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Brain potentials in a memory-scanning task. II. Effects of aging on potentials to the probes ¹

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Summary Brain potentials accompanying the classification of probe items as being members of a previously presented list were recorded from subjects ranging in age from 18 to 86 years old. A group of older subjects (average age = 66 years) was compared to a younger group (average age = 29 years). The items tested were verbal (digits) and non-verbal (musical notes). Digits were presented in the auditory and visual modalities, and notes were presented acoustically. Reaction times (RTs) and performance accuracy were computed. Potentials are described in terms of scalp distribution, latency and amplitude as a function of the type of stimulus (verbal/non-verbal, auditory/visual) and age group (younger/older). Evoked potentials to target notes in an auditory target-detection ('odd-ball') task were also recorded for comparison with the memory tasks.

Potentials evoked by probes consisted of a sequence of sensory components in the first 250 msec followed by a cognitive component that was positive in polarity and sustained in duration (approximately 700 msec labeled P3), consisting of an earlier frontal component, P3a (mean latency: younger = 385 msec, older = 406 msec), and a large (15 μ V) and later parietal constituent, P3b (mean latency: younger = 574 msec, older = 630 msec). The frontal derivation of the younger subjects showed a sustained negative bias of the wave forms in the latency range of 200–500 msec (P2 to P3) compared to the older subjects.

Reaction times were longer in older subjects than in younger subjects for all stimulus types and set sizes. For the potentials evoked by the probes the younger group had consistently larger late parietal components (P3b) than the older group, whereas the late frontal potentials (P3a) were larger for the older than younger subjects. Except for visual stimuli, the latencies of the parietal sustained potentials were not influenced by subject age in contrast to the uniform changes in RT for all stimulus types. Significant amplitude and latency effects on the parietal sustained potentials accompanied the different stimulus types and memorized-set sizes which were similar for the two age groups. These results suggest that the effects of aging on short-term memory are primarily on response selection, as evidenced by RT slowing with aging, and not on memory-scanning processes as evidenced by the similarity of the latency measures of the accompanying brain potentials between the two age groups.

Key words: Memory-scanning task; Event-related potentials; Aging

There are changes in a variety of cognitive functions that accompany aging including memory (see Poon et al. 1980). The neural bases for most of these changes are not known but are most certainly related to the effects of aging on neural structure and function. Event-related potentials

have been employed as one means for quantifying such changes. There are modifications of both sensory (Lueders 1970; Celesia and Daly 1977; Allison et al. 1979; Dorfman and Bosley 1979; Desmedt and Cheron 1980; Sokol et al. 1981; Hume et al. 1982; Allison et al. 1983; Celesia et al. 1987) and cognitive (Goodin et al. 1978; Beck et al. 1980; Smith et al. 1980; Michalewski et al. 1982; Syndulko et al. 1982; Brown et al. 1983; Pfefferbaum et al. 1984; Picton et al. 1984; Polich and Starr 1984; Gordon et al. 1986) components of the event-related potentials associated with aging.

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The present study was undertaken to examine the effects of aging on a particular aspect of cognition, that of short-term memory. We used a memory-scanning task modified from Sternberg (1966) and recorded both event-related potentials and behavior to the probe stimuli as they were judged as being or not being a member of a previously presented set. Both visual and auditory short-term memory were evaluated using both verbal (digits) and non-verbal (musical notes) items. The results are compared to those in a companion report on memory scanning in a group of young subjects to define where along the short-term memory process aging was acting.

Methods

Potentials were recorded during the performance of 2 tasks: (1) a probe identification task involving memory scanning modified from one originally used by Sternberg (1966), and (2) a target-detection task ('odd-ball' paradigm) in which targets were rare relative to frequent, non-target stimuli. In the memory-scanning task, the potentials evoked by the correctly identified probe items were analyzed. In the target-detection task, the potentials evoked by correctly identified target stimuli were recorded and analyzed.

The methods of this study were identical to those detailed in an accompanying report on young subjects (average age = 29 years) (Pratt et al. 1989a), except for the addition of an older group of 11 subjects ranging in age from 51 to 86 years (average age = 66 years, S.D. = 12). The young and older subjects were without neurological complaints, had no difficulty hearing instructions or stimuli throughout the experiments and all had normal or corrected-to-normal vision. Their Mini-Mental State (Folstein et al. 1975) was not lower than 29. Twenty-one of the subjects were right handed.

