Incidental and intentional encoding in young and elderly adults

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Received 12 May 2004; accepted 12 June 2004

Event-related potentials (ERPs) were recorded in young and elderly adults during the performance of an incidental encoding task (subjects were unexpectedly given a recognition test) followed by an intentional task (subjects expected the recognition test). Both tasks consisted of an encoding stage in which subjects classified words (natural/artificial) and a recognition stage in which they indicated whether the words were old (presented during the encoding stage) or new. In both groups and tasks, the ERPs, during encoding, differed as a function of subsequent recognition: the old words correctly recognized generated greater amplitude potentials than the incorrect ones. The memory processes expressed by these ERPs are preserved in elderly adults, independently of whether the information is incidentally or intentionally encoded. NeuroReport 15:1819–1823 © 2004 Lippincott Williams & Wilkins.

Key words: Aged; Encoding; Incidental; Intentional; Event-related potentials; Subsequent memory effects; Young

INTRODUCTION

Encoding is the process by which an experience becomes a trace of memory that can be recovered later. It has been proposed that this process is deficient in elderly adults, which could explain the memory deficits that occur with aging [1]. This proposal is based on the fact that elderly adults generate less complex or sophisticated associations during the encoding stage [2,3], and require a larger number of trials to learn the information compared with young adults [4]. Encoding has been tested by means of intentional and incidental tasks. In the former, subjects know beforehand that their memory will be tested, while in incidental tasks, subjects are unaware of the following memory test. In young adults it has been observed that recognition is greater during intentional tasks than during incidental tasks [5]. However, the advantage of the intentional task disappears when during the incidental task, subjects are requested to perform a semantic judgment of the stimuli during encoding. This was observed in an experiment by Ferrara et al. [6] in which three encoding conditions were compared: intentional (subjects were told to memorize a set of sounds), incidental with a semantic judgment (subjects indicated whether a sound was pleasant or unpleasant) and incidental with a structural task (subjects judged whether a sound was louder in the left or in the right ear). Sound recall was inferior in the incidental condition with a structural task compared with the other two conditions, which did not differ between them. Elderly adults exhibit a lower performance level than young adults in recognition tasks when encoding is incidental [7] and intentional [8]. These findings are drawn from studies in which these tasks were assessed separately; simultaneous evaluation of both tasks in elderly adults has only been performed in free-recall experiments and no differences were found between them [9]. Event-related potentials (ERPs) have been used to study encoding mainly in young adults during incidental [10,11] and intentional [12,13] tasks. In these experiments, during the encoding stage, greater positivity was observed from ~400–800 ms post-stimulus, for those stimuli that are later recognized successfully, compared to non-recognized stimuli. This difference in ERPs has been termed subsequent memory effects (SME) [14]. To our knowledge, only two studies with ERPs have examined SME in elderly adults [15,16]. The first used an incidental task and the second an intentional one, however, only the latter observed SME in elderly adults. The authors [16] concluded that results differed between studies because elderly adults do not use spontaneously sophisticated strategies when performing incidental tasks. However, discrepancies between both studies could have been due to the different tasks used during the encoding stage. In the first study, subjects performed one of two possible classification tasks: to judge if a word was the name of an animal or to indicate if the first and last letters of the word were in ascending alphabetic sequence; whereas in the second study they were only asked to memorize words. It is difficult to conclude that SME only occur during intentional tasks in elderly adults if both types of encoding (incidental and intentional) are not assessed under the same conditions.
The aim of this study was to determine whether SME are present in elderly adults not only during intentional tasks but also during incidental ones, as well as to establish whether these effects differ between young and elderly adults. To achieve this objective, subjects of both groups performed an incidental task followed by an intentional one. Each of these tasks consisted of an encoding and a recognition stage. The ERPs from the encoding stage were analyzed as a function of subsequent recognition to obtain SME. Experiments with both tasks were performed in one session in order to be able to compare the ERPs in the same leads without changing their position. This represents an assessment of both tasks under the same conditions and simultaneously in one same study, an analysis that has not been previously made in elderly adults. If SME in elderly adults differ from that of young adults in one or both tasks, results would provide physiological evidence of a change in the encoding processes of elderly adults associated to a memory deficit with aging.

