CONTROLLING FOR AGE RELATED HEARING LOSS CAN ELIMINATE AGING DIFFERENCES IN LEXICAL COMPETITION: EVIDENCE FROM EYE-TRACKING AS AN ONLINE MEASUREMENT OF AGE AND NOISE EFFECTS ON LISTENING

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1. INTRODUCTION

As people age, they experience greater difficulty understanding speech, particularly in environments with background noise. For example, although a 70-year-old grandmother can enjoy her favorite talk radio program at a normal volume in a quiet room, she may have to substantially increase the volume when her grandchildren are playing in an adjacent room, and even then may not accurately hear all of the dialogue. A central question in lifespan approaches to human communication concerns the origin of these speech comprehension difficulties, whether they stem from age-related sensory decline and/or cognitive changes. For example, the difficulties the grandmother is experiencing might be explained by an information degradation account (Schneider & Pichora-Fuller, 2000) whereby the cognitive system was provided with deteriorated sensory (auditory) input. Alternatively, the difficulties could arise from less effective inhibitory mechanisms (Hasher & Zacks, 1988) that work to inhibit the irrelevant noise in the signal, or from a generalized slowing of all cognitive processes (Cerella & Hale, 1994), including those underlying speech comprehension. The goal of the current study is to provide insights into the origins of age-related changes in speech understanding in noise.

Most studies of age-related declines tend to use traditional accuracy-based tests of speech comprehension, e.g., participants are asked to repeat spoken words or sentences presented in different listening conditions. However, research in the field of spoken word recognition has shown that the mapping of speech sounds to lexical candidates begins immediately on the basis of the initial sounds in an unfolding word, often enabling identification before the end of the word has been heard. This phenomenon highlights the fact that speech recognition mechanisms are continuously responding to the unfolding speech signal. Offline tests of accuracy cannot directly reveal these dynamic aspects of the comprehension process. Rather, it is best explored using real-time measures that capture the incremental aspects of speech comprehension.

In recent years, research on spoken word recognition has increasingly used the so-called "visual world" eye-tracking technique, in which listeners hear sentences related to objects in a visual display (e.g., Tanenhaus, et al., 1995). An eye tracking system records fixations to these objects as speech unfolds. Previous research with young adults has shown that the timing and pattern of eye movements to scene objects can provide a highly sensitive and continuous measure of spoken word processing (see Tanenhaus, et al., 2000 for an overview).

The current study represents the first attempt (to our knowledge) to directly extend this experimental paradigm to a comparison of older and younger listeners' performance in normal and challenging listening situations. We first ensured that overall accuracy was equated. This way, we could directly evaluate whether younger and older listeners differ in terms of the implicit on-line mechanisms that led to correct word identification. We then tested listeners' ability to distinguish the target word from a similar sounding alternative, as the target word unfolded in time.

2. METHOD

2.1 Participants

Twenty-four young adults (M = 20.2) and 24 older adults (M = 70.9) participated in the study. All participants were native English speakers, had minimum Snellen fractions (visual acuity test) and pure-tone air-conduction thresholds (from 0.25 to 3.00 kHz) appropriate for their age group.

2.2 Materials

Visual Stimuli

For critical trials, we used 32 pairs of clip-art objects, whose corresponding nouns were phonologically related. For 16 of the pairs, their respective nouns overlapped in terms of onset sounds (e.g., *cannon* - *candy*). For the remaining pairs, the rhyme portion of the nouns overlapped (e.g., *candle* - *sandal*). On a given critical trial, these phonologically-related objects were displayed with two "unrelated" clip-art objects whose associated nouns matched the other objects in their number of syllables, but did not share onset or rhyme sounds (e.g., *finger* and *zebra*, to accompany *cannon* and *candy*). One of the phonologically-related items was identified as the target object (e.g., cannon), and was referred to in a spoken instruction accompanying the visual display (e.g., "Look at the *cannon"*). The other phonologically-related item constituted the "competitor" object (e.g., *candy*), and was not mentioned in the instruction. On each trial, four images were presented in the four corners of a 3 x 3 grid. An example of a critical trial showing a target-competitor pair with onset overlap is presented in Figure 1. Critical trials were interleaved with 32 filler trials to counteract potential response strategies.

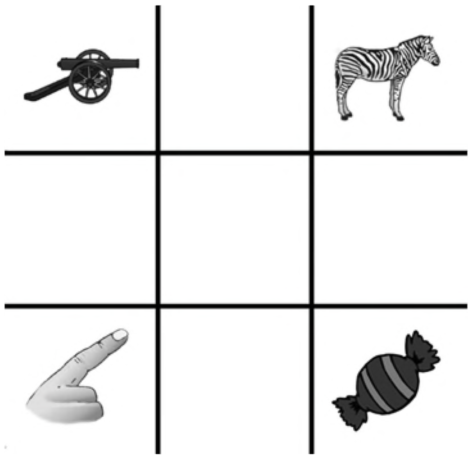

Figure. 1. An example of a typical display presented in the experiment. The target (cannon) and the competitor (candy) share onset sounds.

Audio Stimuli

Each display was accompanied by an instruction of the type "Look at the *X*", pre-recorded by a female native speaker of Canadian English. Half the recorded instructions were played in the "quiet" condition and the other half were mixed with speech spectrum noise. The selected signal to noise ratio (SNR) was tailored to the two groups: -4 for younger adults and 0 for older adults. Different SNRs for younger and older adults were used to create comparable overall listening difficulty in noise for both age groups at the sensory level. The audio instructions were played on two speakers located on either side of the participant

2.3 Procedure

Participants were tested individually in a single-walled acoustic chamber. Eye-movements were recorded via a table-mounted eye-tracking system (EyeLink 1000). At the beginning of each trial, a blank grid appeared on the monitor. Participants initiated the presentation of the four clip-art objects by pressing a button. After 2 s, a short tone was played, directing participants to focus on a black fixation cross in the central square. After the system registered cumulative fixations on the central square for 200 ms, the fixation cross disappeared, and the instruction sentence was played. Participants were instructed to look at and maintain gaze on the object denoted in the instruction until a green ("correct") or red ("incorrect") square masked that cell (which occurred after 750 ms of cumulative fixations within a cell). The objects then disappeared from the grid to signal the end of the trial.

3. RESULTS

3.1 Accuracy

The presence of background noise reduced accuracy, particularly when target-competitor pairs overlapped in terms of onset sounds. However, accuracy rates did not differ by age group (F<1). The absence of an age effect in quiet is characteristic of performance in ideal listening conditions. The lack of an age effect in the noise condition confirms that our selected SNR levels created a similar perceptual (listening) load for both age groups.

3.2 Analysis of Eye Movements

We measured the point in time at which listeners correctly fixated on the target (cannon) and the extent to which listeners momentarily fixated on the acoustic competitor (candy). This measure captures transitory states of indeterminacy that affect the time course of comprehension. Most generally, the eye movement data showed a highly similar pattern of incremental interpretation and target-competitor discrimination for both groups, with greater consideration of the competitor when sentences were presented against a noisy background. These outcomes suggest that after controlling for age-related sensory loss, the cognitive mechanisms underlying on-line spoken word recognition are unchanged over the course of healthy aging.

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