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A psychophysiological investigation of the von Restorff paradigm in children

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ABSTRACT Ten 5th-grade children were asked to memorize series of words. In some of the series, a word was isolated by presenting it in larger font. Event-related brain potentials, elicited by each word were recorded.

The subjects showed an enhanced recall of the isolated words in comparison to non-isolated words matched for serial position (the von Restorff effect). The isolated words also elicited P300's of larger amplitude than the non-isolated words. Furthermore, isolated words which were subsequently recalled elicited larger P300's than did isolated words that were not recalled. Finally, the subjects showed an above-chance performance in a following 'size-recall' test.

The results are discussed in terms of a model of the von Restorff effect that emphasizes the special encoding of isolated items. Children show a large von Restorff effect because they do not make extensive use of elaborative rehearsal strategies that may override the effects of the special encoding processes.

Introduction

The relationship between the initial encoding of a word and its subsequent retrieval has been a central theme in the study of verbal memory. Several factors have been investigated, including the type and amount of processing required of the subject ('the levels-of-processing approach', Cermak and Craik, 1979; Craik and Lockhart, 1972), the relationship between the encoding context and the retrieval context ('the encoding specificity hypothesis', Tulving, 1979, 1983; Tulving and Osler, 1968), and the degree to which the uniqueness of features of an item at encoding influences its recall ('the distinctiveness hypothesis', Hunt and Mitchell, 1978, 1982).

In this paper we are focusing on the effects of distinctiveness on recall. The importance of the relative distinctiveness of an item in determining its subsequent recall has been recognized for a long time. Von Restorff (1933) showed that when an item in a list differs from the other items with respect to some characteristics (e.g. size, color, etc.), it is more likely to be recalled than other, homogeneous, items. She called these distinctive items 'isolates'. The enhanced recall of isolated items has been called the von Restorff, or isolation, effect.

In the von Restorff paradigm, isolation is defined in terms of deviation from the item's background; that is, deviation with respect to a standard feature common to all other items in the list. In the last two decades, a large body of research has shown that deviant items are associated with special psychophysiological responses. Several components of the Event-Related Brain Potential (ERP) appear to be sensitive to stimulus deviance. Considerable attention has been devoted to the effects of stimulus deviance on the P300 component (for a review of the eliciting conditions of this component, see Pritchard, 1981).

The P300, discovered by Sutton, Braren, Zubin and John (1965), is a positive component with a latency exceeding 300 ms, most prominent at the parietal electrode, and elicited by task relevant stimuli (Donchin, Ritter and McCallum, 1978). The amplitude of this component is inversely related to the subjective probability of the eliciting stimulus (Duncan-Johnson and Donchin, 1977; 1982). Donchin (1981; see also Donchin and Coles, 1988a, 1988b) suggested that the P300 may be a manifestation of processes that are invoked in association with the updating of schemas in working memory, and that the amplitude of the P300 should predict the subsequent recall

of the eliciting event. Whether this interpretation is valid or not, it remains true that the more distinctive an event, relative to the context in which it is embedded, the larger the P300 it elicits. Thus, if distinctiveness predicts recall and the P300 is a measure of distinctiveness, then there ought to be a relationship between P300 amplitude and subsequent recall.

Several investigators have reported data consistent with this prediction. For instance, Sanquist, Rohrbaugh, Syndulko and Lindsley (1980) observed that words that were later correctly classified at a recognition test elicited a larger P300 than did words that were not recognized. Similar results were reported by Neville, Kutas, Chesney and Schmidt (1986) and by Paller, McCarthy and Wood (1988). However, a somewhat more complex picture emerged from a series of studies on the relationship between the P300 and recall in the context of the von Restorff paradigm (for a review, see Fabiani, Karis and Donchin, 1986a). In the first of these studies, Karis, Fabiani and Donchin (1984) found that subsequently recalled isolated items elicited larger P300's at encoding than isolated items later not recalled, provided that the subjects did not use elaborative rehearsal strategies.[1] In other words, there was an interaction between P300 amplitude, subsequent recall, and the strategy the subjects used for establishing and maintaining their memories. These results were replicated in a study by Fabiani, Karis and Donchin (in press) in which rehearsal strategies were manipulated within subjects. In addition, Fabiani, Karis and Donchin (1986b) found that, when an incidental memory test is used to reduce individual differences in rehearsal strategies, the amplitude of P300 predicts recall for most subjects.