MATERIALS AND METHODS

Subjects: Twenty young and 20 elderly right-handed adults participated in the study; eight were excluded since they had not enough incorrect responses and eight because their recordings contained numerous eye movement artifacts. Data from 12 subjects of each group were analyzed: seven women and five men in the elderly adults group (mean age (±s.d.) 67.4 ± 7.7 years) and six women and six men in the young group (23.7 ± 2.7 years). All subjects signed an informed consent and received a financial reward for their participation. This project was approved by the Bioethics Committee of the Faculty of Medicine, National Autonomous University of Mexico. The two groups did not differ in schooling (Young 7.0 ± 0.6, p = 0.56; young 14.1 ± 3.1), WAIS [17] vocabulary sub-scale (f(20) = 1.03, p = 0.32; young 13.1 ± 1.8; elderly 13.8 ± 1.8), Miniminal test [18] (U = 71, p = 0.95; median ± range, young 28 ± 5; elderly 28.5 ± 5), and Beck’s Depression Inventory [19] (U = 42, p = 0.08; young 2 ± 8; elderly 6.5 ± 13).

Stimuli: Four hundred and eighty Spanish nouns of 4–9 letters were employed, with an average usage frequency of 68.2 per million (s.d = 114.2) [20]. Fifty percent of the words represented natural objects (e.g. moon, flower) and the rest artificial objects i.e. created by humans (e.g. piano, window). Half of the words were used in the incidental task and the rest in the intentional one. Stimuli were presented in capital letters and had a visual vertical angle of 0.6° and a horizontal angle from 2.1 to 4.9°.

Software E-Prime v. 1 was used for stimulus presentation and behavioral data collection.

Procedure: Each participant attended two sessions. In the first, the subject was interviewed regarding his/her health state and subjected to psychological tests. In the second, ERPs were recorded while subjects performed an incidental task followed by an intentional one. Each task had an encoding and a recognition stage; during the first, 120 words were presented, while at the recognition stage these same words were mixed with 120 new words. In both stages and tasks, each trial started with the presentation of an asterisk for 2 s as a focusing point; 0.5 s thereafter a word was presented for 0.3 s. The subject was allowed 3 s from the start of the stimulus to answer. In the incidental task, during encoding, subjects classified the words in natural or artificial without previous knowledge about the following recognition stage whereas in the intentional task, subjects performed the same natural/artificial judgment and were also told to learn the words since they would have to recognize them later. During the recognition stage of both tasks, subjects indicated whether the words had been presented in the previous stage (old words) or not (new words). The interval between stages and between the incidental and intentional tasks was ~5 min.

Recording: ERPs were recorded during the encoding and recognition stage of both tasks, however, only encoding data are reported. A QuikCap (Neuroscan Inc.) with 28 sintered electrodes (FZ, FCZ, CZ, CPZ, POZ, O3, F3, C3, P3, F1, F4, FC4, C4, CP4, P4, O2, F7, FT7, T7, TP7, P7, F8, FT8, T8, TP8) and 80 electrodes for the electroencephalographic (EEG) recordings using mastoid reference points. The electrooculogram (EOG) was recorded with two electrodes, one placed on the lateral portion of the right eye and the other on the supraorbital region of the left eye. The EEG and the EOG were recorded with a 0–100 Hz band, a knock-out filter of 60 Hz, and a sampling rate of 512 Hz. A low pass filter of 20 Hz and 24 dB roll off were used off-line. Recordings were made with the Grass Neurodata System Model 12. EEG gain was 20000 and for the EOG it was 10000. Impedance of all electrodes was <5 kΩ. Epochs had a 1.2 s duration and started 0.2 s before stimulus presentation.

