hispanics, and 5 percent Blacks. Hearing sensitivity, speech detection thresholds, and word recognition scores were within normal limits in all children. The age comparison group consisted of 60 children (n = 30 boys and 30 girls, 5 to 14 years of age). The receptive vocabulary comparison group contained 60 children (n = 35 boys and 25 girls, 4 to 12 years old). The input phonology comparison group consisted of 30 children
Table 1  Audiologic Characteristics of the Participants with Hearing Impairment

<table>
<thead>
<tr>
<th>Metric</th>
<th>Results (SD)</th>
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| Age at suspected onset of hearing loss | Unknown: 6  
Congenital/at birth: 16  
Birth to 2 yr: 7  
2 through 3 yr: 1 |
| Age at initial identification/amplification of hearing loss | Prior to 2 yr: 7  
2 through 3 yr: 11  
4 yr: 9  
5 through 7 yr: 3 |
| Etiology of hearing loss | Unknown: 13  
Hereditary/genetic: 8  
Meningitis: 2  
Birth problems: 2  
Trauma: 4  
Otoxicity: 1 |
| Unaided hearing sensitivity | 50.56 dB HTL (20.59)  
60.96 dB HTL (21.94)  
57.76 dB HTL (25.48)  
70.34 dB HTL (24.67) |
| Better ear, PTA | | |
| Poorer ear, PTA | | |
| Better ear, 4000 Hz | | |
| Poorer ear, 4000 Hz | | |
| Aided performance | 13.79 dB HTL (7.40)  
89.60% (16.56) |
| Speech detection threshold | | |
| Word recognition | | |

Unaided hearing sensitivity was summarized by averaging hearing thresholds levels (HTLs) across 500, 1000, and 2000 Hz (pure-tone average [PTA]).

(n = 20 boys and 10 girls, 3 to 6 years old). Eleven children were in both the vocabulary and phonology groups and 10 were in both the vocabulary and age groups. There were no overlapping members in the phonology and age groups.

Demographic Materials and Instrumentation

Hearing sensitivity was assessed with a standard pure-tone audiometer. Word recognition was assessed with the Word Intelligibility by Picture Identification (WIPI) test (Ross and Lerman, 1971). The test items were recorded by a male talker with general American dialect into a computer and played back via a speech audiometer and associated loudspeaker. The sampling rate was 22 kHz with 16-bit amplitude resolution. The output intensity levels of the stimuli were adjusted to equivalent peak intensities.

Visual acuity was screened with the Rader Near Point Vision Test (NPVT) (Rader, 1977). Oral-motor function was screened with a questionnaire designed by an otolaryngologist who is also a speech pathologist (Peltzer, 1997). Gross neurodevelopmental deficits were ruled out with the Denver Prescreening Developmental Questionnaire (DPDQ) (Frankenburg et al, 1976) in the younger participants and with the medical and educational histories in the older participants with normal hearing and in all of the participants with HL. Socioeconomic status was estimated with the Hollingshead Four-Factor Index (Hollingshead, 1975).

To estimate nonverbal abilities, visual perception was assessed with the Southern California Figure Ground Visual Perception Test (Ayres, 1978) in children 8 years of age or younger and with the Block Design subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) in children 9 to 15 years. Nonverbal reaction time was quantified as the average (10 trials) time to respond with a key press to a visually presented neutral stimulus. Visual-motor skills were estimated with the Developmental Test of Visual Motor Integration (VMI) (Beery, 1989).

To estimate verbal skills, vocabulary knowledge was assessed with the Peabody Picture Vocabulary Test-III (PPVT-III) (Dunn and Dunn, 1997). Input phonologic knowledge was esti-
imated by onset and rhyme laboratory measures, as detailed in the companion paper (Jerger et al, 2002a). Output phonologic knowledge was estimated by articulatory proficiency (Goldman-Fristoe Test of Articulation; Goldman and Fristoe, 1986). Finally, mixed semantic/phonologic ability was estimated with the Expressive Vocabulary Test (EVT) (Williams, 1997).

**Demographic Procedure**

The battery of demographic measures was administered randomly, with three exceptions. The measures using items from the picture-word test were administered after completing the picture-word testing. The expressive vocabulary and articulation tests were administered prior to the receptive vocabulary test. The VMI test was always the first test because it seemed a helpful tool for establishing rapport. Each of the standardized measures was administered and scored according to the recommended technique. The onset-segment and rhyme measures were administered as described in the companion article (Jerger et al, 2002a).