For the older group we included 40 trials for each set size (1, 3 or 5 items) for each of the 3 stimulus types (auditory digits, visual digits and notes). Statistical treatment of the data was similar to that employed with the young subjects (Pratt et al. 1989a) with the addition of comparisons of

regression constants of young and older subjects using the *t* statistic.

Results

Performance

Performance accuracy in the separate tasks is summarized for older and younger subjects in Table I. No age differences in accuracy between the groups were found. A significant stimulus type and set size interaction ($P < 0.001$) indicated that while there were no differences in accuracy for auditory and visual digits at the various set sizes, both age groups were less accurate for notes as set size increased. Accuracy to positive and negative probe items was equivalent for auditory and visual digits but differed for notes being less accurate to negative probes than to positive probes (stimulus type $\times$ probe type interaction, $P < 0.001$).

Reaction time (RT) means for each age group as a function of set size for the 3 memory-scanning tasks are shown in Fig. 1. Older individuals had longer RTs than the younger subjects for all stimulus types and set sizes ($P < 0.001$). For both age groups RTs were prolonged with increased set size being shorter to the 1-item than either 3- or 5-item memorized sets ($P < 0.001$). Reaction times for notes for set sizes 3 and 5 were longer than the RTs for the same set sizes, respectively, for auditory and visual digits (stimulus type $\times$ set size interaction, $P < 0.001$). Stimulus type effects ($P < 0.001$) indicated that RTs for both age groups were shortest to visual digits, followed by auditory digits and then by notes. Post-tests showed that visual and auditory digits were significantly different from notes but were not different from each other. Reaction times were not different to positive or negative probe items for auditory or visual digits, but for notes were longer for negative probes than for positive probes (stimulus type $\times$ probe type interaction, $P < 0.002$). The pooling of positive and negative probes to notes in Fig. 1 should, therefore, be regarded with reservation and is only presented for graphical illustration of age effects on RT.

In the 'odd-ball' target detection task, accuracy was high for both younger (average = 99.8%) and

TABLE I

Memory-scanning performance in young and old subjects. Averages and standard deviations (S.D.) of the percentage of correct responses from the total number of probes presented. Tasks are designated by 3-character codes: A (auditory digits), V (visual digits) or T (notes) representing the 3 stimulus types; P (positive, in-set) or N (negative, out-of-set) representing probe type; 1, 3 or 5 for the size of the memorized set.

		Auditory digits					
		AP1	AN1	AP3	AN3	AP5	AN5
Young	Average	96	97	97	99	96	98
	S.D.	3	3	3	2	5	2
Old	Average	98	99	98	98	95	98
	S.D.	2	2	3	3	9	3
		Visual digits					
		VP1	VN1	VP3	VN3	VP5	VN5
Young	Average	97	97	96	99	94	97
	S.D.	2	3	3	3	6	3
Old	Average	96	98	99	97	94	95
	S.D.	6	5	2	5	5	6
		Musical notes					
		TP1	TN1	TP3	TN3	TP5	TN5
Young	Average	98	90	90	76	83	71
	S.D.	3	14	6	22	8	14
Old	Average	95	87	85	69	78	59
	S.D.	5	20	14	27	15	21

older (average = 99.2%) groups. Reaction times in the 'odd-ball' task were on the average 60 msec longer for the older subjects (average = 422 msec, S.D. = 111) than younger subjects (average = 361, S.D. = 104) but the difference between groups did not reach a significant level. Thus, although significant age differences in RT were evident throughout the memory-scanning series, this was not the case for the 'odd-ball' target task.

Evoked potentials

Component definition. Fig. 2 presents the wave forms of the potentials evoked by the probe items averaged for each age group across memorized-set sizes for each of the 3 presentation modes. Probe items to all types of stimuli evoked potentials that included an initial positive, negative, positive, negative sequence (P1–N1–P2–N2) in the first 250 msec following stimulus onset. Subsequently, 2 prominent positivities were recorded: (a) an earlier, frontal transient P3a, which in the central and parietal electrodes was superimposed on (b) a sustained (> 700 msec) positivity (P3b) that re-

solved close to the end of the analysis period. The sustained positivity was largest parietally. The earlier components (P1–N2) did not appear to be affected by factors other than stimulus type, suggesting exogenous origins (see Pratt et al. 1989a, b) and were not analyzed further.

