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DOES AGING AFFECT THE CHANNEL CAPACITY FOR IDENTIFYING PURE TONES DIFFERING ONLY IN INTENSITY?

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Abstract

Murphy et al. (2006) showed that normal-hearing younger and older adults do not differ in their ability to identify a set of eight pure-tones differing in intensity only (52, 58, 64, 70, 76, 82, 88, and 94 dB SPL). Their results suggest that auditory channel-capacity is preserved in aging. However, it is possible that using perfectly discriminable stimuli did not allow age-related differences to surface in Murphy et al's experiment. In the current study, we repeated Murphy et al's experiment using more closely spaced stimuli (60, 61.5, 63, 64.5, 66, 67.5, 69, 70.5 dB SPL), and found that while discrimination was generally poorer, absolute identification was equivalent for both age groups. Our results thus replicate Murphy et al's findings, and suggest that auditory channel capacity is not affected by normal aging even when the ability to discriminate two closely spaced intensities is.

Normal aging is accompanied by auditory declines that can undermine the speech comprehension abilities of older adults. At the peripheral level, cochlear degeneration reduces temporal and spectral resolution of auditory signals, resulting in degraded representations of signals beyond the cochlea (Schneider & Pichora-Fuller, 2000). In cognitively demanding situations, the reallocation of cognitive resources to compensate for these poorer sensory signals might manifest itself as deficits in speech comprehension. However, even older adults with clinically normal audiometric thresholds experience speech-processing difficulties in noisy and/or multi-talker environments. This has led researchers to explore age-related auditory changes beyond the cochlea, and has resulted in an accumulation of evidence pointing toward age-related declines in central auditory processing (Martin & Jerger, 2005). Recently, Murphy, Schneider, Speranza, and Moraglia (2006), investigated potential age-related differences in one attribute of central auditory processing, namely auditory channel capacity. Channel capacity refers to the amount of information that can be transmitted through a sensory channel (i.e., the channel's bandwidth). Miller (1956) showed that auditory channel capacity was limited to 2-3 bits of information for pure tones varying in intensity only. He also showed that this auditory channel capacity was independent of the intensity difference between stimuli, as long as the stimuli used were not too difficult to discriminate. Murphy et al. (2006) measured age-related differences in auditory channel capacity for pure tones varying in intensity only using an absolute identification paradigm. In an absolute identification paradigm, one of a given set of stimuli is presented on each trial, and a listener is asked to "identify" the stimulus by indicating which one of the set of stimuli he or she believes the presented stimulus to be. Murphy et al. (2006) asked normal-hearing younger and older adults to identify sets of 2 to 8 tones (52, 58, 64, 70, 76, 82, 88, and 94 dB SPL) based

on their intensity alone. They found no differences in the ability of younger and older adults in identifying these tones, and concluded therefore, that aging does not diminish auditory channel capacity. However, Murphy et al's (2006) stimuli were spaced at 6 dB apart, and were presumably perfectly discriminable by both younger and older adults. It is possible, that under more strenuous conditions where the pairwise discriminability of adjacent tones is significantly reduced, age-related differences in auditory channel capacity will begin to surface. In the current experiment, we attempted to replicate Murphy et al's (2006) experiment using less discriminable stimuli. We first measured how using tones whose intensities differed in 1.5 dB steps affected pairwise discriminability, and then used those same 8 tones in an absolute identification paradigm to investigate age-related changes in auditory channel capacity.

