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Journal
Developmental Neuropsychology, 9(3-4)

ISSN
8756-5641

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Publication Date
1993-07-01

DOI
10.1080/87565649309540554

DEVELOPMENTAL NEUROPSYCHOLOGY, 1993, 9(3 & 4), 225–240

Importance of Contemporary Sequences and Historical Patterns on Brain Responses Across the Life Span

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Brain and behavioral responses to infrequent but equiprobable, predictable (fixed) and unpredictable (random) targets were measured to test the hypothesis that a shift in focus from local to global (historical) events occurs across the life span. Memory of sequence was informative in the fixed condition because the occurrence of a target could be perfectly predicted. Recalling the sequences contributed to the development of global probability estimates in the random condition, but did not provide specific information about the occurrence of an event. A highly significant advantage was evident in brain and behavioral responses only in young and middle-aged subjects to predictable targets (i.e., use of local information). Among elderly subjects, the event-related potentials and reaction times to predictable and random targets were indistinguishable. The relations of age and reaction time to P3 amplitude were topographically discrete and consistent with earlier literature.

Coupling between the brain and behavior has been illustrated consistently by the manipulation of expectancy (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982). Expectancy influences both reaction time (RT) and event-related potentials (ERPs) of the brain. A highly predicted (expected) event produces faster RT and smaller ERP components, especially P3, than do unexpected or surprising events (Duncan-Johnson & Donchin, 1977; Helfley, Wickens, & Donchin, 1978; Johnson & Donchin, 1982; McCarthy & Donchin, 1981; Sutton, Brarenm, Zubin, & John, 1965). Decomposition of large sequences of events into smaller, local sequences (Remington, 1969) has provided information about

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how P3 responses can vary over the course of an experiment (Squires, Wickens, Squires, & Donchin, 1976). Squires et al. discovered that both global (historical events) and local (immediate events) probability contributed to P3 amplitude. Local sequences with a high ratio of common to rare events yielded the largest P3 response regardless of global probability. It was reasoned that P3 amplitude was a sensitive index of memory because response to local sequences depended on recollection of these sequences.

Retrieval of recent events declines with advancing age (Craik, 1984), suggesting that the ability to recall (or use) local sequences may also decline. The memory system measured by the Squires et al. (1976) model, and a contemporary version (Donchin & Coles, 1988), assumes that the environment is monitored continuously to detect patterns (local events) and to formulate and update expectations (global probabilities). Because the P3 response is a manifestation of memory (or schema) updating, it is elicited by rare or unusual events, presumably because frequent (or predictable) events already are resident in memory (Donchin, Karis, Bashore, Coles, & Gratton, 1986) and can be ignored. Although several studies have reported diminished P3 amplitude in expectancy studies with subjects of advancing age (Ford, Hink, et al., 1979; Ford, Pfefferbaum, Tinklenberg, & Kopell, 1982; Ford, Roth, Mohs, Hopkins, & Kopell, 1979; Goodin, Squires, Henderson, & Starr, 1978a, 1978b; Pfefferbaum, Ford, Wenegart, Roth, & Kopell, 1984; Podlensky & Dustman, 1982; Syndulko et al., 1982), only a few have examined the influence of global or local probabilities on P3 amplitude (Ford, Duncan-Johnson, Pfefferbaum, & Kopell, 1982; Picton, Stuss, Champagne, & Nelson, 1984). Picton et al. (1984) found that elderly subjects retained the ability to differentiate global probabilities. In their study, P3s were larger as the global probability of an event decreased in both young and aged subjects. Sensitivity to local events was reported by Ford, Duncan-Johnson, Pfefferbaum, and Kopell (1982) using decomposition sequential tree analysis. They found increased P3 amplitude to discontinuations of common and rare tone alternations and, especially, repetition. However, elderly subjects appeared more sensitive than younger subjects to discontinuation of repetition. These findings were interpreted as suggesting that in some instances elderly subjects use, and then remember, short-term sequences better than younger subjects.

In our previous study (Sandman, Donnelly, O'Halloran, & Isenhart, 1990), the P3 response of the elderly was sensitive only to global probabilities and apparently was immune to changes in local sequences. Only subjects below age 50 had brain responses that significantly distinguished predictable and unpredictable equiprobable rare targets. Among the elderly, P300 amplitude was governed primarily by global events. In contrast, local events were the primary factor influencing the amplitude of P300 in younger subjects. A variation of this age-sensitive procedure (Sandman et al., 1990) was used in the current study to examine further the sensitivity to global and local factors across the life span.

