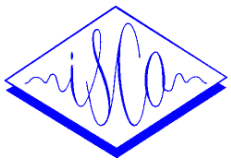

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THE INFLUENCE OF CONTEXT ON SPOKEN LANGUAGE PERCEPTION AND PROCESSING AMONG ELDERLY AND HEARING IMPAIRED LISTENERS

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ABSTRACT

In real-world speech communication, listener-based factors influence the timing and nature of fluent spoken language understanding. Such human factors might include the listener's knowledge base, language experience and auditory sensitivity. This study examined how aging and diminished hearing sensitivity influence a listener's use of context to perceive and process time-gated monosyllabic words. The results indicate that age, hearing sensitivity, and contextual factors significantly ($p. \leq .0001$) influenced the timing and nature of the spoken word recognition process.

I. INTRODUCTION

The underlying intent of this investigation was to study how normally hearing and hearing impaired older and young adult listeners use context to cope with spoken utterances that may be acoustically unavailable. This preliminary experiment focused on normal and disordered real-time recognition processes and listeners' abilities to use phonemic restoration. A subtle unconscious perceptual "fill-in-the blanks" phenomenon, phonemic restoration is a powerful auditory illusion that occurs when listeners perceptually restore disrupted words or word portions. Unaware of any acoustic disruption, listeners report that the interrupted speech appears intact [1,2,3,4]. Phonemic restoration represents a linguistic adaptation of a nonverbal phenomenon called "Auditory Induction" and belongs to a special classification referred to as "Temporal Induction". It has been proposed that Temporal Induction acts to prevent the perceived disruption of such steady-state signals as pure-tones and such time-varying signals as speech [5].

In the United States, hearing impairment is the third most prevalent chronic disability of adults over the age of sixty-five years. Aging not only causes a deterioration in peripheral hearing sensitivity [6,7,8,9], but also is associated with changes in central neurophysiologic aspects of speech recognition [10].

In everyday circumstances, real-time speech occurs in a rapidly changing temporal sequence, listeners must quickly recognize phonemes, syllables and words based on preceding contextual cues and on-going acoustic-phonetic information. Comprehension of fluent speech and spoken language involves the initial sensory and perceptual analysis of the acoustic-phonetic input to the processing system and the interaction of the sensory system information output with higher level information resources. Listeners who are able to identify words from their earliest onset demonstrate powerful and complex perceptive and processing capabilities [11].

Current findings indicate that elderly adults may be at a severe disadvantage when they listen for rapidly changing acoustic-phonetic elements of speech. Using simple temporal sequencing, speech identification, and minimal contrasting discrimination tasks, researchers report that although peripheral hearing impairment accounts for much of their age-related speech identification performance results, age-related temporal processing deficits also contributed to reduced performance [12,13].

It has been shown that among listeners with good word-recognition scores, time-compressed NU-6 test speech samples were less intelligible as a function of age and that older listeners demonstrated steeper rates of accuracy decline as speech rate increased [14,15]. Fox, Wall and Gokcen found that the older adults showed a decrement in their ability to temporally process dynamic perceptual cues for vowel identification [16]. Most recently, Gordon-Salant and Fitzgibbons studied percent-correct recognition scores based on three forms of time-distorted speech (time-compression, reverberation, and interruption) and reported that age-related factors other than peripheral hearing loss contribute to the diminished speech recognition performance of elderly listeners [17]. Craig applied a time-gated paradigm to study older listeners and reported a gradual improvement in accuracy as the gated-in portion of the signal

increased. The mean percent of identification of all time-gated words at the final gate (when the entire word was presented) for the older listeners was 76%. The comparable mean NU-6 word-recognition test score was 98%. A portion of the lower time-gated accuracy performance measures was attributed to list effects, and fatigue produced by the repetitive time-gated test materials or the potential influences of misdirected "garden path" lexical searching activities. It appeared reasonable that older adults might place a greater reliance on linguistic-contextual intra-word information then on-going acoustic-phonetic information and therefore their lexical searching process would be less accurate. Her results further indicated that overall the older listeners require greater amounts of a gated-in signal to achieve isolation. Within older group correlation analyses based on chronological age, pure-tone thresholds at 500, 1000, 2000, 4000 and 6000 Hz (re: ANSI, 1989) indicated no significant correlation between any pure-tone threshold and IP. However, a significant correlation between chronological age and IP was observed.