The operational definitions for normalcy were the following:

1. Hearing sensitivity—bilaterally symmetric hearing threshold levels (HTLs) (ANSI, 1989) of ≤ 20 dB at all test frequencies between 500 and 4000 Hz on both ears
2. Speech recognition ability—score of at least 90 percent correct on the WIPI test.
3. Visual acuity—100 percent correct identification of targets on the NPVT at 20/25 Snellen acuity (including participants with corrected vision)
4. Gross neurodevelopmental status—within the pass criteria for the child's age on the DPDQ or on the medical and educational histories
5. Visual-motor integration—score above the tenth percentile on the VMI
6. Oral-motor function—no difficulty with any of the five items on the Peltzer questionnaire concerning eating, swallowing, and drooling

**Comparison of Groups**

Table 2 summarizes results on the variables used to equate performance in the HL and comparison groups. Statistical analyses were carried out to determine whether performance on the equated variables was equivalent between groups. All analyses were negative, indicating no significant differences (all p values > .76). Results for the HL and age comparison groups showed that chronologic ages and nonverbal skills were equivalent between groups. Results for the HL and receptive vocabulary comparison groups showed that vocabulary knowledge was comparable between groups. Results for the HL and input phonology comparison groups showed that input phonologic skills for audiovisual stimuli were comparable between groups.

With regard to vocabulary skill in the groups representing other comparisons, receptive vocabulary ability differed significantly between the HL and age groups and the HL and input phonology groups. The HL group had a lower PPVT-III raw score and percentile score than the age comparison group, with raw scores of 116 and 150,

| Table 2 Performance on Variables Equated between HL and Comparison Groups (Ranges in Parentheses) |
|------------------------------------------------------|--------------------------------------|
| Hearing Impairment (n = 30) | Age Comparison (n = 60) |
| Chronologic age (mo) | 128 (64–185) | 125 (64–177) |
| Visual perception (age equivalency, mo) | 145 (66–203) | 149 (69–203) |
| Visual simple reaction time (msec) | 504 (287–728) | 513 (287–728) |
| Receptive vocabulary (raw score) | 116 (38–197) | 115 (51–190) |
| Input Phonology Comparison (n = 30) |
| Onset (%) | 96 (90–100) | 99 (90–100) |
| Rhyme (%) | 91 (60–100) | 95 (60–100) |
respectively, t = -4.95, p = .0001, and percentile scores of 31st and 81st, respectively, t = -9.47, p = .0001. The HL group had a higher PPVT-III raw score, but lower percentile score, than the input phonology group, with raw scores of 116 and 88, respectively, t = 3.56, p = .0008, and percentile scores of 31st and 76th respectively, t = -6.96, p = .0001. With regard to age in the groups representing other comparisons, age differed significantly between the HL and input phonology groups and the HL and vocabulary groups. The HL group was about 5½ years older than the input phonology group, t = 10.78, p = .0001, and about 4 years older than the vocabulary group, t = 8.03, p = .0001.

Experimental Tasks

Instrumentation/Materials

For the picture-word task, colored pictures were scanned into a computer as 8-bit PICT files and edited to achieve objects of a similar size and complexity on a white background. The auditory distractors were recorded directly into the computer by the same male talker as above. The sampling rate was 22 kHz with 16-bit amplitude resolution. The pictures were presented via a computer monitor. The auditory distractors were presented via the speech audiometer and associated loudspeaker. The output intensity levels of the stimuli were adjusted to equivalent peak intensities. 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. When naming each picture, the child spoke into a directional microphone mounted on an adjustable stand. To obtain naming latency, the computer triggered a counter/timer with 1 msec resolution at the initiation of a target. The timing board was stopped by the onset of the child's vocal response into the microphone, which was fed to a voice-operated relay (VOR). A pulse from the VOR stopped the timing board, which displayed the time in fractional seconds.

The development of the items and details regarding the Children's Picture-Word Test has been detailed previously (Jerger et al, 2002b). In brief, children were asked to name pictures in the presence of various types of auditory distractors that represented either semantic or phonologic relations between the pictures and the words (see also Jerger et al, 2002a). For the semantic items, naming was evaluated in the presence of four different types of auditory distractors, representing a categorically related word, an unrelated word, a verbal baseline, and a nonverbal baseline. For example, when asked to name the picture pizza, auditory distractors were the related word "hotdog," the unrelated word "dress," and the baselines "five" and a drumroll sound. The drumroll sound was the average duration of the other distractors (515 msec). Eight pictures were named in the presence of each type of distractor, for a total of 32 trials.