METHOD

Subjects

Sixty-six right-handed subjects were recruited from hospital staff and their children, and from a group of elderly (over 60) volunteers.

Procedure

Subjects were tested in an electrically shielded, sound-attenuating chamber. Subjects reclined in a comfortable chair and electrodes were applied to their scalp. Binaural headphones were placed over their ears and white noise, supplied by room speakers, saturated the cubicle to mask extraneous noise. Low-level illumination (provided by a direct-current source) permitted the subjects to be viewed by closed-circuit television from the control room. A communication system maintained continuous audio monitoring of the subjects.

The subjects were tested in two different conditions: (a) one with a *fixed* or predictable distribution of common-to-rare (i.e., AAA*B*AAA*B*AAA*B* . . .) targets, and (b) one in which the occurrence of the stimuli was *random* (i.e., A*B*AAAAA*B*AAAAA*B* . . .). In both conditions, the rare-to-common target ratio was 1:4. Subjects were tested with the fixed and random targets separately but during the same session, with the order of presentation balanced across subjects.

Subjects were informed of the test condition and asked to close their eyes and press a key with their right index finger each time the target stimulus was presented. A pretesting session determined that all subjects included in the analysis were able to discriminate the common and rare tones. The common (450 Hz) and rare (550 Hz) tones (250 ms duration, 50 ms rise time) were presented with 18 db target-to-background difference (90 db SPL against white-noise background of 72 db SPL at the headphone cone; Bruel and Kjaer, Model 2203 sound-level meter).

EEG procedure. Physiological recordings were made with a Grass polygraph, Model 79, equipped with 7P511 amplifiers. Analog data were collected and digitized with a PDP 11/73 computer (Digital Equipment Corporation). Stimuli were initiated by the computer via a Grass Click-Tone Control Module (Model S10CTCMA).

Gold cup electrodes were placed according to the International 10–20 system at C3, C4, Fz, and Pz and were referenced to linked mastoids. The electrodes were filled with EC–2 creme (Grass) and affixed to the scalp. Electrode placements were matched for impedance (no greater than 1k-Ω differences). Electrodes with impedance of greater than 10kΩ were replaced. The electroen-

cephalogram (EEG) signals were amplified with ½-amplitude settings at 100 Hz (high) and 0.30 Hz (low).

ERP analysis. ERPs were collected by sampling the EEG at 200 Hz for 1280 ms. The ERP was set to zero by the average of the 280-ms prestimulus sample. Forty ERPs to the targets in both conditions were averaged for each subject. An analog filter conditioned the signal prior to digitization (12 db/octave, 3 db at 100 Hz) minimizing aliasing and phase errors.

Identification of peak latencies and peak-to-peak amplitudes was automated. The results of the automated procedure were evaluated by a trained technician who identified the prominent components occurring within specified latency windows (P1, 30 to 80 ms; N1, 70 to 150 ms; P2, 130 to 250 ms; N2, 180 to 320 ms; P3, 250 to 600 ms). The ERPs were displayed on a cathode-ray tube with cursors placed at the points of greatest positivity and negativity. The components were calculated as *peak-to-peak amplitude differences* (in μV) between adjacent points.

Artifact rejection. Single-trial EEG responses exceeding ±50 μV at any electrode placement, within 1000 ms of the stimulus were eliminated automatically. This procedure reliably detected artifacts related to eyeblinks, scalp muscle activity, and postural adjustments. Separate testing indicated that 98.4% of the trials with lateral eye movement and 100% of eyeblinks (verified by electrooculogram measured from outer canthus and suborbital electrodes reference to mastoids) were rejected by this procedure. Common–rare tone sequences rejected because of artifact in the EEG were repeated. In this procedure, very few (2%) of the trials were repeated. Trials with RTs exceeding 1700 ms also were rejected.

RESULTS

Analysis of Variance

A 2 (Target: Fixed vs. Random) × 4 (Placement: Fz, Pz, C3, or C4) × 2 (Order) analysis of variance tested the effectiveness of the procedures to evoke the P3 component. No effects or interactions with order were significant so it was omitted from the design.

Component amplitude. The main effect of target (fixed vs. random) was evaluated for all ERP components but was significant, $F(1, 64) = 12.56$, $p < .001$, only for the amplitude of P3. The P3 response to the random target was nearly twice the amplitude of the response to the fixed target.

