

Auditory temporal processes in the elderly

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Abstract

Several studies have reported age-related decline in auditory temporal resolution and in working memory. However, earlier studies did not provide evidence as to whether these declines reflect overall changes in the same mechanisms, or reflect age-related changes in two independent mechanisms. In the current study we examined whether the age-related decline in auditory temporal resolution and in working memory would remain significant even after controlling for their shared variance. Eighty-two participants, aged 21-82 performed the dichotic temporal order judgment task and the backward digit span task. The findings indicate that age-related decline in auditory temporal resolution and in working memory are two independent processes.

Introduction

Over the past several decades, researchers have focused on age-related decline in auditory temporal resolution as an explanation for the difficulties in speech comprehension observed in the elderly (e.g., Gordon-Salant & Fitzgibbons, 1993; Schneider, Daneman, & Pichora-Fuller, 2002). The rationale underlying this approach is that the appropriate use of speech cues relies on auditory temporal resolution that has been shown to decline with age (Gordon-Salant, 2005; Pichora-Fuller & Souza, 2003; Schneider, *et al.*, 2002; Schneider & Pichora-Fuller, 2001). In addition to the decline in temporal resolution, aging also affects non-auditory cognitive functions that have been shown to be related to speech comprehension, such as working memory (Berry, Zanto, Clapp, Hardy, Delahunt, Mahncke, *et al.*, 2010; Craik & Salthouse, 2000; Kessels, Meulenbroek, Fernandez, & Olde Rikkert, 2010).

Recently there has been a tendency in the literature to posit a singular mechanism for the age related changes in central and peripheral functions. For example, Hogan (2004) posited that the age-related decreases in cognitive performance and processing speed are related to degeneration in the frontal cortex and cerebellum. Findings of age-related decline in processes that are controlled by the cerebellum, such as timing (Duchek, Balota, & Ferraro, 1994) and classical conditioning (Woodruff-Pak, & Thompson, 1988) have been cited as support for the Fronto-Cerebellar hypothesis. However, there is no consensus regarding the existence of a significant and strong relationship among cognitive and perceptual age-related changes. In fact, several researchers have found only mild relationships between the decline of a variety of different cognitive functions and sensory processes (e.g., Lindenberger & Ghisletta, 2009; Park, Lautenschlager, Hedden, Davidson, & Smith, 2002; Salthouse, Hambrick, & McGuthry, 1998). Furthermore, despite the large number of studies of temporal resolution and working memory among the elderly, there has not yet been a direct test of whether the age-related decline in auditory temporal resolution and in working memory are parts of the same process, or whether changes in the two functions reflect different, although possibly, parallel, ongoing changes in the aging individual. In the present study we test the hypothesis that the age-related decline in auditory temporal processing and in working memory are independent processes, by testing each relationship when controlling for the other.

Methods

Participants

Eighty-two adults, ranging in age from 21-82 years (42 males and 40 females) participated in the study. All participants were screened for normal hearing thresholds meeting the criteria of Lebo and Reddell (1972), and had interaural threshold differences less than 10 dB. All participants reported they were healthy and independent in their functioning, with no history of central nervous system diseases. Participants over 60 years old also performed the Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). All scores were 29-30 reflecting a high level of mental ability (Crum, Anthony, Bassett, & Folstein, 1993).

Tasks and stimuli

Participants were tested on dichotic temporal order judgment (TOJ) and on backward digit span. In addition, to control for individual and age-related differences in hearing sensitivity, the intensity of the stimuli was set individually for each participant, based on his or her absolute threshold for 1.8 kHz 15 msec duration tones, with rise and fall time of 2 msec. Absolute threshold was obtained using a 2-alternative, forced-choice adaptive threshold paradigm with a two-down-one-up methodology (Grimault, Bacon & Micheyl, 2002; Levitt, 1971).

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Dichotic temporal order judgment