In addition to the picture-word task, two additional tasks assessed the effectiveness of the distractors for each individual child. First, we assessed whether each child appreciated the categorical relation between the picture-word pairs. The eight semantically related picture-word pairs were displayed on a picture-response card containing four other pictures, that is, the categorically related pair (knife-gun) plus foils (cheese, dog, fish, present). Different response cards varied the position of the alternatives across children. Second, we assessed whether each child could perceive the 16 auditory word distractors and the verbal baseline accurately. Each child repeated each of the words as they were presented over the loudspeaker. Then the experimenter asked the child to identify each word on a picture card. Each card had six pictures, the target and five foils with the same number of syllables as the target. Different response cards varied the position of the alternatives across children.

Procedure

Testing was carried out within a 12 x 14 ft double-walled sound-treated booth. The participant was seated at a child-sized table, and the computer monitor was adjusted to be at eye level. A tester sat at the computer console to administer the experiment, and a cotester sat alongside the child, keeping him/her focused on the task. All trials judged to be flawed were deleted on-line and readministered after intervening items, for example, lapses of attention, squirming out of position, triggering the microphone in a flawed manner, and mis-hitting the response key. The intensity level of the auditory stimuli was approximately 70 dB SPL, as measured at the imagined center of the participant's head with a sound level meter. The child's responses to the picture-word test, the standardized articulation test, and the laboratory repetition measures were digitally recorded and scored off-line by two speech pathology stu-
The participants received a small toy for participating.

Prior to beginning the picture-word task, a simple naming task without any auditory distractors was completed. The target picture was always “lamp.” The task quantified the child’s ability to detect and name a predetermined target. The simple naming task was repeated at the completion of all picture-word testing. Each presentation consisted of 2 practice trials and 10 test trials.

For the picture-word task, the child was instructed to name each picture as quickly and as accurately as possible and to ignore the auditory distractor. The picture remained in view until the child’s naming response. Each trial was initiated by the tester’s pushing the space bar, out of sight of the child. The picture-word task was administered in a practice session prior to the primary experimental procedure. During the practice run, each picture was presented once, coupled with one of its auditory distractors selected at random. The SOA was held constant at 0 msec. At the end of the practice trials, the tester showed each picture on a 5 x 5” card to the child, teaching her the target names of any pictures named incorrectly and helping her practice saying the names without “a.”

During the primary run, each picture was presented with each of its auditory distractors at each of three SOAs: -150, 0, 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). No picture or distractor was allowed to recur without at least one intervening item.

For the category knowledge measure, a tester spoke the nominal descriptor for the target category for each of the semantic picture-word pairs (“Which ones are food?”). The child responded by pointing to the two correct pictures on the response card (pizza-hotdog). If the child responded incorrectly, the tester spoke a functional descriptor for the category (“Which ones do we eat?”). The child’s score was percentage correct performance. For the distractor perception task, each distractor was presented auditorily, and the child was asked to repeat it and then to identify it from a set of pictured alternatives. The scores were percentage correct repetition and identification. Consistent mispronunciations were not scored as incorrect.

**Data Analysis**

The total number of deletions (with replacement) represented 9.6 percent (HL), 7.0 percent (age), 7.8 percent (vocabulary), and 9.9 percent (phonology) across all trials. The total number of missing trials after replacement was 2.1 percent (HL), 0.7 percent (age), 1.2 percent (vocabulary), and 1.7 percent (phonology) of overall trials. Naming responses that were more than three standard deviations from an item's conditional mean were also discarded. This procedure resulted in the exclusion of 0.6 percent (HL), 0.4 percent (age and vocabulary), and 1.7 percent (phonology) of trials. Overall, a total of 2.7 percent (HL), 1.1 percent (age), 1.6 percent (vocabulary), and 3.4 percent (phonology) of trials were missing or excluded. The remaining picture-word results were analyzed by subjects ($F_1$) and by items ($F_2$) with a mixed-design analysis of variance. The $F_2$ analyses have reduced statistical power relative to the $F_1$ analyses owing to the small number of items in each condition (n = 8).