Amplitude of ERP components was topographically distinct. The amplitude of P3 was equal over both Fz and Pz and significantly larger at these two sites,

$F(3, 189) = 4.91$, $p < .003$, than at C3 and C4. The amplitudes of N1, $F(3, 189) = 6.01$, $p < .001$; P2, $F(3, 189) = 4.34$, $p < .01$; and N2, $F(3, 189) = 7.31$, $p < .001$, were largest at Fz. The amplitude of P1, $F(3, 189) = 2.93$, $p < .04$, was largest at Pz. The interaction between targets and electrode placement was not significant.

Component latency. The main effect of target (fixed vs. random) was significant, $F(1, 64) = 6.14$, $p < .02$, only for the latency of P3. Average P3 responses to the random target (362 ms) were longer than to the fixed target (352 ms).

RT. The main effect of target was highly significant, $F(1, 63) = 51.59$, $p < .001$, with faster RTs to the fixed target (Table 1).

Stepwise Discriminant-Function Analysis

For analysis of age, subjects were arbitrarily divided into the following separate groups: young ($n = 12$, mean age = 13.5 ± 3.4 years), middle-aged ($n = 39$, mean age = 41.3 ± 12.1 years), and elderly ($n = 15$, mean age = 69.7 ± 5.8 years). Waveforms for three age groups were entered into a five-step, jackknifed program to test the ability to discriminate fixed and random conditions. This analysis tested the hypothesis that ERP responses of elderly subjects, especially in the P3 region, would not differ between targets. As is apparent from Table 2 and Figure 1, fixed and random targets did not generate significantly different waveforms among the elderly over Pz in the five-step model. Subsequent steps improved the discrimination. For the elderly, however, no single point on the ERP significantly separated the fixed and random targets.

In contrast to the elderly, ERP waveforms for the young and middle-aged subjects to the fixed and random targets were significantly different at all placements. Different components contributed to the statistical separation of the ERP in these subjects. For the young subjects, an epoch within the P3 region was the most significant at each electrode site with the largest difference between

TABLE 1
Mean RT for Total Sample and Age Groups Separately

		Target	
Group	*Mean Age*	*Fixed*	*Random*
Total	42.3	469	543*
Young	13.5	304	431*
Middle aged	41.3	456	522*
Elderly	69.7	646	695

*$p < .01$, for RT difference between predictable (fixed) and unpredictable (random) targets.

TABLE 2
Stepwise Discriminant Function Separation of the ERPs to Predictable and Unpredictable Targets for Each Electrode Site in Young, Middle-Aged, and Elderly Subjects

Site	*Age Group*	*Accuracy*[a]	*p Level*	*Selected Points (ms) on Waveform*[b]
Pz				
	Young	92%	.0001	300, 140, 160, 640, 540
	Middle	76%	.001	140, 600, 400, 240, 46
	Elderly	59%	ns	
Fz				
	Young	75%	.01	380, 540, 200, 560, 280
	Middle	79%	.001	520, 380, 280, 320, 180
	Elderly	68%	ns	
C3				
	Young	75%	.05	380, 540, 200, 560, 280
	Middle	79%	.001	540, 380, 260, 400, 300
	Elderly	84%	ns	
C4				
	Young	83%	.001	400, 140, 260, 520, 480
	Middle	75%	.001	589, 380, 260, 640, 420
	Elderly	75%	ns	

[a]Chance level for classification accuracy is 50% (fixed vs. random). [b]Points on waveform contributing to the discriminant equation.

targets at the Pz placement. In the middle-aged subjects, very late (500 ms), negative waves were the best discriminators over C3, C4, and Fz. At Pz, however, the N1 component was selected.

The accuracy of separation indicated a much greater than chance prediction (50% is chance; see Table 2). The best separation of the ERP between targets was observed in the younger subjects, consistent with the effects observed for RT. The ability to discriminate conditions better than 90% at Pz was highly significant ($p < .001$). Discrimination of targets at Pz also was most significant for the middle-aged group. However, the Pz location was least effective for the elderly.

The second stepwise discriminant-function analysis tested the ability to separate age groups based on ERP responses to the fixed and random targets. As presented in Figure 2 and Table 3, subjects were accurately (approximately 60% with 33% as chance) identified by age group based only on ERPs to the fixed and random targets. Differences among age groups to the random target are related to the dampened and delayed P3 in the elderly subjects and to the robust response in the young subjects. Age differences to the fixed target are more complex with responses of middle-aged and elderly subjects dampened at both placements. However, responses to the fixed target in young subjects are characterized by a large P3 at Fz but a suppressed response over Pz. These effects are represented in the classification matrix in Table 3.