II. EXPERIMENT

Time-gated monosyllabic words in predictability-contrasting sentence contexts and were presented under two experimental conditions: a) a forward 60-ms time gating word recognition task; and b) a phonemic recognition task where continuous noise was added to the gated-out portion of the time-gated stimuli. The link between the time-based features of perceptual phonemic restoration research and time-gating research has powerful implications for speech perception and processing research. Both techniques manipulate attributes of temporal sequencing and timed disruptions of the acoustic signal. In time-gating the timed feature is the gate duration and the amount of the gated-in signal. In phonemic restoration the gated feature is the number of interruptions and the duration of the masked or missing portion of the speech stimuli. Both time-gating and phonemic restoration methodologies focus on a listener's ability to use acoustic-phonetic and linguistic contextual cues for speech understanding. While phonemic restoration and real-time effects have been well-studied among normal young adults, the abilities of older or hearing-impaired adults had not been previously studied.

2.1 Method

Four groups of adults (N = 143) served as subjects: (a) 52 normally hearing young adults [18 - 30 years old ($\underline{M}$ = 23 yrs)] with hearing levels $\leq$ 20 dB from 250 - 8000 Hz (re: ANSI 1989); (b) 24 normally hearing older adults (re: sensitivity for age group) [60 - 75 yrs old ($\underline{M}$ = 70 yrs)] with hearing levels $\leq$ 20 dB from 250 - 4000 Hz (re: ANSI 1989); (c) 35 hearing impaired young adults, [19 - 38 years old ($\underline{M}$ = 30 yrs)] and (d) 32 hearing impaired older adults, [60 - 85 years old ($\underline{M}$ = 72 yrs)].

Pre-recorded speech samples were drawn from the speech-only portion of the Revised Speech Perception in Noise Test [19]. A revised method of time-gating speech stimuli, applying the Micro Speech Laboratory (MSL), was developed. The average word duration for both the PH and PL word conditions was matched and was approximately 7.5 gates or 450-ms. A summary description of this method and discussion of its advantages and disadvantages was reported by Kim and Craig [20]. The continuous noise masker (-10 dBA S/N) was introduced at the offset of the gated-target word signal. Subjects were presented with the disrupted, time-gated, time-gated with noise stimuli via earphones (TDH-49, MX/41-AR cushion) at 70 dB-SPL, monaurally.

A data tabulation scheme was developed to quantify the timing of intermediate representations. Each word response was tabulated to indicate six major events in the real-time recognition process: (a) when the first phoneme (FP) occurred, (b) when a semantically-related (SEM) response occurred (e.g., if the target word was pork and the response was beef), (c) when a synonymous word response occurred (e.g, if the target word was chunks and the response was bits or pieces), (d) when the actual target word occurred (IP) and the related level of confidence (CIP), and (e) when the target word occurred with confidence (TAP4, TAP5).

2.2 Results

The preliminary results revealed the effects of word predictability on time-gated PL and PH word recognition performance with and without the noise filler in the four subject groups. This paper focuses on the first phoneme (FP) and isolation point (IP) results that indicated significant ($\underline{p} \leq .0001$) differences based on the main effects of age, hearing impairment, word predictability, and noise/quiet factors. Significant interactions were