Effect of age. Younger subjects had larger late positive sustained potentials in the parietal derivation ($P < 0.02$) but smaller frontal potentials than older individuals ($P < 0.001$) for all stimulus types (Fig. 2). Age differences in amplitudes were limited to main effects, and the higher order interactions of age with other factors (stimulus type, set size and probe type) did not reach significant levels for either parietal or frontal derivations.

While older subjects generally had later sustained parietal latencies than younger subjects for all stimulus types, only the age differences for visual digits attained significance (age $\times$ stimulus type interaction, $P = 0.004$). The mean late potential latencies for both age groups for stimulus type and set size are shown in Fig. 3. Older subjects also had generally longer late frontal latencies

Fig. 1. Average reaction time (combining positive and negative probes) for young and old subjects for each stimulus type and memorized-set size.

than younger subjects for all stimulus types but the age difference was only marginal ($P = 0.06$).

Effect of set size. A significant set size and stimulus type interaction was indicated for the late parietal potential amplitudes ($P < 0.005$). The means for each stimulus type at each set size are shown in Fig. 4 separately for each age group. The potentials for visual digits and notes were larger for the 1-item sets than for the 3- or 5-item sets. In contrast, the potentials to auditory digits were generally of comparable amplitude for the 3 set

sizes. The latencies of the sustained potentials were prolonged with increased set size ($P < 0.001$). Latencies for the 1-item memorized sets were shorter (average = 544 msec) than for either the 3-item (621 msec) or 5-item (641 msec) sets; differences between 3- and 5-item sets were not significant.

Frontal late potentials were affected by set size for amplitude ($P < 0.001$) but not for latency (Fig. 3). Only main effects were indicated for the frontal amplitudes. Larger frontal potentials were recorded to 1-item (average = 5.6 μV) memorized sets than to 3-item (3.6 μV) or to 5-item (3.7 μV) memorized sets.

Effect of stimulus type. Significant main effects for stimulus type (see Fig. 2) were indicated for parietal amplitudes ($P = 0.01$) and latencies ($P < 0.001$). Late sustained parietal potential amplitudes to visual digits (average = 11.3 μV) were larger than the potentials to either auditory digits (9.0 μV) or to notes (9.3 μV) (Fig. 4). Parietal latencies were shorter to notes (average = 564 msec) than either visual (587 msec) or auditory digits (655 msec), but only the difference between notes and auditory digits attained a significant level (Fig. 3).

Similar patterns of main effects for stimulus type were found for frontal amplitudes ($P < 0.001$) and latencies ($P < 0.001$). The frontal amplitudes were larger to visual digits (average = 5.8 μV) than to auditory digits (3.2 μV) or notes (4.0 μV). Only the difference between visual digits and auditory digits was significant. Frontal late potential latencies were shorter for notes (average = 374 msec) than visual (400 msec) or auditory digits (413 msec); only the difference between notes and auditory digits was significant.

Effect of probe type. No amplitude differences between positive or negative probe items for either parietal or frontal locations were indicated. There were significant differences, however, in the latencies of the late potential to probe type. On the average, potentials to positive probes recorded from the parietal site were approximately 32 msec shorter than to negative probes ($P < 0.003$), whereas at the frontal site potentials to the positive probes were about 7 msec shorter than to the negative probes ($P < 0.03$). Probe type appeared

Fig. 2. Superimposed wave forms of the grand-average evoked potentials to the probe items for young and old subjects, averaged across set sizes and positive and negative probes for the 3 stimulus types. Note the negative bias of the frontal records from the young compared to old subjects.

only as a main effect and was not affected by the factors of age, set size or stimulus type.

RT and EP correlations with set size

RT/set size correlations. Correlations and regression slopes and intercepts between RT and set size for the old subjects are shown in Table II. All

Fig. 4. Average late sustained parietal amplitudes for each stimulus type and memorized-set size (combining positive and negative probes) for both age groups. Note that amplitudes are less for the old subjects compared to the young group.