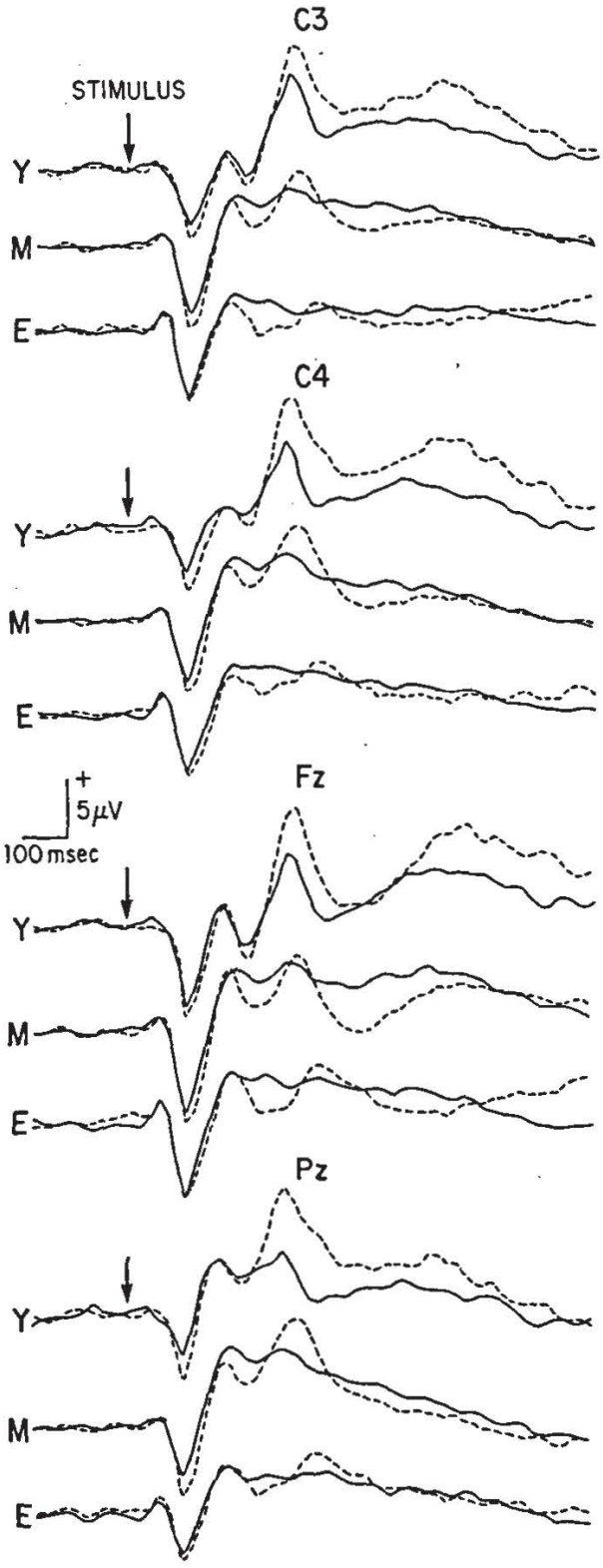

FIGURE 1 ERPs for young (Y), middle-aged (M), and elderly (E) subjects at C3, C4, Fz, and Pz for fixed (solid line) and random (dotted line) targets. Points on the waveform that distinguished the targets within each age group are presented in Table 2.