Participants, Materials, and Procedures

Twelve university students, and 12 seniors from the local community participated in this experiment. Participants were required to have audiometric thresholds that exceeded 25 dB HL for at most one frequency (threshold no greater than 35 at that frequency) for frequencies below 2 kHz. At 3 kHz, thresholds could not exceed 35 dB HL. At 4 kHz, thresholds could not exceed 45 dB HL. No restrictions were placed for frequencies above 4 kHz. Participants were also required to have normal, or corrected to normal vision. The stimuli in this experiment were eight 1 kHz pure tones, each 500 ms in duration. The following intensities were selected: 60, 61.5, 63, 64.5, 66, 67.5, 69, 70.5 dB SPL. All stimuli were generated digitally at 16 bits, at a sampling rate of 20 kHz. The stimuli were converted to analog using a Tucker Davis Technologies (TDT, Gainesville, FL) System III. The stimuli were converted to analog using the TDT system, then low-pass filtered at 10 kHz, and presented to participants diotically over Sennheiser HD 265 headphones. Participants were seated at a table inside an Industrial Acoustic Company (Bronx, NY, USA) double-walled sound-attenuated chamber. The first part of the experiment consisted of a discrimination task in which the following seven pairwise comparisons were made: 60 vs. 61.5, 61.5 vs. 63, 63 vs. 64.5, 64.5 vs. 66, 66 vs. 67.5, 67.5 vs. 69, and 69 vs. 70.5 dB SPL. Each pairwise comparison was administered in a block consisting of 10 practice trials and 100 experimental trials (50 trials per intensity). The order of blocks was randomized across participants. During each trial, participants had to indicate whether they believed a presented tone was the 'softer' or 'louder' one of the pair. Responses were made by pressing one of two buttons (one labeled 'softer', one labeled 'louder') on a NEC MultiSync LCD touch-screen monitor. After a response was made, a red square would briefly appear above the correct response, after which the next trial was initiated. Participants were allowed no more than 2.5 seconds for each response. Failure to respond within this time frame resulted in having to restart a given block of trials. The absolute identification portion of the experiment consisted of 50 practice trials and 400 experimental trials (50 trials for each tone). Participants were presented with one of eight tones on each trial, and had to indicate which one of eight tones they thought the presented tone corresponded to. Feedback was provided in the same fashion as the discrimination portion of the experiment. Confusion matrices were generated for each participant at the end of the experiment and used in subsequent analyses.

Analysis and Results

In absolute identification paradigms where stimuli vary along a single dimension, the presentation of each stimulus from a set is assumed to elicit a response along a decision axis. Due to noise in the stimulus and/or the nervous system, responses to repeated presentations of

the same stimulus will vary from trial to trial, and thus give rise to a distribution along the decision access, with a mean equal to μ, and a standard deviation equal to σ. Schneider (2007) showed that when confusion matrices are determined by averaging across participants differing in their ability to discriminate among stimuli, or within a participant when discriminability is changing over time, responses along the decision axis can be best described as being Laplacian in shape with all distributions having the same variance. Figure 1 depicts a model of such a decision process for a set of 8 stimuli.
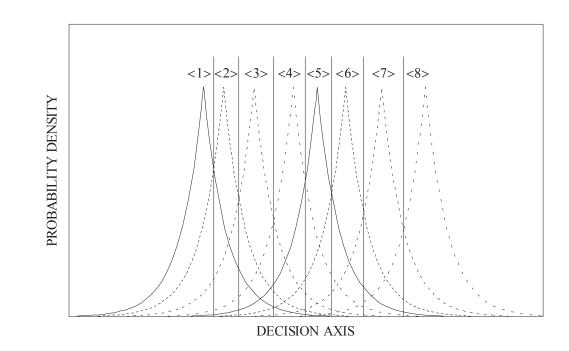

Figure 1. The equal-variance Laplace distribution model for an absolute identification paradigm with an 8 stimuli. Response criteria depicted by vertical lines divide the decision axis into 8 response regions. Variances are equal for all distributions.