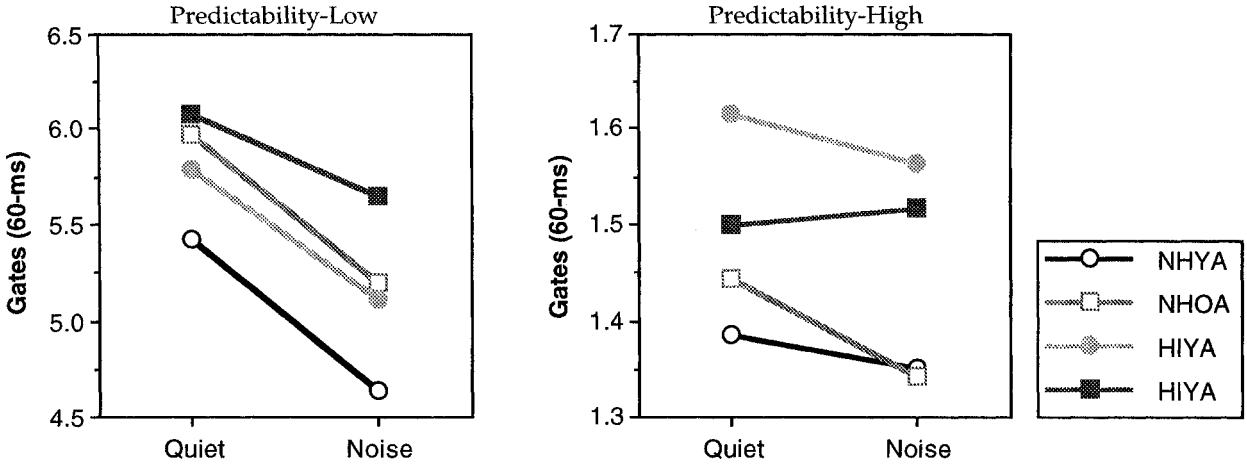

Figure 1. Isolation point for normally-hearing young adults (NHYA), normal-hearing older adults (NHOA), hearing-impaired young adults (HIYA), and hearing-impaired older adults (HIOA).

also observed between the effects of predictability and age ($p \leq .0001$); predictability and age ($p \leq .0001$); noise/quiet and predictability (FP: $p \leq .0001$; IP: $p \leq .001$); and hearing impairment and predictability ($p \leq .05$). Significant IP interactions were also observed between the hearing impairment and noise/quiet ($p \leq .05$) factors.

Specifically, the PL results revealed significant age-related effects on the timing of both FP and IP measures. Figure 1 shows the PL isolation point measures by gate (60-ms) for the experimental subject groups: normally hearing young adults (NHYA), the normally hearing older adults (NHOA), the hearing impaired young adults (HIYA), and the hearing impaired older adults. Inspection of this figure reveals that significant timing differences occurred between each of the young adult groups and the older listeners. Although the older normally hearing adults had better pure-tone sensitivity, the hearing impaired young adults significantly outperformed them. This result suggests that puretone threshold sensitivity may not be a good predictor of real-time word recognition behaviors. The PL results also indicate that each group's PL word recognition performance improved in the noise condition. Figure 1 also contains the PH isolation point results for each experimental group. Inspection of these results reveals that, in contrast to the PL results, the PH word results show that the normally hearing older adults significantly outperformed the hearing impaired young adults. In the PH-noise conditions the normally hearing older adults' performance was almost identical to that of their younger adult counterparts. In the PH-noise condition, the young hearing impaired adult performance indicated that temporal masking may have occurred.

III. DISCUSSION

Based on the time-gated results, our preliminary findings are consistent with previous time-gated results [20, 21] indicting that although relative age-related difference exist, all normally hearing and hearing impaired listeners used the semantic-contextual information in PH contexts to facilitate their time-gated recognition processes. In addition, normally hearing and hearing impaired older and young adult listeners require more gated-in PL acoustic-phonetic information to recognize PL words (re: PH words).

These results further suggest that the older listeners with minimal or no hearing sensitivity problems demonstrated greater real-time PL word recognition difficulties (re: normal young adults). Although borderline hearing impairment may account for some of the age-related results, it is proposed that age-related temporal processing deficits reduced PL time-gated word recognition performance. In the PH condition, both the normally hearing age groups demonstrated early word isolation and first phoneme recognition. The relatively poor PH performances of the young

hearing impaired adults may be explained by the age of acquisition of their hearing loss and related language development or experience issues. Although the time-gated noise condition results are consistent with those obtained in the disrupted speech experiments, any conclusion that the listeners' performances improved due solely to phonemic restoration is premature. It is possible that the subjects were also relying on word durational cues that were present in the noise condition. Regardless, in both the disrupted speech and the time-gated experiments older listeners, especially normally hearing older listeners, demonstrated improved performance in a noise-filler listening conditions. In conclusion, these results are not easily explained by differences in hearing sensitivity. Two potential explanations are proposed: (1) age-related temporal resolution changes place older listeners at some disadvantage when they listen for rapidly changing acoustic-phonetic elements of real-time speech. This might partially explain the age-related PL vs. PH results, however, no time-gated research has directly studied older listeners temporal resolution or processing performance. And, (2) older adults place greater reliance on linguistic-contextual information than on-going acoustic-phonetic information and therefore are at an advantage when contextual information is made more available.

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