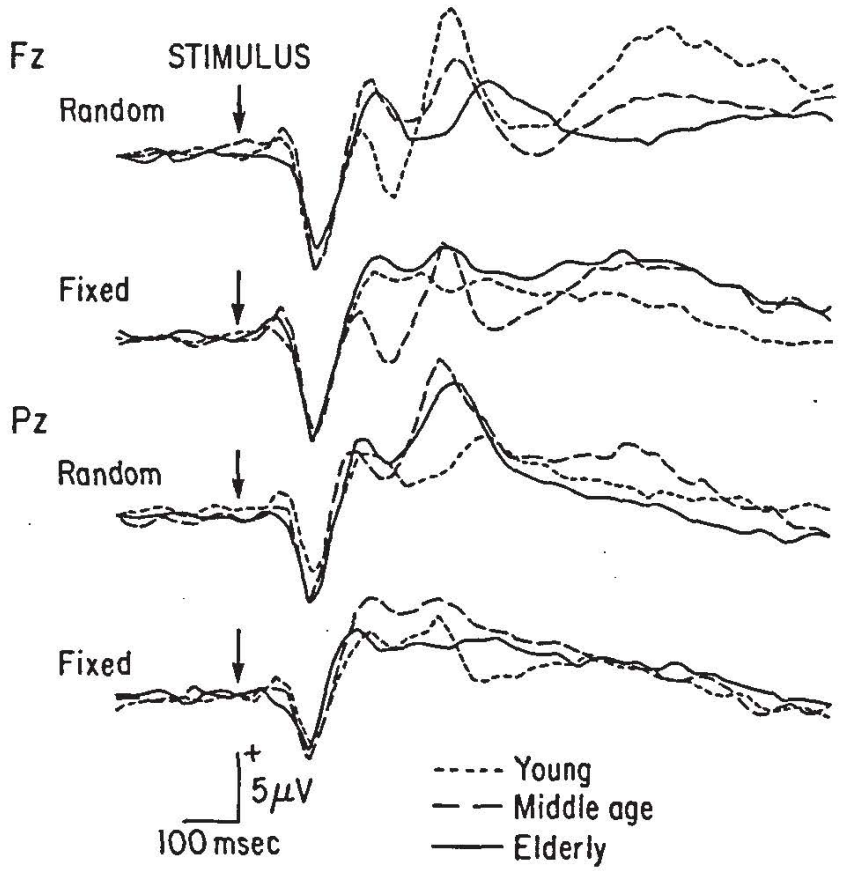

FIGURE 2 Comparison of ERPs in young, middle-aged, and elderly subjects separately for fixed and random targets over Fz and Pz. Epochs on the waveform differentiating the groups are presented in Table 3.

TABLE 3
Separation of the Three Age Groups by Stepwise Discriminant Analysis in the Fixed and Random Conditions at the Pz and Fz Electrode Sites

Site	*Condition*	*Accuracy*[a]	*p Level*	*Components (ms)*[b]
Pz				
	Random	60%	.001	340, 240, 160, 600, 380
	Fixed	56%	.01	360, 400, 520, 340, 440
Fz				
	Random	61%	.001	340, 260, 320, 280, 440
	Fixed	63%	.001	240, 340, 420, 320, 580
C3				
	Random	61%	.001	340, 240, 480, 160, 320
	Fixed	59%	.001	320, 240, 320, 420, 380
C4				
	Random	50%	.001	600, 360, 260, 340, 620
	Fixed	63%	.001	240, 340, 400, 280, 360

[a]Chance level for classification accuracy is 33% (young, middle aged, or elderly). [b]Temporal components of the ERP contributing to the separation.

Correlations Among Variables

RT and age. Significant slowing of RT was associated with age for both random ($r = .37$, $p < .01$) and fixed ($r = .42$, $p < .01$) targets at Fz (Table 4). The RT–age correlations were not significant within each age group and they did not reflect the life-span trend.

To test a primary hypothesis of the study, age was correlated with *RT efficiency* defined as the advantage gained in response to a fixed target:

$$\frac{RT_{random} - RT_{fixed}}{RT_{fixed}} \times 100$$

This relation was significant, $r(65) = -.36$, $p < .01$, indicating that an advantage in RT was evident for fixed targets among younger subjects. The advantage declined with increasing age to the fixed target.

P3 and age. The linear relation between age and P3 amplitude was significant only at Fz ($r = -.30$, $p < .05$) for the fixed target (Table 4). This trend is especially apparent in the elderly subjects for both targets. However, stronger second-order relations ($r = .45$, $p < .01$) existed between age and P3 amplitude (see Figure 3 for the random target at Fz). The different linear slopes for the young (negative), middle-aged (flat), and elderly (positive) groups contributed to the quadratic trend.

The positive relation between age and P3 latency is presented in Table 4. As with RT, the relation across the life span is not apparent within age groups. The correlation between P3 latency and age was small and negative in the young and middle-aged groups, but was positive in the elderly group.