Data analysis: Recordings were visually inspected and those presenting artifacts were excluded. In both tasks, incidental and intentional, data analysis from the encoding stage was based on subjects’ performance in the recognition stage: old words subsequently recognized or not. Only those stimuli correctly classified during the encoding stage were included. The number of epochs included in each average was 20.9 ± 5.5. The mean amplitude was measured between 80 and 250 ms, between 250 and 450 ms, and between 450 and 800 ms. Data were analyzed through mixed ANOVAs. For the central electrodes data, we used the factors group (young/elderly), task (incidental/intentional), performance (subsequently recognized words/subsequently unrecognized words), and electrode (FZ, FCZ, CZ, CPZ, POZ, and O2). For the lateral leads, the design was: group, task, performance, hemisphere (left or right), and electrode (F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P3/4, FT3/8, and O1/2). Behavioral performance and reaction time were also analyzed through mixed ANOVAs. Results were corrected with the Greenhouse and Geisser method; we report the degrees of freedom without correction, the corrected probability and the value of Δ when used. Level of significance was set at p < 0.05. Tukey’s honestly significant difference (HSD) post hoc test was used for within significant interactions and t-test with Bonferroni adjustments for significant interactions including within and between factors.
RESULTS

Behavioral results: No significant differences were found for data from the encoding stage either in the behavioral performance and reaction time between tasks (incidental or intentional) or between the young adults and the elderly (Table 1). Recognition was defined as correct responses to old items minus incorrect responses to new items (false alarms). The mixed ANOVA computed for these data included the factors group and task (incidental or intentional). The factor group was significant (F(1,22)=8.35, p=0.009): recognition was lower in the elderly adults (mean ± s.e 46.7 ± 3.5) than in the young adults (61.1 ± 3.5), independent of the task. The reaction time analysis included the factors group, task, type of stimulus (old–new), and performance (correct–incorrect): only the performance factor was significant (F(1,30)=65.53, p<0.001) since reaction times were faster during correct responses (1137 ± 36 ms) than during incorrect ones (1278 ± 46 ms).

Positive component between 80 and 250 ms: Figures 1 and 2 depict the ERPs recorded during encoding of the incidental and intentional tasks, respectively. In the central electrodes, the group (F(1,22)=5.84, p=0.02) and performance (F(1,22)=7.55, p=0.01) factors were significant. This component was greater in the young adults (1.6±0.3 µV) than in the elderly (0.6±0.3 µV), and the subsequently unrecognized words (0.9±0.2 µV) were associated with lower amplitude potentials than the recognized words (1.3±0.2 µV). In the lateral electrodes the same factors were significant: group (F(1,22)=5.32, p=0.03) and performance (F(1,22)=10.47, p=0.004). Amplitude of this component was greater in young adults (1.2±0.2 µV) than in the elderly (0.6±0.2 µV), and that for subsequently unrecognized words (0.7±0.2 µV) differed from recognized words (1.2±0.2 µV).

Negative component between 250 and 450 ms: Data from the central electrodes differed significantly according to performance (F(1,22)=16.08, p=0.001): subsequently unrecognized words were associated with a smaller amplitude (−0.02±0.2 µV) than recognized words (0.7±0.2 µV). The interaction between performance and electrode was significant (F(5,110)=3.40, p=0.04, ε=0.4). The post hoc test revealed that the difference between subsequently recognized and unrecognized words was present in all electrodes, except for OZ. In the lateral electrodes, a significant difference was also observed (F(1,22)=12.77, p=0.002) between the amplitude recorded for subsequently unrecognized (0.2±0.2 µV) and recognized words (0.9±0.2 µV).