The observer in this model is assumed to divide the decision axis into 8 response regions (7 criteria). For each individual, the discriminability of two stimuli in an absolute identification experiment can be computed by taking the difference between the means of two stimulus distributions and dividing this mean by the common standard deviation of the stimuli. In the pairwise discrimination case, in which only two stimuli are presented on a trial, *d'* is computed from hits and false alarms assuming equal variance Laplace distributions rather than equal variance normal distributions (which we refer to as Laplace d' values). Laplace d' values were computed for both younger and older adults for each pairwise comparison. To evaluate the effect of Stimulus, Age, and the interaction of Age by Stimulus, these *d'* values were evaluated using a 7 Stimulus (60 vs. 61.5, 61.5 vs. 63, 63 vs. 64.5, 64.5 vs. 66, 66 vs. 67.5, 67.5 vs. 69, and 69 vs. 70.5 dB) by 2 Age (younger, older) mixed factor Analysis of Variance (ANOVA) with Age as a between-subjects factor. The main effects of Age and Stimulus, and the interaction of Age and Stimulus were not statistically significant. Hence, when considered pairwise, the stimuli were equally discriminable by younger and older adults (average Laplace *d'* value between adjacent intensities = 0.80). Therefore, any age differences in performance in the absolute identification experiment cannot be attributed to basic differences in discriminability among the stimuli.
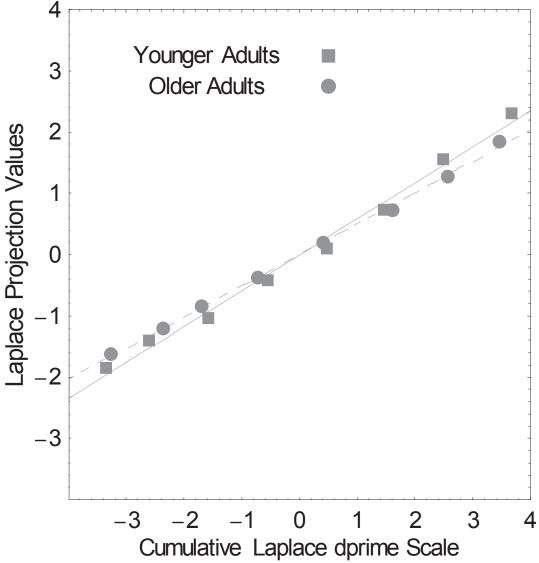
*Figure 2. The average Laplace projection values obtained from the absolute identification
task are plotted against the average cumulative d' values from the discrimination task for
younger (filled squares) and older (filled circles) adults. Both Laplace projection values and
cumulative d' values have been shifted along the decision axis so that they have a mean of 0 in
both cases.*

An equal-variance Laplace model was fit to the absolute identification data using a
procedure that minimizes χ^2 (Parker et al., 2002). The projection values thus determined
represent how discriminable the stimuli are in the identification experiment. We can then
compare these values to a measure of the maximum discriminability that could theoretically
be achieved given the participants' abilities to discriminate between adjacent pairs of stimuli.
If we assign an arbitrary value of 0 along the decision axis to stimulus 1, the maximal
achievable discriminability in the identification experiment between stimulus 1 and 2 would
be obtained if stimulus 2 was assigned the Laplace d' value found in the pairwise case.
Stimulus 3 would then have the value of stimulus 2 plus the d' value between stimulus 2 and

3, and so on. We refer to this scale as the cumulative Laplace d' scale. If channel capacity
was unlimited, we would expect the Laplace d' values obtained from the identification
experiment to be linearly related to the cumulative d' values obtained from the pairwise
experiment, with a slope = 1.0. Slopes < 1 would indicate that the channel capacity was
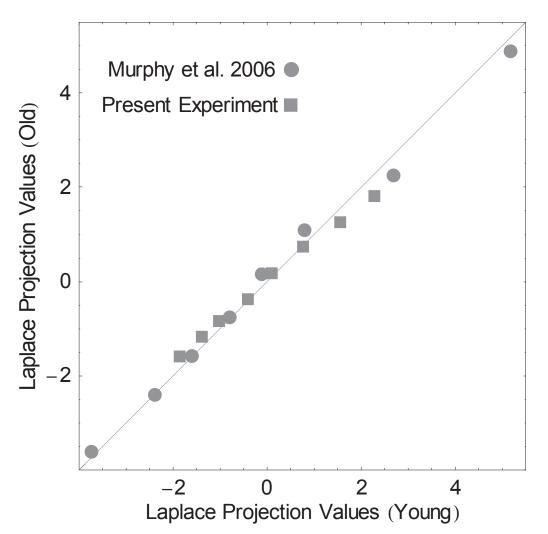limited.