Fig. 3. Average late potential latencies for frontal (Fz) and parietal (Pz) late potential latencies in young and old subjects (positive and negative) for each stimulus type and memorized-set size.

slopes were different from zero indicating significant relationships of RT with set size. Since there were no slope or intercept differences between positive and negative probes for any of the stimu-

TABLE II

Correlation coefficients (r) and linear regression intercepts (a) in msec and slopes (b) in msec/item for reaction time (to correctly classified stimuli) as a function of the number of items in the memorized set for the old subjects. The values of the t statistic and associated probability (P) are also indicated. The types of tasks are represented by 2-letter codes: A (auditory digits), V (visual digits) or T (notes), followed by P (positive) or N (negative) indicating probe type.

	Auditory digits		Visual digits		Musical notes	
	AP	AN	VP	VN	TP	TN
r	0.66	0.61	0.63	0.46	0.65	0.43
a	783	771	675	733	759	971
b	82	81	75	74	129	93
t	4.666	4.100	4.250	2.710	4.508	2.547
P	< 0.001	< 0.001	< 0.001	0.011	< 0.001	0.017

lus types, positive and negative probes were pooled for stimulus-type comparisons. Pooled RT/set size slopes and intercepts were not significantly different between stimulus types for the older subjects.

The pooled RT/set size slopes of the older subjects were 82, 74 and 111 msec/item for auditory digits, visual digits and notes, respectively. These slopes were steeper than the slopes of the young for auditory digits ($P < 0.05$) and approached significance for the visual digits ($P = 0.08$). The slopes for notes were comparable between the two age groups. The intercepts for the older subjects for auditory digits, visual digits and notes, respectively, were 777, 704 and 865 msec. These intercepts for the older individuals were approximately 250 msec higher than for the younger subjects. The intercept differences between age groups were significant for all stimulus types (auditory digits = $P < 0.0001$, visual digits = $P < 0.0005$ and notes = $P < 0.0005$).

EP/set size correlations. For older subjects, the correlations of EP latency with set size and EP amplitude with set size were low and did not attain significant levels for either visual digits or notes. There were significant relationships, however, between the latencies of the late parietal potential to auditory digits and set size (positive probes: $r = 0.37$, slope = 32 msec/item, intercept = 528 msec, $P < 0.05$; negative probes: $r = 0.37$, slope = 20 msec/item, intercept = 638 msec, $P < 0.05$). This is to be contrasted to the significant relationships obtained between late parietal latencies and set size for all stimulus types for the young subjects (Pratt et al. 1989a).

Since there were no slope or intercept differences for the old subjects between positive and negative probes for any of the stimulus types, positive and negative probes were pooled for comparisons between stimulus types (Table III). The slopes of the functions relating the latencies and amplitudes of P3a and P3b with set size were not different between stimulus types (auditory digits, visual digits and notes). The intercepts of the functions relating P3a amplitude with set size were smaller for auditory compared to visual digits ($P < 0.02$). For P3b amplitude/set size, the intercept for auditory digits was significantly smaller than the intercepts for both visual digits ($P <$

TABLE III

Linear regression intercepts (a) in msec and slopes (b) in msec/item for P3a (Fz) and P3b (Pz) latency (lat) and amplitude (amp) as a function of the number of items in the memorized set for the old subjects. Intercepts are in msec for latencies and μV for amplitudes, slopes are in msec/item for latencies and μV /item for amplitudes.

		Auditory digits	Visual digits	Musical notes
P3a (Fz) lat	r	0.15	0.13	0.26
	a	403	395	376
	b	4.9	4.0	5.8
	amp	r	0.01	-0.12
		a	4.4	7.5
		b	0.2	-0.3
P3b (Pz) lat	r	0.34	0.20	0.14
	a	583	602	550
	b	26.0	13.6	9.2
	amp	r	0.22	-0.13
		a	5.9	10.5
		b	0.5	-0.3

0.001) and notes ($P < 0.05$). None of the P3a and P3b latency/set size intercept differences between stimulus types were significant for the old group.