On each trial participants were presented with a pair of 15 msec duration 1.8 kHz tones, presented dichotically, i.e., the first tone to one ear, the second tone to the other ear. Participants were required to judge the order in which they heard the tones (left first then right; or right first then left). Tone combinations were presented in a random order with inter-stimulus intervals (ISI) of 5, 10, 15, 30, 60, 90, 120 and 240 msec. ISI order was also random. Each ISI value was repeated 16 times, resulting in a total of 256 trials. After every 32 trials participants received a short recess. Percent of correct responses was recorded for each participant, for each ISI. To familiarize the participants with the tones, they were first presented with six tones presented to one ear, then six tones to the other ear. Training then proceeded with 24 trials, 12 for stimuli to each ear, randomly intermixed. On each trial, the participant was required to identify the sound location by pressing the correct key. Visual feedback (*right/wrong*) was provided for each response. In the last stage of the familiarization phase, the stimuli were presented in random order, with no feedback, until the participant met the criterion of 20 correct responses in 24 consecutive trials. Testing was terminated for participants who did not meet the criterion within 30 trials; Participants who were successful in the familiarization phase were then presented with 16 pairs of stimuli in two possible patterns: left-right, right-left, with an ISI of 240 and 60 msec, resulting in 64 pairs of stimuli. Participants were asked to identify which pattern they heard by pressing the key for the first sound followed by the key for the second sound. Visual feedback was provided on all training trials. No feedback was provided during the experimental session.

Backward digit span

The WAIS-III subtest for backward digit span was used to measure working memory (Gathercole & Pickering, 2000). In this subtest, the experimenter read aloud lists of digits at a rate of one digit per second. Immediately after the set of digits had been read, participants were instructed to report the digits verbally in the reverse order. Participants received two trials at each set size starting at set size 2 and working up to set size 8. Testing was terminated when participants were incorrect on both trials of a given set size. The digit backward score was the number of digit backward trials in which all digits were reported accurately (maximum score of 14) (Wechsler, 1997).

Results

In order to test the hypothesis that dichotic TOJ and backward digit span are two processes independently associated with aging, we performed two hierarchical regression analyses, one predicting dichotic TOJ by aging while controlling for backward digit span, and the other predicting backward digit span by aging while controlling for dichotic TOJ. If the two processes are independently associated with aging, age should predict that aging would predict each of the two variables, even while the other is controlled. As indicated by the regression outcomes, age significantly predicts both dichotic TOJ and backward digit span, independent of each other (Table 1).

Discussion

Findings show a significant age-related increase in dichotic TOJ, indicating a decline in auditory temporal processing as measured by dichotic TOJ and a significant age-related decline in working memory as measured by backward digit span. The results of the present study thus confirm and complement the frequently reported findings of age-related decline in working memory and auditory temporal resolution. In

Table 1. Multiple linear regression analyses predicting. (a) Dichotic temporal order judgment by aging while controlling for backwards digit span. (b) Backward digit span by aging while controlling for dichotic temporal order judgment

a.	β	t	R ²	F	R ² cha	Fcha
Step 1			.05	3.77 [†]	.05	3.77 [†]
Backward digit span	-.21	-1.94 [†]				
Step 2	.11	5.00*	.07	5.93*		
Age	.27	2.44*				
b.	β	t	R ²	F	R ² cha	Fcha
Step 1			.05	3.77 [†]	.05	3.77 [†]
Dichotic TOJ	-.21	-1.94 [†]				
Step 2	.11	5.00*	.07	5.93*		
Age	.26	2.34*				

†P=.056; *P<.05. TOJ, temporal order judgment.

addition, the present study also provides evidence of an age-related decline in auditory temporal resolution and working memory even when controlling for any shared variance between these variables.

A number of recent and earlier studies reported age-related decline in both perceptual and cognitive tasks (e.g., Duchek, *et al.*, 1994; Ezzatian, Pichora-Fuller, & Schneider, 2010; Ross, Schneider, Snyder, & Alain, 2010). However, these studies did not indicate whether the decline in perceptual and cognitive performance are manifestations of the same overall, general age-related decline and consequently are predictable from one another, or whether the various age-associated declines are orthogonal processes that may change with age with some degree of independence from one another. The results of the present study show that the association between age and temporal processing was found to be independent of the age-related decreases in working memory. Similarly, the association between age and working memory was found to be independent of the age-related decline in temporal processing.

These findings may imply that the dynamics of the age associated decline in temporal processing may differ from the dynamics of the age associated decline in working memory. Thus, for example, it is possible that among the elderly, some individuals may show decline in auditory temporal resolution with little or no decline in working memory, while others may experience a decline in working memory and show little or no change in auditory temporal resolution. Such a hypothesis may have important implications, both theoretically and for therapeutic purposes. Furthermore, such differences could result in different patterns of change over the lifespan for different functions, such that the extent of change in working memory might differ at any given age of any given individual from the change in auditory temporal resolution.

In summary, in the current study we found that age is related to temporal processing and to working memory, even when controlling for their shared variance. These results may imply that the rate of decline of cognitive and perceptual abilities with age may be independent of each other and may be manifested differently among different people, as they age.

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