TABLE 4
Correlations of Age with RT, P3 Latency, and P3 Amplitude

	Fixed			*Random*		
Site/Age Group	*RT*	*P3 Latency*	*P3 Amplitude*	*RT*	*P3 Latency*	*P3 Amplitude*
Fz						
Young	.23	−.09	−.37	−.13	−.31	−.39
Middle aged	.02	−.22	−.07	.04	−.29	.05
Elderly	.22	.26	.49	.19	.31	.56
All subjects	.42	.31	−.30	.37	.28	−.19
Pz						
Young	xx	−.09	−.25	xx	−.19	−.37
Middle aged	xx	−.12	.01	xx	−.09	−.02
Elderly	xx	.14	.41	xx	.28	.49
All subjects	xx	.25	−.13	xx	.30	−.17

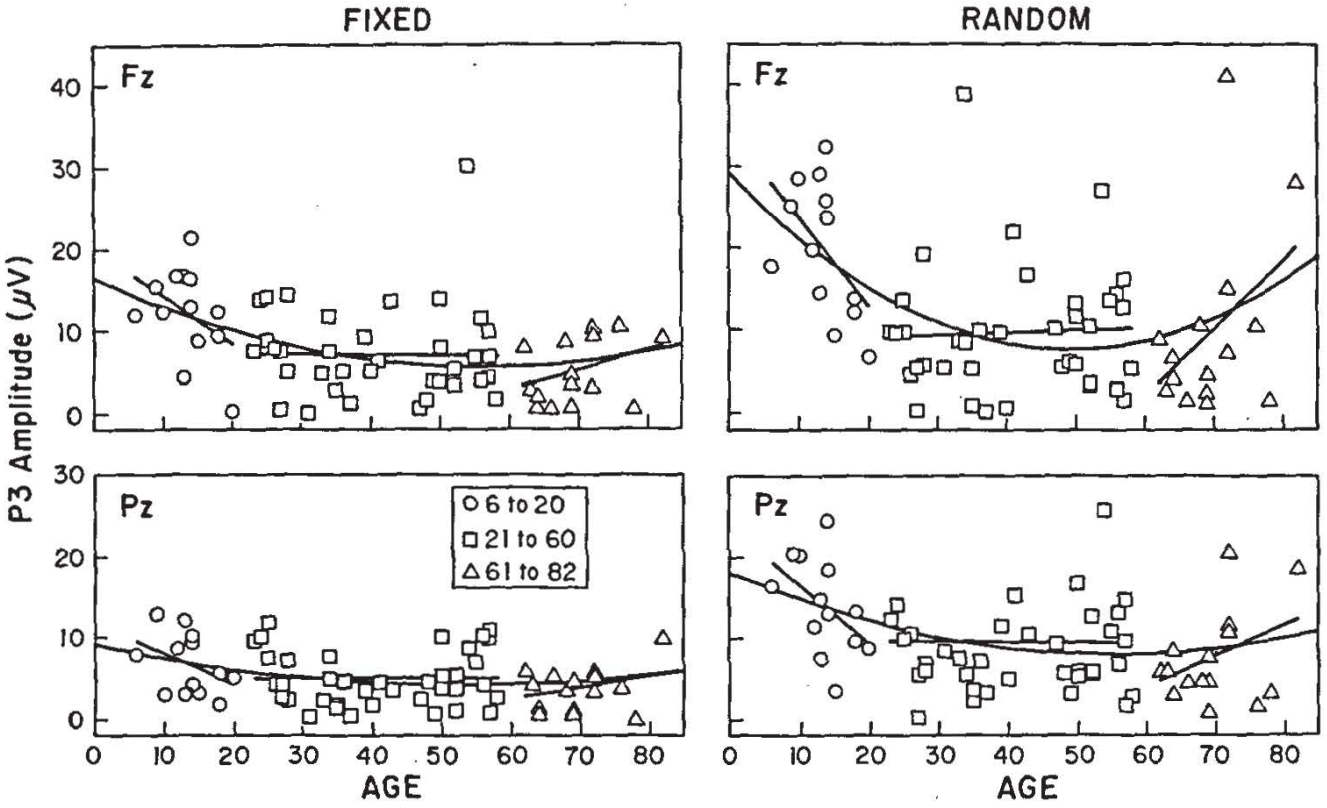

FIGURE 3 Correlations between P3 amplitude and age over Fz and Pz for the fixed and random targets. Linear relations are plotted within the age groups (young, middle aged, and elderly) and quadratic functions are expressed across the life span (see Table 4).

RT and P3. The positive correlations between RT and P3 latency were significant for both fixed and random targets at Fz (random, $r = .28$; fixed, $r = .31$) and Pz (random, $r = .30$; fixed, $r = .25$). The negative relation between P3 amplitude and RT was significant only at Fz in fixed ($r = .34$) and random ($r = .25$) conditions.

Correlations between P3 amplitude and RT efficiency (relative advantage in response to fixed target) were significant at Fz (random, $r = .31$; fixed, $r = .34$) but not at Pz (random, $r = .19$; fixed, $r = .07$). Larger amplitude P3s over Fz were measured in subjects with increased efficiency. This effect was not age dependent.