Measures of EP amplitude and EP latency as a function of set size were affected by age (Figs. 3 and 4). P3a amplitude/set size slopes were steeper for the young compared to the old group for auditory digits ($P < 0.01$) and notes ($P < 0.005$). Latency and amplitude/set size slopes for P3b were steeper for the young than for the older subjects for notes ($P < 0.05$ and $P < 0.01$, respectively). Intercepts for P3b latency/set size were longer for older adults than for the young for notes ($P < 0.02$) and visual digits ($P < 0.0005$). P3b amplitude/set size intercepts were smaller for the old than the young for all stimulus types (auditory digits $P < 0.0005$, visual digits $P < 0.025$, and notes $P < 0.0005$).

Comparing the behavioral and evoked potential measures showed that for older subjects RT/set size slopes were significantly steeper than the P3b latency/set size slopes for all stimulus types (auditory digits = $P < 0.001$, visual digits = $P < 0.005$ and notes = $P < 0.0003$), whereas for the young subjects this relationship applied only to auditory digits and notes. For the old subjects, the respec-

TABLE IV

Linear regression intercepts (*a*) in msec and slopes (*b*) in msec/item for P3a (Fz) and P3b (Pz) latency (lat) and amplitude (amp) as a function of reaction time for the old subjects. Intercepts are in msec for latencies and μV for amplitudes, slopes are EP latency vs. RT latency (msec/msec) and μV /msec for amplitudes.

		Auditory digits	Visual digits	Musical notes
P3a (Fz) lat	<i>r</i>	0.25	0.25	0.06
	<i>a</i>	350	355	386
	<i>b</i>	0.07	0.06	0.01
	amp	<i>r</i>	-0.10	-0.03
		<i>a</i>	5.8	5.6
		<i>b</i>	-0.001	-0.0002
P3b (Pz) lat	<i>r</i>	0.30	0.13	0.15
	<i>a</i>	483	582	523
	<i>b</i>	0.17	0.06	0.04
	amp	<i>r</i>	-0.17	-0.33
		<i>a</i>	10.1	11.8
		<i>b</i>	-0.003	-0.004

tive intercepts were significantly different for auditory digits ($P < 0.001$) and notes ($P < 0.0005$), whereas for the young subjects there were no intercept differences for the different stimulus types.

EP/RT slope and intercept comparisons. Correlation and regression procedures were used to assess evoked potential measures and RT in the older subjects. EP/RT slope differences between positive and negative probes were not significant for any of the stimulus types for either latency or amplitude. Consequently, positive and negative probes were pooled for stimulus-type comparisons. The resulting correlations, slopes and intercepts are listed in Table IV. For the older subjects, the slopes of the functions relating latencies and

amplitudes of P3a and P3b with RT as well as their respective intercepts were not significantly different between stimulus types (auditory digits, visual digits, notes).

When the EP/RT slopes were compared between the young and old subjects, significant differences were noted for most measures. P3a amplitude/RT slopes were steeper for the young compared to the older subjects for auditory digits ($P < 0.005$), visual digits ($P < 0.05$) and notes ($P < 0.05$). P3b amplitude/RT slopes were steeper in the young for visual digits ($P < 0.05$) and notes ($P < 0.05$) and approached significance for auditory digits ($P < 0.07$). No age-related slope differences were noted for P3a latency/RT functions. P3b latency/RT slopes were steeper in the young compared to the older group for notes ($P < 0.05$) and approached significance for auditory ($P = 0.055$) and visual ($P = 0.09$) digits. P3a latency/RT intercepts were longer in the older subjects for notes ($P < 0.05$). P3b amplitude/RT intercepts were larger in the young group for auditory ($P < 0.05$) and visual ($P < 0.02$) digits and for notes ($P < 0.05$). P3b latency/RT intercepts were longer in the older group for visual digits ($P < 0.02$) and notes ($P = 0.05$).

