Age-related Changes in Temporal Processing Mechanisms of Speech Production and Hand Movement: An ERP Study

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Introduction

Background:

Temporal prediction is a key function of the motor system that enables use to generate temporally precise movement in response to sensory stimuli. Studies have suggested the brain can learn the temporal association between motor commands and expected sensory feedback [1-2]. The consequence of this process is generation of temporal predictive codes that estimate the next state of the movement and generate temporally precise movement in response to sensory stimuli [2]. Besides these internal predictions, studies have shown that temporal aspects of sensory stimuli can further enhance the temporal predictive code in the motor system and consequently accelerate movement response time [3,4].

Neuropsychological studies have suggested that neural activities before movement initiation may be a neural signature of such temporal predictions in the motor system [3,4]. Moreover, it has been found that ERP activities in response to temporally predictable vs. unpredictable sensory stimuli are attenuated before movement onset, and are correlated with accelerated motor response [5]. These findings indicate that temporal aspects of sensory stimuli can further enhance the generation of temporal predictive codes in the motor system, and these predictive mechanisms are more robust and precise when stimulus timing is predictable.

Previous studies have mainly focused on aging effects on temporal processing during hand movement and found that diminished temporal prediction in older adults compared to younger adults [3,5]. The diminished temporal mechanisms in older adults, subsequently, led to slower hand movement in response to temporally predictable and unpredictable stimuli. Studies in younger adults showed that speech production and hand movement share common temporal mechanisms to generate motor response. However, it is not clear how normal aging would affect the neural and behavioral correlates of temporal predictive coding mechanism during speech production.

The primary goal of the present study was to examine the age-related changes in neural and behavioral correlates of temporal predictive codes in the motor system during speech production and hand movement.

Methods

Subjects:

Fourteen older (50 to 80 years old; mean age: 63) and fourteen younger (20 – 30 years old; mean age: 23) adults were enrolled in the present study. Subjects were right handed and they did not have any vision or hearing problems.

Procedure:

Event-related potentials (ERPs) were recorded in younger and older adults while they were visually-cued to prepare to produce a steady vocalization of a vowel sound or press a button in a randomized order, and to initiate the cued movement following the onset of a go signal on the screen (Fig.1). Experiment was conducted in two counterbalanced blocks in which the time interval between visual cue and go signal was temporally-predictable (fixed delay at 1500 ms) or unpredictable (variable between 1000 and 2000 ms). For each subject, measures of reaction time and also ERP analysis were computed for speech and hand movement initiation.

