accuracy and speed) was less efficient in the secondary task when performed under dual-task conditions and the dual-task condition induced significant increases in false alarms in elderly but not young adult subjects. Elderly adults exhibited smaller parietal and central P300 amplitudes and longer parietal P300 latencies than younger adults in both single and dual-task conditions. Neither performance nor ERP measures were influenced by smoker–nonsmoker status. The results will be discussed in relation to cognition in normal and pathological aging.

11. Age-Related Differences in Brain Activation during Encoding and Retrieval under Divided Attention: A Positron Emission Tomography (PET) Study

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A PET study was conducted to examine the neural correlates of encoding and retrieval under divided attention (DA) and full attention (FA) in young and old subjects. The subjects performed both the memory and the pitch discrimination task concurrently. PET scans were obtained using $H_2{}^{15}O$ as a tracer and the data were analyzed by SPM96. In the young subjects during encoding, the right inferior parietal lobule was activated under DA, whereas the left inferior temporal and left inferior frontal cortex were activated under FA. The left anterior cingulate and the right cerebellum were related to DA. In the comparison between the young and old, the neural network involved in the age-related decrements in memory and attention included the right cerebellum, left thalamus, left inferior frontal, right medial temporal, and right medial frontal cortex.

Rationale

Behavioral studies have shown that divided attention (DA) at encoding is associated with a substantial drop in later memory performance, but in contrast, DA at retrieval resulted in comparatively slight drops in memory performance. The first aim of the present study is to examine the effects of DA on encoding and retrieval processes in young subjects, and to reveal the nature of differences between them by using PET. A PET study concerning age-related differences in memory has revealed that old subjects failed to activate hippocampal and other cortical regions during encoding. The second aim of the present study is to examine the effect of aging on encoding and retrieval processes in a DA paradigm.

Methodology

Participants. Twelve young (M/F; 3/9, aged from 21 to 31, mean; 24 years) and eight old (M/F; 3/5, aged from 63 to 76, mean; 69 years) subjects participated in the study after giving informed consent. All subjects spoke English as their first language and were right-handed. No subject had a history of psychiatric or neurological diseases. None of the subjects were taking any drug that affected cerebral blood flow.

In the experiment, subjects were instructed to perform both the memory task and the secondary task concurrently. The experimental conditions were (1) encoding under full attention (EF), (2) encoding under divided attention (ED), (3) retrieval under full attention (RF), and (4) retrieval under divided attention (RD). In the memory task, 20 word pairs were presented on display. During encoding, subjects read aloud the second word of the pair and memorized the pair for subsequent retrieval. During retrieval, only the first word of each pair was presented in a random order and subjects were instructed to recall the associated word or say ''pass.'' As a secondary task we employed a pitch discrimination task. In DA conditions subjects were instructed to listen to randomly presented high and low tones, discriminate the level of the pitch, and press the corresponding button of the mouse. In full attention (FA) conditions the low tone was repeatedly presented and subjects pressed a left mouse button each time in response to the tone. In the control condition, a simple word-reading task plus the FA secondary task were employed.

PET scans were obtained with a GE PC2048–15B scanner. After taking a transmission scan, 60-s emission scans were performed following a bolus injection of 35 mCi of $H_2{}^{15}O$. Nine PET scans were conducted 11 min apart (twice for each of the four experimental conditions and once for the control condition). The order of the conditions was counterbalanced across subjects. The data were analyzed by SPM96. We set the statistical significance at a p value of 0.05 (corrected for height and uncorrected for extent) for the first aim of the study in young subjects, and at a p value of 0.001 (uncorrected for height) for the comparison between young and old subjects.

Results

Behavioral data. Mean memory performance of the young subjects in EF, ED, RF, and RD conditions was 0.79, 0.58, 0.78, and 0.75 respectively. In the old subjects, memory performance in each condition was 0.52, 0.34, 0.52, and 0.44, respectively. A two-way ANOVA revealed significant main effects of condition (performance in ED was lower than the other three conditions) and age (performance in the young subjects was lower than in the old subjects), but there was no interaction.

PET data. In the young subjects, the ED–EF contrast revealed three activated clusters in right cerebellum, left anterior cingulate gyrus (BA32), and right inferior parietal lobule (BA40). In the RD–RF contrast, the activated clusters were located in left anterior cingulate gyrus (BA32) and right premotor area (BA6). In the EF–ED contrast, two activated clusters were found in left inferior temporal gyrus (BA37) and left inferior frontal gyrus (BA44). There was no significant activation in the RF–RD contrast. In the comparison between the young and old subjects, the young subjects demonstrated significant activation in the right cerebellum in the ED–EF contrast, left thalamus in the RD–RF contrast, left inferior frontal gyrus (BA9/44) and right medial temporal cortex in the EF–ED contrast, and right medial frontal cortex (BA9/11) in the RF–RD contrast.

Discussion

For young subjects our study showed that in the DA condition the right cerebellum and the right inferior parietal lobule were more activated in encoding than in retrieval, whereas activation in the left anterior cingulate was common to both of them. In FA, the inferior temporal cortex and inferior frontal cortex in the left hemisphere were activated during encoding. These results may imply that a trade-off exists between the auditory and visual systems during encoding; that is, greater attention was paid to auditory information in DA, whereas greater attention was paid to visual information in FA. The involvement of the cerebellum in episodic memory encoding may relate to its modulatory function in human cognition.

The comparison between the young and old indicates that the old subjects failed to activate several regions of the brain. The neural network involved in the age-related decrements in memory and attention included the right cerebellum, left thalamus, left inferior frontal, right medial temporal, and right medial frontal cortex.

12. The Neurophysiological Effects of Aging on the Ability of the Visual Cortex to Process Temporal Information

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Aging can produce a decline in the ability to process visual motion. It has been suggested that this decline is due in part to a slowing down in temporal processing, the locus of which may reside in central, as opposed to peripheral, visual system. We used critical flicker fusion (CFF), or the frequency of flickering light (Hz) required to