Target detection EPs

The potentials recorded to targets from the younger and older subjects in the 'odd-ball' task are shown in Fig. 5. Note the negative bias of the potentials in the P2–N2 range, particularly in the frontal averages of the younger subjects compared to the older subjects. The frontal manifestation of P3 was less positive and earlier in the younger subjects than in the older subjects, but these age differences did not attain a significant level. In

Fig. 5. Superimposed target wave forms in the 'odd-ball' task averaged across all subjects in each age group. Note the negative bias of the frontal records from the young subjects compared to the old subjects in the time domain extending from N1 to N2.

contrast, the parietal P3 was larger and earlier in the younger subjects, but here again, the differences between the age groups did not reach a significant level. The corresponding peak latencies were shorter for the younger subjects by an average of 15 msec frontally and 20 msec parietally compared to the older subjects, respectively.

Discussion

The results of this study show that performance accuracy in the memory-scanning tasks was no different for older and younger age groups, whereas RT was consistently and significantly longer in the older individuals than in the younger subjects (Fig. 1). RT slopes were about 50% steeper for the older subjects compared to the younger subjects, and the intercepts for the older group were approximately 250 msec above the younger group (Table II). These results differ in some respects from previous studies of young and old adults during memory scanning. Some (e.g., Marsh 1975; Wilson et al. 1980) have reported relatively small differences in RT slopes between young and old, whereas others (e.g., Anders et al. 1972; Ford et al. 1979) have reported RT slopes that were approximately twice as steep for the old compared to the young. A comparison of RT intercepts among studies of young and old also shows some disagreement. Wilson et al. (1980), for example, reported comparable RT intercepts between young and old subjects, whereas others (e.g., Anders et al. 1972; Marsh 1975; Ford et al. 1979) found that older subjects have higher intercepts than younger individuals. Some of the differences among reports may be in part attributable to factors such as the age range between the groups studied, the number of subjects studied and procedural variations in the memory-scanning methodologies. In the Wilson et al. (1980) study, for example, the age difference between old (mean = 68.8) and young (mean = 55.7) was narrow which may account for the small differences found among age groups for RT intercepts and slopes. Marsh (1975) suggested that in his study the older group may not have fully understood or was confused by the task in some instances, particularly for the mem-

orized sets containing only a single element (1-item memorized set) interspersed among 3- and 5-item memorized sets. The full extent of procedural differences in memory scanning on age needs separate consideration and study.

In our study, there were no accuracy or RT differences between positive or negative probe items to auditory or visual digits, whereas for notes higher accuracy and shorter RTs were recorded to positive than to negative probes. Late potentials in general had shorter latencies for all stimulus types to positive than to negative probes. In a companion study on young subjects (Pratt et al. 1989a) this effect was only marginal. In both our studies, slopes relating late potential latency and set size were not different between probe types. Ford et al. (1979) reported no RT differences between positive and negative probes to visual digits but longer P3 latencies to negative than to positive trials. In contrast, Marsh (1975) found no latency differences in the late positive component between positive and negative probes, and no RT differences between probe type for the young group but a difference for the old group. In the conventional memory-scanning model, comparable RTs between positive and negative probe items are taken to reflect exhaustive search of the memory list. The model also requires accurate performance. In the present study both age groups had comparable performance accuracy and no RT differences to positive and negative probes for auditory and visual digits. Notes showed some departure from this model; both accuracy and RT differed between positive and negative probe notes, and accuracy diminished for 3- and 5-item set sizes. However, our results overall remain consistent with the previous RT results during memory scanning, compatible with scanning of the entire memorized list before response selection occurs in both age groups.

We found that late potential latencies (P3b) were significantly longer in old than young adults for the visual digit presentation but not for auditory presentation of digits or notes. Similar findings have been reported for visual presentation by others but the differences between age groups have been either marginal (Ford et al. 1979) or not significant (Marsh 1975). However, there is good

agreement among these studies that set size affects each age group equivalently for visual presentation, and they also confirm the dissociation of RT and late potential latency in the older compared to the younger individuals as observed in the present study.

Significant correlations were obtained from younger subjects to all stimulus types for the late sustained potential latency and set size (Pratt et al. 1989a). For older subjects, in comparison, only the correlation for auditory digits between the late sustained parietal potential latency and set size attained a significant level. Yet the correlations between RT and set size were significant for both age groups, suggesting that the relation between late potential latency and set size, whether high or low, has little influence on the RTs of the older subjects. In agreement with our findings, Ford et al. (1979) reported significant correlations between P3 latency and RT for young subjects for visual digits, but low or no correlations for the old subjects. It is therefore likely that the prolonged RTs observed for older subjects during memory scanning reflect age effects on response selection processes more than on memory scanning.