Significantly shorter P3 latencies (at Pz: fixed, $r = -.46$; random, $r = -.47$; at Fz: fixed, $r = -.46$; random, $r = -.46$; all $p < .01$) were evident in subjects with increased RT efficiency. Thus, as differences increased between RT to the fixed and random targets (i.e., the ability to predict and use local sequences improved), P3 latencies decreased in all conditions.

Finally, correlations were computed between derived measures of efficiency for RT and a similar measure computed for P3 amplitude. The covariation between these derived measures of efficiency was statistically reliable for the Fz ($r = .29$, $p < .05$) but not the Pz ($r = .05$, ns) ratio. Efficient RT (faster fixed RT compared to random RT) was associated with larger P3 amplitude to the random relative to the fixed target over Fz.

DISCUSSION

The primary purpose of this study was to determine if responses to novel or "*important*" (Donchin et al., 1986) targets shifted across the life span from control by immediate sequences to historical events. It was assumed that because younger subjects are still developing "schemata" (Perlmutter et al., 1987) or neural models to predict events, the composition and order of immediate events are critical and are the primary factors contributing to their P3 amplitude. Further, it was assumed that, with advancing age, schemata are fully developed and the primary factor controlling response, shifts to global or general principles (or use of the schema). These assumptions were tested with a procedure that compared P3 and RT to predictable and unpredictable sequences of rare events. The unique contribution of local and global factors could be determined across the life span because the infrequent targets had identical global probabilities but arrived in different (i.e., fixed vs. random) sequences. Memory of sequence for the fixed target was informative because its occurrence *could be* predicted. Recalling sequences of random targets contributed to the development of global probability estimates (Johnson & Donchin, 1982), but did not provide specific information about the occurrence of a target.

Multivariate modeling indicated that responses to fixed and random target sequences resulted in significantly different ERPs across the life span. The P3 to the random target was largest at all placements for the young and middle-aged subjects. Young and middle-aged subjects gained a greater advantage with the fixed (predictable) target by displaying significantly faster RTs. However, these effects were not observed in the elderly subjects. ERP waveforms and behavioral RTs to the fixed and random targets were not significantly influenced by target predictability in subjects over 60.

Failure among the elderly to discriminate between, or respond differently to, fixed and random targets suggested that they were not as sensitive as younger subjects to information contained in immediate or local sequences. Predictable information provided no advantage for the elderly in behavioral or neural efficiency. From these findings it can be reasoned that decisions and perceptions of elderly subjects are not governed primarily by local (i.e., fixed and random) sequences but rather by "historical" (i.e., global) events or by schemata (Perlmutter et al., 1987). This shift in strategy (Donchin et al., 1986) or perception across the life span may produce insensitivity to episodic or local changes. Events that do not conform to global expectations or schemata may be ignored. Because schemata among the elderly have been validated over a lifetime, it may be adaptive to ignore immediate or episodic perturbations to reduce cognitive load and, instead, operate with global and general models of the environment. However, poor memory for recent events may be one consequence of ignoring immediate events in favor of general models.

Compatible findings have generated different interpretations. For instance, Rabbit and Vyas (1980) argued that the elderly were unable to base expectations on long "immediate" sequences because they could not remember them. These findings were interpreted to suggest that the elderly suffer a deficit in "memory-driven selective attention" (p. 918). This is not inconsistent with the analysis we have proposed that immediate or recent sequences are not *preferred* by the elderly and may not be recalled because they are not encoded (and perhaps ignored). However, with sequential tree analysis (Remington, 1969), Ford, Pfefferbaum, Tinklenberg, and Kopell (1982) concluded that elderly subjects may be *more* sensitive than younger subjects (i.e., 22-year-olds) to certain features (change in alternations) of immediate or local information. Disagreement among studies may relate to the fact that Ford et al. tested very low-probability (10%) events. Results from other procedures indicate that it may be easier to update (i.e., attend to local events) schemata with extreme targets (Brown & Kulick, 1977). Furthermore, the sample of elderly in this study by Ford and colleagues was composed of accomplished individuals and the interactions between aging and lifetime accomplishments are not clear.

Our results suggest that expectation in younger subjects is influenced primarily by immediate events and with advancing age, new information is organized into schemata (Perlmutter et al., 1987) that may grow and strengthen over the life span (Baltes & Brim, 1984; Horn, 1982). However, future studies, modeling a variety of global probabilities, are needed to test these speculations.