Owing to the overlapping membership in the various TD groups, three separate analyses were carried out: HL versus age, HL versus vocabulary, and HL versus input phonology. Individual variability in the degree of interaction between the picture-distractor pairs was further assessed with multiple regression analysis in the HL group. To address a multicollinearity problem among some of the demographic variables (e.g., significant correlations between age, PPVT-III, etc.), data were transformed into standard scores, and a single composite variable was formed to represent age/age-related variables (Pedhazur, 1982).

**RESULTS**

**Baseline Condition**

Figure 2 shows average naming latencies in the groups for the verbal and nonverbal baseline distractors. Average overall naming latencies ranged from about 865 msec in the age comparison group to 1445 msec in the input phonology comparison group. The slower naming times in the phonology and vocabulary groups, relative to the HL and age groups, are consistent with their younger ages. Age-linked improvements in

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"Children's tendency to say "a" before a picture's name is a significant problem. Instructing them not to do this makes the tendency worse. Practice naming runs, alternating between the tester and the child, with the tester illustrating the correct style, seemed particularly valuable."
reaction time have been reported for decades (Goodenough, 1935; Jerger et al., 1988). Three statistical analyses by subjects and by items included the between factor of group (HL vs age, HL vs vocabulary, or HL vs input phonology). Each analysis contained the same within factors, namely SOA (−150, 0, and +150 msec) and distractor type (word and drumroll). Overall naming latencies changed significantly as the SOA varied from −150 to +150 msec: HL-age: $F_1 = 33.28$, $df = 2, 176$, $p = .0001$; $F_2 = 31.93$, $df = 2, 28$, $p = .0001$; HL-vocabulary: $F_1 = 43.07$, $df = 2, 176$, $p = .0001$; $F_2 = 49.52$, $df = 2, 28$, $p = .0001$; HL-phonology: $F_1 = 22.37$, $df = 2, 116$, $p = .0001$; $F_2 = 35.38$, $df = 2, 28$, $p = .0001$. Naming responses were relatively delayed when the distractor's onset was after the picture's onset (+150 msec SOA). The variation in naming times across SOA was greater in the vocabulary and phonology groups than in the HL group, with a significant SOA × group interaction: HL-vocabulary: $F_1 = 6.45$, $df = 2, 176$, $p = .002$; $F_2 = 9.09$, $df = 2, 28$, $p = .0009$; HL-phonology: $F_1 = 4.91$, $df = 2, 116$, $p = .009$; $F_2 = 10.37$, $df = 2, 28$, $p = .0004$.

The type of distractor also significantly affected the baseline naming latencies: HL-age: $F_1 = 32.32$, $df = 1, 88$, $p = .0001$; $F_2 = 38.70$, $df = 1, 14$, $p = .0001$; HL-vocabulary: $F_1 = 38.06$, $df = 1, 88$, $p = .0001$; $F_2 = 46.17$, $df = 1, 14$, $p = .0001$; HL-phonology: $F_1 = 22.53$, $df = 1, 58$, $p = .0001$; $F_2 = 40.88$, $df = 1, 14$, $p = .0001$. Overall naming times in all groups were slower in the presence of the word distractor than the drumroll distractor. This finding agrees with previous results in adults (Martin et al., 1988; LeCompte et al., 1997). The type of distractor influenced naming more in the vocabulary and phonology groups than in the HL group, with a significant type × group interaction, HL-vocabulary: $F_1 = 5.70$, $df = 1, 88$, $p = .02$; $F_2 = 6.75$, $df = 1, 14$, $p = .02$; HL-phonology: $F_1 = 3.70$, $df = 1, 58$, $p = .05$; $F_2 = 10.37$, $df = 1, 14$, $p = .006$. In the results below, we subtracted each participant's baseline from his/her experimental measures to render the experimental effects easier to discern graphically. The patterns of semantic interference were comparable for the different baselines. Thus, data are presented only for the verbal baseline.
Semantic Interference Effect