Although both subject groups achieved high accuracy in the behavioral tasks, their evoked potentials differed. A superimposed sustained frontal negativity was identified in the records of the younger subjects that was not evident for the older subjects (Fig. 2). This finding supports the results of an earlier study on age differences in P3 and RTs (Pfefferbaum et al. 1980). The frontal negativity may be associated with the reduced amplitudes of the frontal late potentials, observed for the younger group compared to the older group, and may account for the age differences in amplitude found for the frontal derivation. Kramer et al. (1986) reported the occurrence of a similar sustained negativity associated with probes in a memory-scanning task which was found to be sensitive to the degree of probe mismatch in a controlled mapping condition, a situation which is likely to lead to automatic processing. These results, combined with our findings on the frontal amplitude differences between age groups, suggest that younger subjects perhaps maintained high accuracy with a more automatic evaluation,

whereas the older subjects may have employed an alternate strategy to accomplish similar performance. The frontal negativity we recorded in the younger subjects may be related to the match/mismatch negativities described by Näätänen et al. (1982).

Stimulus-type effects were evident in the memory-scanning tasks for both RT and late potential measures. While RTs for visual and auditory digit presentations were essentially equivalent, they were both shorter than for the notes. For normal subjects of both age groups, this suggests that the nature of the stimulus material processed, e.g., verbal or non-verbal, has more of an effect on memory scanning than modality of presentation. Late potentials for both age groups in both the frontal and parietal regions showed that amplitudes to the verbal digits presented in the visual modality were larger than to verbal digits in the auditory modality or to non-verbal notes. Parietal amplitudes for visual digits and notes decreased with set size, whereas the amplitudes for auditory digits did not appear influenced by set size (Fig. 4). Further, late potential latencies were generally shorter for the notes than either of the verbal digit presentations in the auditory and visual modalities.

For notes, P3b/set size slopes were found to be steeper in the young than in the older subjects. This finding would imply faster scanning by old subjects compared to the young. However, observing Fig. 3 and the significant intercept difference between groups would suggest that this difference was due to longer latencies for the 1-item set size in the old subjects. This explanation also suggests that the 1-item memorized-set comparisons involved different task strategies, especially for the non-verbal items.

In general, however, memory scanning was comparable in the two age groups using different stimulus modalities and stimulus types. The latency of the late parietal positivity was correlated with set size regardless of stimulus modality and type in young subjects, whereas this was true only for verbal auditory material in old subjects. The significance of this discrepancy, coupled with the slope and intercept differences between age groups, may reflect changes in task strategy with

aging or the primacy of verbal auditory scanning mechanisms with aging. The amplitude of the sustained parietal positivity accompanying memory scanning was significantly reduced in the old subjects relative to the young subjects. We have no evidence that this reduction reflects specific changes in the functioning of neural structures subserving memory scanning. Certainly, the slowing of RT with aging has been, in the most part, attributed to non-specific effects of aging on the motor and response systems. Further studies are needed to evaluate the significance of the amplitude change of these potentials with aging.

In the present study, P3a and P3b latency and amplitude in the 'odd-ball' task yielded no significant age differences. Linear regression analyses of these evoked potential measures with age did not yield significant relationships. This is in contrast to the finding of significant age effects for the latency of the sustained parietal potentials in the visual presentation and age effects for amplitude of the late sustained potentials evoked in memory scanning for all stimulus types. It may be that the failure to detect age effects in the 'odd-ball' task was due to the relatively small number of subjects spread over the entire age range (18–86 years), resulting in an average of only 3 subjects per decade. In addition, these subjects presented a large latency variation (S.D. = 111 msec for the old and 104 msec for the younger group) compared to earlier studies (e.g., Goodin et al. 1978; Pfefferbaum et al. 1984). However, this explanation is not entirely satisfactory since the effects of age on brain potentials accompanying cognition were revealed by the changing requirements of the tasks, i.e., target detection compared to memory scanning, and testing different modalities.

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