The apparent transition across the life span in response to contemporary and historical factors was paralleled by changes in topographic distribution of the *memory-dependent* ERP. For the middle-aged subjects, targets were discriminated at all placements, characterized by large P3s to the random target and suppressed responses to the predictable target. The unique pattern of the young subjects was characterized by two features: (a) large P3s to both targets over Fz, C3, and C4; and (b) significant discrimination of the targets over Pz, where P3 was suppressed to the predictable target (similar to middle-aged pattern for all placements). For elderly subjects, differences between targets were not reliable, especially over Pz. This pattern is identical to that for an earlier study (Sandman et al., 1990) of different subjects instructed to count the targets rather than depress a key.

The topographic changes over the life span suggest a program of brain development that may reflect a shift in perceptual preference or strategy. The selective response over Pz in young subjects to the difference between fixed and random targets evolved into generalized discrimination of targets at all placements by middle age. With advancing age, by ERP response, the targets were not discriminated. Among the elderly, responses to predictable targets became disinhibited, diffuse, and undifferentiated at all placements. If this life-span pattern is reliable, it indicates that perceptual preferences change by response inhibition to predictable information that progresses from posterior (i.e., Pz) to frontal areas. Features of this pattern are consistent with Courchesne's (1978)

observation that with age, emergence of a frontal P3 may reflect development of sophisticated neurocognitive networks. Recent ERP studies (Segalowitz, Unsal, & Dywan, 1992) have confirmed delayed maturation of anterior (prefrontal) areas of the brain until late adolescence. Other investigators (Goodin et al., 1978a; Miller, Bashore, Farwell, & Donchin, 1987; Pfefferbaum et al., 1980b; Picton et al., 1984) have reported a shift in scalp distribution of P3 from posterior to anterior areas with advancing age that may be consistent with the topographical transition found in the current study.

The general slowing of RT and P3 across the life span is consistent with the interpretation that a major effect of aging on cognition may be decreased speed of information processing (Salthouse & Somberg, 1982). However, this interpretation cannot fully explain the failure of elderly subjects to gain an advantage (i.e., faster RT and shorter latency P3) with the predictable (fixed) target. Several attributes of information processing were equal for both targets (i.e., probability of target, response requirements). Increased RT and P3 latency and failure to gain an advantage with predictable information among the elderly support the argument that the elderly tend to ignore information contained in local sequences. The most reasonable explanations for these differences include decreased ability with age to predict the occurrence of a stimulus (Rabbit & Vyas, 1980), decreased memory with age (Craik, 1984), or a shift in preference for features (i.e., local to global) of information.

As expected (cf. Ford, Hink, et al., 1979; Marsh & Thompson, 1972; Marshall, Bashore, Miller, Coles, & Donchin, 1983; Pfefferbaum et al., 1984; Picton, Cerri, Champagne, Stuss, & Nelson, 1986), P3 *latency* and RT decreased significantly across the life span, but not *within* age groups (Ford, Duncan-Johnson, & Kopell, 1982; Pfefferbaum, Ford, Roth, & Kopell, 1980a, 1980b). Although P3 and RT latencies were significantly coupled, only 8% to 10% of the variance was explained. Linear, but especially quadratic, relations between age and P3 *amplitude* were significant at Fz (Brown, Marsh, Larue, 1983; Syndulko et al., 1982). This finding reflected slowing in brain response both early in development and then late in life. Specifically, P3 latency increased with age from pre-adolescence through adolescence and then again between age 60 and the late 80s. The effect of age on P3 latency was negligible between ages 20 and 60.

CONCLUSIONS

These results suggest that information processing in elderly subjects is governed by general principles and that local (immediate) perturbations in the environment are less likely to influence their response. Thus, in elderly subjects, disconfirming local events do not perturb expectations because existing models of the environment may be useful and resistant to change. This possibility is an alternative to the suggestion that elderly individuals are merely poor statistical

predictors of events because of declining memory (Rabbit & Vyas, 1980), and it proposes different strategies for analysis of age-related decline. One strategy is to explore the possibility that increased insensitivity to local events during aging is a manifestation of increased cautiousness (Salthouse, 1982; Strayer, Wickens, & Braune, 1987; Wallach & Kogan, 1961; Zuckerman, Eysenck, & Eysenck, 1978). Of course, loss of local sensitivity during aging may result in persistence of invalid global models and be expressed as an increase in rigidity (Schaie & Parhan, 1976). However, decisions based on valid global models may reflect wisdom.

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