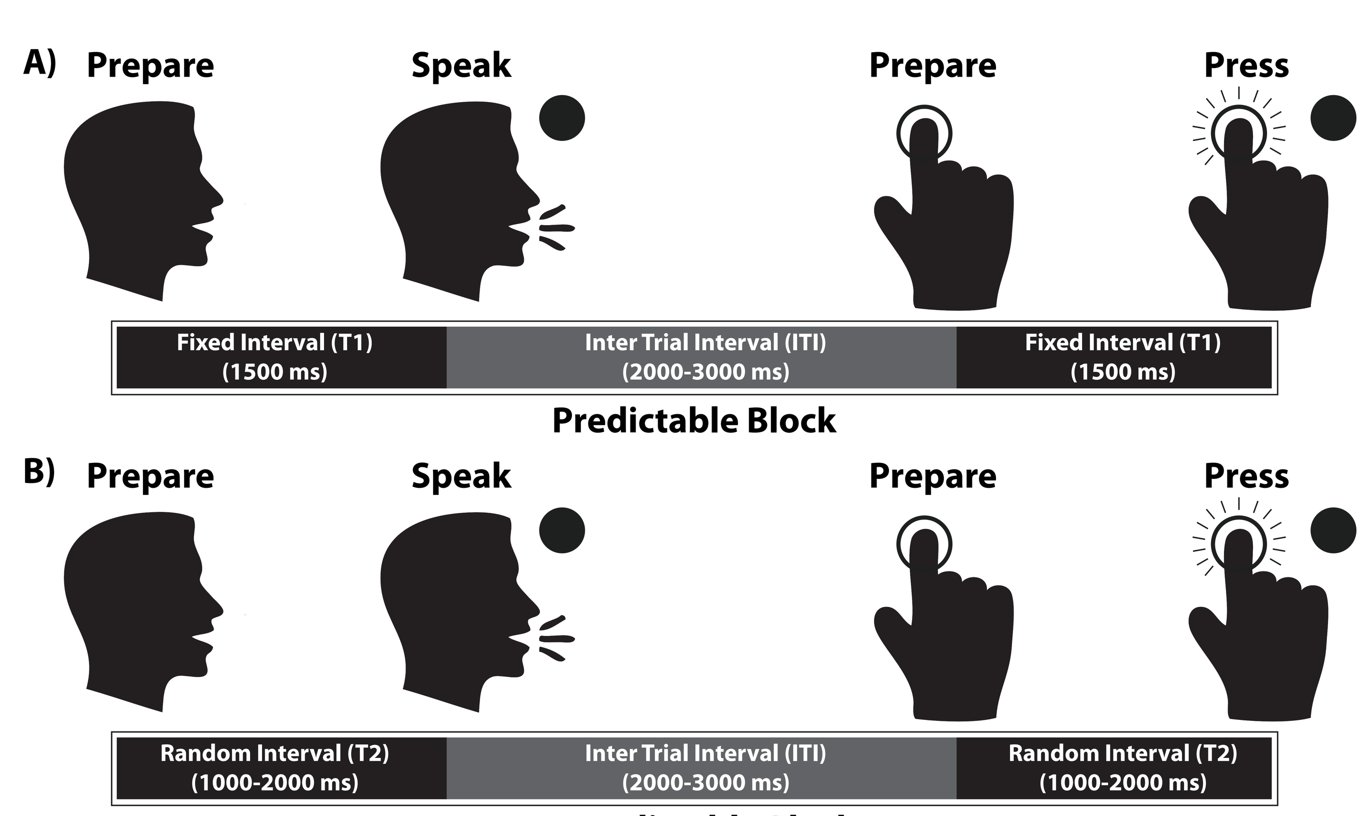

Figure 1. Experimental design.

Results

Behavioral results:

Behavioral findings indicated that older adults exhibited slower motor reaction times during speech production compared with younger adults, only when stimulus timing intervals were unpredictable (Fig.2A). However, for hand movement, younger and older adults' reaction times were not significantly different in response to temporally predictable and unpredictable stimuli (Fig. 2B).

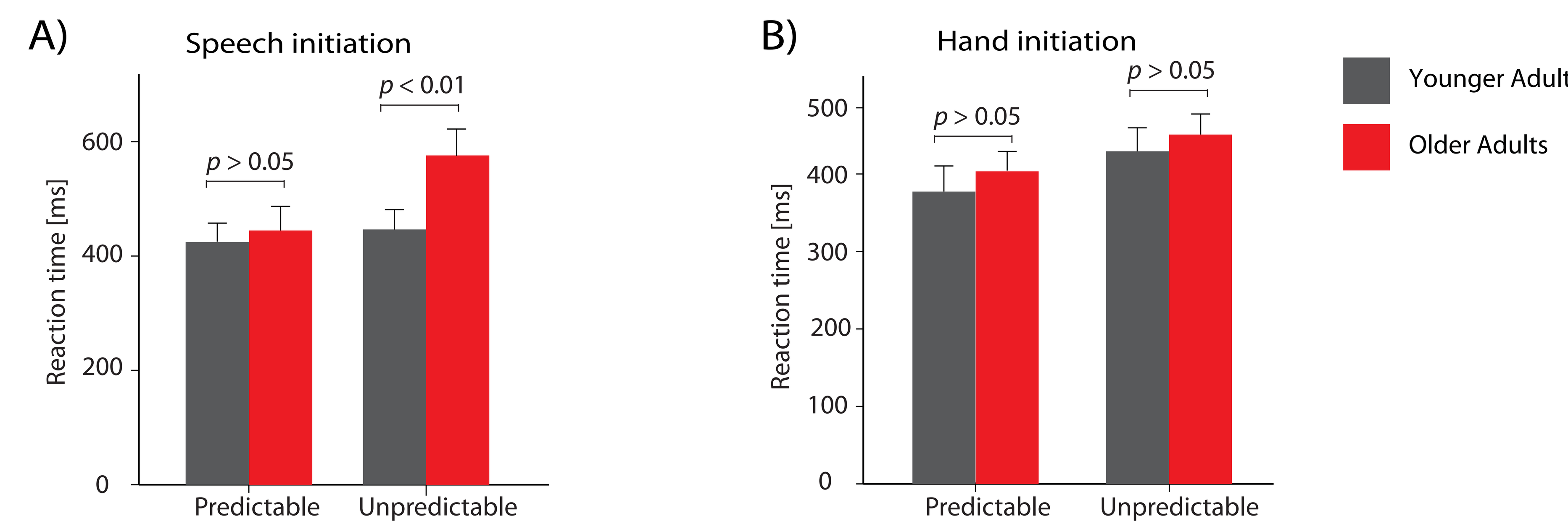

Figure 2. Behavioral results for younger vs. older adults during A) speech, and B) hand movement initiation.