Prior to analyzing results, the individual data were refined on the basis of performance on the category knowledge and distractor recognition tests. Results showed that all of the children appreciated the categorical relation between all of the pictures and their related auditory distractors. No modifications to the individual data were indicated. With regard to the distractor recognition test, all TD children and 24 HL children correctly identified all of the semantically related distractors. Six of the HL children misheard from one to three related distractors, one (n = 3), two (n = 1), three (n = 2). Each picture-word pair containing a misheard distractor was deleted from the individual data. Performance in these six children was, thus, the average of seven (misheard one), six, or five picture-word pairs rather than eight pairs. With regard to the unrelated distractors, all of the TD children and 21 of the HL children correctly identified all items. Nine of the HL children misheard from one to four distractors, one (n = 5), two (n = 3), four (n = 1). Since each misheard word was also semantically unrelated to the picture, we did not eliminate any items from the individual data of these nine HL children. Statistical analysis indicated that results for the semantic condition did not differ in the HL children with 100 percent correct versus less than 100 percent correct distractor recognition. The data below for the HL group, therefore, represent results in all 30 children.

Figure 3 shows average adjusted naming latencies for the related and unrelated distractors in all groups. Both types of distractors produced some interference in performance in all groups relative to the baseline. This finding agrees with previous findings in adults (Schriefers et al, 1990). Statistical analyses by subjects and by items included the between factor of group (HL and normal) and the within factor of SOA and type (related and unrelated). Overall adjusted naming times declined significantly in all groups as the SOA varied from −150 msec to +150 msec: HL-age: $F_1 = 5.71, df = 2, 176, p = .004; F_2 = 8.64, df = 2, 28, p = .001; HL-vocabulary: $F_1 = 6.41, df = 2, 176, p = .002; F_2 = 7.03, df = 2, 28, p = .003; HL-phonology: $F_1 = 4.29, df = 2, 116, p = .02; F_2 = 4.93, df = 2, 28, p = .01$. More importantly, the type of

![Phonology Comparison](image)

![Age Comparison](image)

![Hearing Impairment](image)

![Receptive Vocabulary Comparison](image)

Figure 3 Average adjusted naming latencies (experimental minus baseline latencies) in all groups in the presence of semantically related and unrelated word distractors. The baseline was the syllable “five.”
Variables were minimal, with $r^2$ values ranging from .01 to .10 (all $p$ values > .05). The age-related variable was formed by a linear combination of age, receptive vocabulary, expressive vocabulary, articulation proficiency, visual perception, and word recognition. The intercorrelations among the age-related variables were significant, with $r^2$ values ranging from .32 to .57 (all $p$ values ≤ .001).

Results showed that the degree of interference at -150 msec SOA could not be predicted from knowledge of the demographic variables, $R^2 = .14$, omnibus $F = 1.04$, $p = .41$. The degree of interference at +150 msec SOA, however, was significantly associated with the set of predictor variables, $R^2 = .40$, omnibus $F = 4.21$, $p = .01$. Both the baseline naming speed, partial $F = 4.71$, $p = .04$, and the age at identification/amplification of the loss, partial $F = 6.10$, $p = .02$, uniquely accounted for a significant proportion of the variation in interference at +150 msec SOA.

Figure 4 details the degree of interference at each SOA as a function of the baseline naming speed and the age at identification/amplification of the loss. At -150 msec SOA, all subgroups showed interference, as expected from the statistical analysis. At +150 msec SOA, however, semantic interference occurred primarily in the subgroups with an unusually slow baseline naming speed and an early age of identification/amplification. It is also the case that the degree of interference in these subgroups appeared more pronounced at +150 msec SOA than at -150 msec SOA. The suspected onsets of the loss were roughly comparable in the subgroups, so it is difficult to interpret the differences in the age of identification/amplification. Numerous possible explanations exist, such as progressive hearing losses in the late identification/amplification subgroup. The demographic data indicated that the children who were identified/amplified earlier had slightly more hearing loss, slower baseline naming speeds, and poorer receptive vocabularies than the children who were identified/amplified later (about 56 dB HL vs 37 dB HL; 1045 msec vs 825 msec; 18th percentile vs 41st percentile). With regard to the baseline naming speed subgroups, the age of identification/amplification in the slowest subgroup was about 1 year earlier than the age in the fastest subgroup. Further studies are necessary to disentangle the factors associated with individual variability in a sensitive manner.