These data suggested a model of the von Restorff effect which takes into account both the early processing that occurs immediately after the presentation of a word, and the prolonged rehearsal that follows. According to this model, the distinctiveness of a word, at least to the extent that is manifested by the P300, operates to enhance the retrievability of the episodic trace that is established by the very presentation of the word. However, elaborative rehearsal strategies introduce new sources of variance in the determination of the retrievability of the traces by modifying these traces or by generating new ones. Thus, when retrieval is controlled by these elaborative strategies, the distinctiveness of a word (again to the extent that is reflected by the P300) no longer predicts the retrieval of the word. Therefore, this model predicts that, when subjects use rote rehearsal, the retrievability of the words is mostly determined by their initial encoding. When subjects use elaborative rehearsal, retrieval is based mostly on the subsequent elaboration rather than on the initial processing.

The purpose of the present study was to determine whether this model accounts for some findings concerning the isolation effect in children. Cimbalo, Nowak and Soderstrom (1981) reported that children have large von Restorff effects. We hypothesized that this may be due, at least in part, to the effect of rehearsal strategies. It is plausible that children may only be able to use rote rehearsal strategies (Bjorklund, 1985; Bjorklund and Bernholtz, 1986; Bjorklund and Muir, 1988; Ornstein and Naus, 1978), and that, therefore, they would show clear von Restorff effects and reduced individual differences in the relationship between P300 amplitude and subsequent recall. Therefore, we replicated the Karis *et al.* (1984) study with 5th-grade children as subjects.

Our prediction was, then, that children would show a large isolation effect and that most children tested would show a relationship between P300 amplitude and recall. In addition, we expected that the relationship between P300 and recall should be even more evident in children than it is in studies involving young adults. In fact, previous reports have shown that the amplitude of the P300 component may be larger in children than adults (Courchesne, 1977, 1983) appearing first in the parietal areas at about 4 years of age and in the frontal areas about 6–8 years of age (Chiarenza, Guareschi-Cazzullo, Roncaroni and Rho, 1979). Note, however, that the latency of P300 appears to be longer in children than young adults (Goodin, Squires, Henderson and Starr, 1978).

Method

Subjects

Ten 11-year-old children (5 females) participated in the study. They were all in 5th grade, and were recruited, with their parents' permission, from two elementary schools in sub-

[1] Elaborative rehearsal strategies are defined as attempts to organize the words in some fashion, mainly on the basis of their meaning (e.g. by forming sentences). In contrast, rote rehearsal involves repeating the words over and over without attempting to group them.

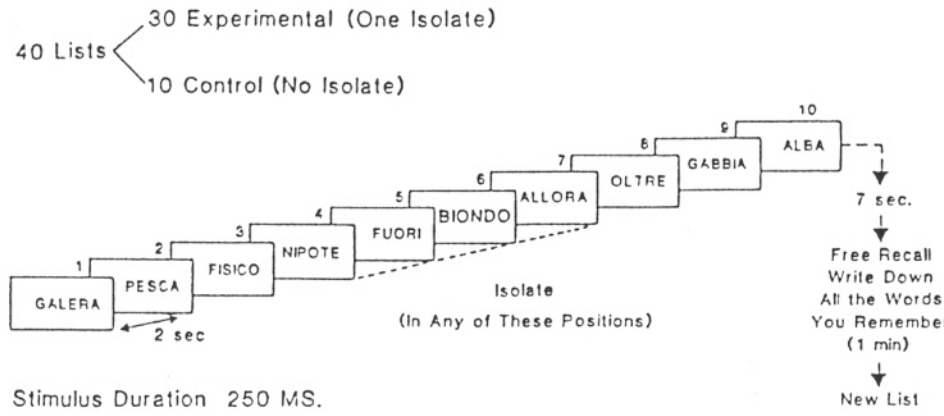

Figure 1 The experimental paradigm.

urban Milan, Italy. All of them had normal or corrected to normal vision.

Data collection

The electroencaphalogram (EEG) was recorded by means of Ag-AgCl Burden electrodes affixed along the midline of the scalp at frontal, central, and parietal sites (Fz, Cz, and Pz, 10–20 System, Jasper 1958). The subjects were grounded via an Ag-AgCl Burden electrode, affixed to the forehead. Electrodes of the same type were affixed above and below the right eye to record the electrooculogram, and on the mastoids. Linked mastoids were used as references. Electrode impedance did not exceed 5 Kohm. The EEG was amplified with Physio-Amp Marazza preamplifiers (time constant 8 sec, upper half-amplitude frequency 35 Hz, 6 dB/octave roll-off) and was digitized at the rate of 100 samples/sec, for a 1280 ms recording period starting 100 ms before stimulus presentation.

All aspects of experimental control and data collection were controlled by a PDP-11/23 computer system interfaced with a MINC data presentation and collection system. Eye movement artifacts were corrected off-line using a procedure described by Gratton, Coles and Donchin (1983).