Positive component between 450 and 800 ms: In the central electrodes, the factor task (F(1,22)=5.66, p=0.03) was significant: greater amplitude potentials were observed for

![Fig. 1. Selection of some electrodes showing the average of the event-related potentials during incidental encoding in young and elderly adults. The signal was averaged as a function of subsequently recognized or unrecognized words.](image)

Table 1. Mean average of correct responses (%) and reaction time (ms) during the encoding and recognition stages. Recognition was defined as correct responses to old items minus incorrect responses to new items (false alarms). Standard deviations are shown in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Young</th>
<th>Intentional</th>
<th>Elderly</th>
<th>Intentional</th>
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<tr>
<td><strong>Encoding</strong></td>
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<tr>
<td>Correct</td>
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<td>94.0 (3.8)</td>
<td>874 (13.4)</td>
<td>91.5 (5.2)</td>
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<td>1027 (230)</td>
<td>1142 (223)</td>
<td>1145 (178)</td>
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<td>Incorrect reaction time</td>
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<td>1389 (502)</td>
<td>1475 (397)</td>
<td>1340 (379)</td>
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<td><strong>Recognition</strong></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Old correct</td>
<td>73.6 (10.7)</td>
<td>78.8 (12.3)</td>
<td>70.8 (12.0)</td>
<td>74.4 (10.8)</td>
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<td>False alarms</td>
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<td>18.6 (16.4)</td>
<td>23.8 (13.3)</td>
<td>28.1 (13.2)</td>
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<tr>
<td>Old correct – False alarms</td>
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<td>47.1 (12.1)</td>
<td>46.3 (11.6)</td>
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<td>1220 (226)</td>
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<td>Old incorrect reaction time</td>
<td>1224 (256)</td>
<td>1228 (233)</td>
<td>1377 (271)</td>
<td>1383 (288)</td>
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</table>

Vol 15 No 11 6 August 2004

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the intentional (1.3 ± 0.4 μV) than for the incidental task (0.4 ± 0.4 μV). Interaction of task and electrode was significant (F(1,22) = 3.49, p = 0.015, ε = 0.4). Post hoc analyses revealed that the amplitude of this component was greater during the intentional than during the incidental task in electrodes FZ, FCZ, and CZ. Likewise, the performance factor was significant (F(1,22) = 11.79, p = 0.002). Subsequently recognized words were associated to greater amplitudes (1.2 ± 0.4 μV) than the unrecognized words (0.6 ± 0.4 μV). In the lateral electrodes, the group factor was significant (F(1,22) = 6.17, p = 0.02). The amplitude of this component was larger in the young adults (1.4 ± 0.4 μV) than in the elderly (0.1 ± 0.4 μV). The interaction between the factors group and electrode was also significant (F(10,220) = 3.3, p = 0.04, ε = 0.2): the amplitude of this component was greater in the young adults than in the elderly in F7/8 (t(22) = 3.49, p = 0.002). The performance factor was also significant (F(1,22) = 7.81, p = 0.011): the subsequently recognized words yielded greater amplitude (1.0 ± 0.3 μV) than the unrecognized words (0.3 ± 0.3 μV).

**DISCUSSION**

During encoding, the behavioral performance and reaction time did not differ significantly between the young and elderly adults, indicating that the classification task (natural vs artificial) implied a similar level of complexity for both groups. This task assesses semantic memory processes and the results show that these are preserved in the elderly as demonstrated in other studies [1]. Performance at the recognition stage differed significantly between elderly and young adults. Elderly recognition was 14% less than for young adults independently of the task (incidental or intentional). The present study allowed us to evaluate the effect of incidental and intentional tasks on memory in the same subjects and under the same conditions. Results confirmed that performance did not differ between these two tasks in elderly adults, a finding previously made in young adults [6]. This indicates that the natural/artificial judgment task employed during encoding favored recognition in both tasks, and that the explicit instruction of memorizing added no benefits to the intentional task. In contrast to other studies [21], the reaction time of the elderly adults was no longer than that of the young adults. However, the reaction times in both groups were larger for the incorrect than for the correct trials, which is a frequent finding reported in the literature with young subjects [22].