To recap, semantic interference in the TD groups occurred when the onset of the distractor was before the onset of the picture (-150 msec)
but not when the onset of the distractor was after the onset of the picture (+150 msec), mirroring previous findings in normal adults (Schriefers et al., 1990; Damian and Martin, 1999). In contrast, semantic interference in the HL group occurred at all SOAs. As seen in Figure 3, the degree of interference (about 100 to 125 msec) was similar in all groups at -150 msec SOA. At +150 msec SOA, however, the pattern of results for the HL and TD groups diverged; naming latencies for the related and unrelated distractors were similar in the TD groups but differed prominently in the HL group, again by about 125 msec. Analysis of individual variability in the HL group revealed that the children who showed the unexpected interference at +150 msec SOA had unusually slow baseline naming speeds and an early age of identification/amplification.

DISCUSSION

This research examined the influence of auditory semantically related distractors on picture naming by children with HL with a new children’s cross-modal picture-word test. Results showed significant semantic interference in all groups. Similar to adults, accessing the semantic content of words was mandatory during linguistic processing by young children, even those with HL. This finding agrees with our previous observation of Stroop interference in TD children and children with mild-to-moderate HL (Jerger et al., 1997). The presence of interference effects also indicates that both the TD children and the children with HL appreciated the conceptual categorical relations between the picture-word pairs. The organization of semantic memory appears highly structured in terms of categorical knowledge in these children. Although the items used are early learned and highly familiar, the results suggest nonetheless that semantic representations are strikingly similar in TD children and children with, on average, moderate HL. Thus, early lexical learning appears to remain robust across a range of auditory input experiences.

With regard to the time course of semantic interference, the degree of interference was similar in the HL and TD groups at -150 msec SOA. At +150 msec SOA, however, the HL group continued to show pronounced interference, whereas the TD groups showed none. In the TD groups, the semantic distractors had an effect only at an early stage of lexical access for picture naming, yielding a time course similar to that seen previously in adults (Schriefers et al., 1990; Damian and Martin, 1999). Apparently, for TD children, as well as adults, there is a point at which a lexical item is selected, and beyond that point, the semantic information of the distractor no longer influences the picture-naming process.

In the presence of childhood HL, however, the time course of semantic interference was abnormally prolonged. An analysis of individual variability in the HL group indicated that all children showed semantic interference at -150 msec SOA but not at +150 msec SOA. Semantic interference at the latter SOA occurred primarily in the children with HL who had unusually slow baseline naming speeds and an early age of identification/amplification of the loss. With regard to inferences about the time course of
Two other explanations for the abnormally prolonged lexical semantic stage of processing should also be considered. One concerns a possible delay in development of the capacity for inhibition and resistance to interference (Jerger et al., 1997, 1999). Inhibition refers to the ability to inhibit a response, whereas resistance to interference refers to the ability to ignore irrelevant information (Bjorklund, 1995). Delayed inhibitory skills and resistance to interference would render the distractor more difficult to ignore, perhaps increasing competition between coactivated picture-word lexical representations and hence slowing lexical access. Immaturity of these skills is also consistent with the trend toward a greater degree of semantic interference in the HL group (see Figs. 3 and 4). Thus, an explanation based on delayed development of inhibition and resistance to interference seems consistent with the overall evidence.

The other possible explanation concerns the evidence that children with auditory discrimination difficulties may rely disproportionately on semantic processes (Rodda and Grove, 1987; Stackhouse and Wells, 1997). For example, false recognition errors on tests requiring new/old judgments to each item of a to-be-remembered list indicate the use of a semantic code in children with HL (falsely say "yes" to "pony" when "horse" was the previous item) and a phonologic code in normal children (falsely say "yes" to "boat" when "goat" was the previous item) (Frumkin and Anisfeld, 1977). Possible reasons that children with HL may rely disproportionately on semantic coding for processing is that (1) the formation of temporary phonologic representations for learning and remembering (Gathercole and Baddeley, 1993) is less efficient (Gilbertson and Kamhi, 1995; Briscoe et al., 2001) and (2) syntactic knowledge is relatively impoverished (Swisher, 1976; Yoshinaga-Itano, 1997). Both phenomena might promote prolonged semantic activation by increased reliance on word meaning and world knowledge for remembering and comprehending. Overall, however, an explanation based on increased reliance on semantic processes does not seem consistent with all of the evidence. It is not immediately apparent, for example, why a normal, but abnormally prolonged, lexical semantic stage of activation would produce abnormally slowed baseline naming speeds. Slowed baseline naming times seem more consistent with slowed access to object names owing to limitations in processing capacities and skills. It will be important for further studies to assess
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