ERP Reults:

The topgographical distritbition maps of ERP activities are illustrated for young vs. older adults during predictable and unpredictable conditions for speech production (Fig. 3A) and hand movement (Fig. 3B).

ERP results revealed that for unpredictable stimuli, premotor neural activities over the frontal and parietal areas were significantly increased in older vs. younger adults for speech production (Fig.3C) but not hand movement (Fig. 3D). However, ERP findings did not show aged-related changes in ERP activities for both speech production (Fig. 3C) and hand movement (Fig. 3D) in response to sensory stimuli with predictable timing patterns.

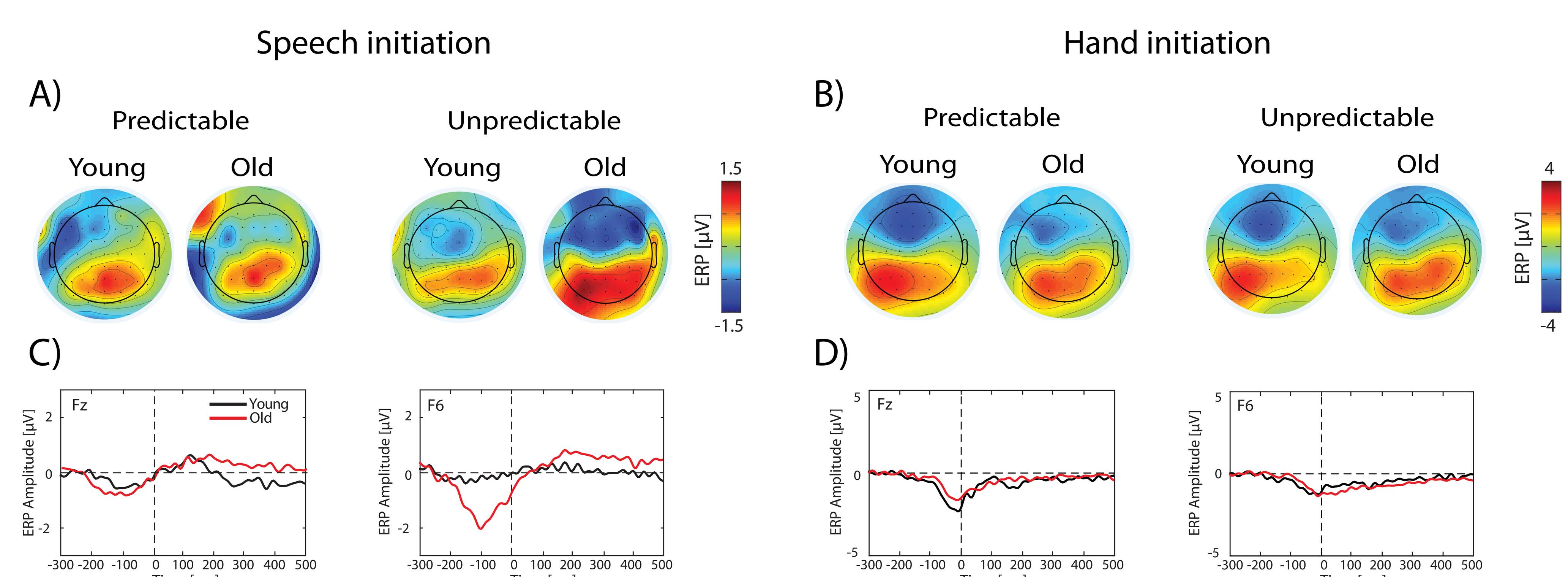

Figure 3. ERP reponse for movement initiation.

Discussion

Our findings suggest that the temporal predictive coding mechanisms are relatively spared for hand movement in older adults, whereas for speech, these mechanisms are impaired as a result of normal aging, specifically in response to sensory stimuli with unpredictable timing intervals.

Based on these findings, we propose that an aged brain may selectively compromise the processing of temporally unpredictable stimuli while performing a complex motor task such as speech production.

These results reveal the modality- and temporal-specific effects of aging on motor function in the human brain.

References

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