SME are characterized by larger amplitude potentials during the encoding stage between 400 and 800 ms after stimulus onset for words that are later on recognized as compared to the unrecognized words [11–14]. In the present study, SME were observed in the young and elderly adults in both, incidental and intentional tasks; however, they started earlier, from 200 ms after stimulus onset. These effects were observed in the central and lateral electrodes, without depicting hemispheric differences in either group. Friedman and Trott [16] also observed SME between 410 and 1000 ms after stimulus onset in old and young adults during an intentional task where subjects were explicitly told that their memory for the item and the list in which it was presented will be tested. The only previous study with young and old adults that had explored SME during an incidental task, reported SME at central sites between 300 and 1100 ms after stimulus onset only in their young subjects [15]. In the present study, SME were observed during the incidental task and did not differ between young and elderly adults, indicating that, in the elderly, this neurophysiological evidence is also associated to successful encoding as in young adults. The absence of SME in the elderly adults of the study by Friedman et al. [15] might be explained by the fact that words were presented twice during encoding, and SME were tested with ERPs collapsed for both first and second presentation stimuli which might have been affected by repetition effects. Indeed, they found that ERPs recorded during the second stimulus presentation differed between the older and young adults. A recent event-related fMRI study [23] which tested incidental memory in young and elderly adults found that most of the encoding areas activated in young adults are also activated in older adults, in particular, left inferior prefrontal cortex and left hippocampal formation. These results are consistent with the findings of the present study, and indicate that encoding processes are preserved in old adults.

A positive component between 80 and 250 ms and a negative one between 250 and 450 ms were associated to successful encoding in both groups. Both components depicted greater amplitude to recognized words compared to those unrecognized. The positive component had not been previously identified in elderly adults, and in young adults [24] it has been associated to a subsequent successful recall. Smith [24] related this component with attention or
working memory processes and suggested that when these fail during the encoding stage, the memorability of stimuli can be affected. A similar negative component to that observed in the present study has been recorded in elderly adults, revealing marginal differences between recognized and unrecognized stimuli [16]. In experiments, including only young adults, it has been identified that this component predicts the subsequent memory of words [13,25].

The amplitudes recorded in the central and lateral electrodes were lower in the elderly adults than in the young adults between the 80 and 250 ms; a similar difference was also observed between the 450 and 800 ms in the frontal lateral electrodes. The decrease in ERPs amplitude in elderly adults has been observed previously [21] and it has been proposed to be associated to structural changes undergone by the nervous system with age. Likewise, between 450 and 800 ms larger amplitudes were observed during the intentional than during the incidental task for both groups in electrodes FZ, FCZ, and CZ. Noldy et al. [5] also observed a difference in amplitude between both types of tasks using images. This difference could be a consequence of a greater demand for attention implicated in the explicit instruction of memorizing during the intentional task.

CONCLUSION
The subsequent memory effects were present in both the young and elderly adults independent of whether the encoding process was incidentally or intentionally performed, evidencing that at least the encoding processes expressed by SME are preserved with age. This ERP prediction of recognition in incidental tasks, in which subjects are unaware that their memory will be evaluated, had not been observed previously in elderly adults. Likewise, in both groups and tasks, two more components that predicted subsequent recognition of the words were recorded during the first 450 ms after stimulus onset. As a whole, these findings demonstrate that incidental encoding is preserved in elderly adults, since the same neurophysiological traits were observed as in intentional tasks, and these were, in turn, similar to those observed in young adults.

REFERENCES

Acknowledgements: We are grateful to A. Ruiz, P. Trejo, and E. Hernández for assistance with the experiments, and to I. Pérez Montfort for revising the manuscript. This study was supported by a grant from CONACyT (36203-H) and from the National Autonomous University of Mexico (DGAPA PAPIIT IN304202).