*Figure 3. The Laplace projection values obtained from older adults in the absolute
identification experiment are plotted as a function of the Laplace projection values
obtained from younger adults from the current experiment (filled circles) and for the
identification experiment from Murphy et al. (2006, filled squares). In all cases Laplace
projection values have been shifted along the decision axis so that the projection values
for each group have a mean of 0.*

Laplace projection values from this model were computed for each individual, and
plotted against their cumulative d' value from the discrimination task. The average of these
individual plots are displayed in Figure 2 for both younger and older adults. As can be seen
from this figure the slope of this function is clearly < 1 for both age groups (.68 for young,
and .56 for old), indicating limited channel capacity in both groups. In addition, the slope for

older adults is shallower than that for younger adults, however, this difference is not statistically significant (p > .2, two-tailed). Finally, in Figure 3, the Laplace projection values of older adults in the current identification experiment and those in the experiment by Murphy et al. (2006) are plotted as a function of the Laplace projection values obtained from the younger adults in the same experiments. The straight line in this plot (slope = 1, intercept = 0) is what we would expect if the identification performance of older adults was exactly identical to that of younger adults. As can be seen from this figure, despite the fact that pairwise discriminability was reduced in the current experiment due to smaller intensity separation between adjacent tones, older adults appear to perform as well as younger adults in both experiments. These results indicate that younger and older adults perform equivalently in identification tasks, independent of the range of stimuli employed.

Discussion

The current experiment replicates Murphy et al's (2006) findings that auditory channel capacity is preserved in aging. Despite using a much smaller range of stimuli than Murphy et al. (2006), we found no age differences in the performance of younger and older adults in absolute identification task with tones varying in intensity only. Our findings, together with those obtained by Murphy et al. (2006), indicate that auditory channel capacity does not diminish with healthy aging.

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PERCEPTUAL INTEGRATION BETWEEN TARGET SPEECH AND TARGET-SPEECH REFLECTION REDUCES MASKING FOR TARGET-SPEECH RECOGNITION IN YOUNGER AND OLDER ADULTS

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Abstract

This study evaluated unmasking functions of perceptual integration of target speech and simulated target-speech reflection, which were presented by two spatially separated loudspeakers. In both younger adults and older adults with clinically-normal hearing, reducing the time interval between target speech and target-reflection simulation (inter-target interval, ITI) from 64 to 0 ms progressively released target speech from either speech masking or noise masking. But the longest ITI at which a significant release from speech masking occurred was significantly shorter in older listeners than in younger listeners. These results suggest that in reverberant environments with multi-talker speech, perceptual integration between the direct sound wave and correlated reflections, which facilitates perceptual segregation of various sources, is critical for unmasking attended speech. The age-related reduction of the ITI range for releasing speech from speech masking may be one of the causes for the speech-recognition difficulties experienced by older listeners in such adverse environments.

In noisy, reverberant environments, it is more difficult for older adults than for younger adults to recognize speech (e.g., Nabelek and Robinson, 1982). Under these conditions, listeners receive not only sound waves that directly emanate from various sources but also filtered and time-delayed reflections from surfaces at various locations. Fortunately, the reflected waves can be perceptually integrated with their direct wave by the auditory system to form the "precedence effect" (Litovsky et al, 1999). The precedence effect weakens auditory echoes. Also, the perceptual integration of direct and reflected waves can increase speech recognition under multiple-talker conditions (e.g., Freyman et al., 1999; Li et al., 2004; Wu et al., 2005) by enhancing perceptual differences (i.e. differences in perceived spatial location and in auditory image such as compactness/diffusiveness, timbre, and/or loudness) between target speech and masking speech, leading to improved selective attention to target speech (Schneider et al., 2007). When the time interval between the direct and the reflected waves is short (such as 3 or 4 ms), there is no difference of the advantage of perceptual difference for target speech recognition between older and younger adults (Li et al., 2004; Helfer and Freyman, 2008). However, some studies on younger adults have shown that the