Word lists

A master list composed of 400 Italian words with 3 to 6 letters was generated by selecting words from children's textbooks and from word frequency norms for the Italian language (Bartolini, Tagliavini and Zampolli, 1972). Two word lists were constructed from the master list by randomizing the order of the words. Each word list was presented to half of the subjects, and, within each word list, no word was ever repeated. The word lists were composed of 40 series of 10 words each. Thirty of the series contained one isolated item, in any position from 4 through 7 (experimental series). The isolation was achieved by writing the word in a larger size font.[2] The remaining 10 series did not contain any isolated item (control series). The subjects reported knowing the meaning of the words presented to them, and being able to read them easily, regardless of their size.

Procedure

Experimental apparatus. Subjects sat comfortably in a dimly illuminated room, facing a CRT screen located at a distance of 70 cm. The experimenters were in an adjacent room controlling the recording instruments and the presentation of the stimuli, and communicated with the subject via an intercom. The behavior of the subjects was monitored by means of a TV circuit.

Free recall task. The words in each of the 40 series were presented indvidually, and displayed to the subject for 250 ms, at a rate of one every two sec. At the end of each series the subjects were asked to write down all the words they could remember from that list, in any order that came to their minds (free recall). The experimental paradigm is illustrated in Figure 1. At the end of the session, subjects were questioned

[2] Each letter in an isolated word was included in a 16 × 16 mm rectangle. Each letter in a non-isolated word was included in a 8 × 8 mm rectangle. Previous data (Karis *et al.*, 1984) indicated that isolating words by presenting them in either a larger or smaller size font than the background produced similar results. Thus, in the present study, only the large size font was used to produce isolation.

about the strategies they used to memorize the words.

Size recall task. At the end of the experimental session the subjects were presented with a printed list that included all the isolated words and an equal number of non-isolated words coming from comparable positions (4 through 7) in the same series. Words in the printed list were presented in random order, and were all typed with the same font. Subjects were asked to identify which words had originally been presented in the large font and which ones had been presented in the standard font. This test was unexpected, and subjects were not instructed earlier in the experiment to pay particular attention to the size of the words.

Results

Rehearsal strategies

All the subjects reported having used rote rehearsal as their main strategy. In addition to using rote rehearsal, 4 subjects reported other strategies. Two of these 4 subjects (1 and 2) reported occasionally associating some of the words together. Subject 9 reported attempting to form sentences, and subject 10 reported associating words that rhymed. Thus, in general, the self-report confirmed our expectation that 11-year-old subjects would not make extensive use of elaborative rehearsal strategies.

Recall performance and the von Restorff effect

The recall performance in the free-recall task, the percent recall for isolated words, non-isolated words in position 4–7 from experimental and control series, as well as the difference between the percent recall for isolated and non-isolated words matched for position (the von Restorff Index, or VRI) are presented in Table 1.

The subjects recalled the isolated words better than the non-isolated words in comparable serial positions. $t(9) = 4.48$, $p < 0.01$. This effect was maintained when the recall of the isolates was separately compared with the recall of non-isolates coming from experimental series ($t(9) = 4.49$, $p < 0.01$), and from control series ($t(9) = 3.27$, $p < 0.01$). Finally, there was no significant difference in the percent recall of non-isolated words in position 4 to 7 from series that contained an isolate (experimental series) and series that did not (control series). $t(9) = -1.26$.

Table 1 Overall recall performance (P), percent recall for various word groups and von Restorff index (VRI).

Subject number	P	Isol.	NI(E)	NI(C)	NI(all)	VRI
01	41	36	23	23	23	13
02	62	70	44	42	43	27
03	41	73	23	20	22	51
04	47	66	33	32	33	33
05	32	50	16	12	15	35
06	36	20	16	15	16	4
07	45	43	39	40	39	4
08	47	50	23	37	27	23
09	48	39	36	50	40	−1
10	35	60	30	40	33	27
Mean	43.4	50.7	28.3	31.1	29.1	21.6
SE	2.4	5.3	3.0	4.1	3.2	5.2

P (overall recall performance) = % words recalled from all positions

Isol. = % isolated words recalled (pos. 4–7)

NI(E) = % non-isolated words recalled from experimental series (pos. 4–7)

NI(C) = % non-isolated words recalled from control series (pos. 4–7)

NI(all) = % non-isolated words recalled from all series (pos. 4–7)

VRI (von Restorff index) = % isolates recalled (pos. 4–7)—% non-isolates recalled (pos. 4–7)

The average free recall curve across the 10 subjects is shown in Figure 2. This figure reveals that 11-year-old subjects showed the standard serial position curve, with relatively better recall for words in the initial and final positions (primacy and recency effects), and depressed recall for words in intermediate positions. The recall of isolated words was quite close to that for words in the initial and final positions. Furthermore, similar serial position curves were obtained in experimental and control series.

Size recall analysis

The data of the size recall task are presented in Table 2.[3] The subjects were better than chance at remembering the size with which the words were originally presented (69.4% correct responses. $t(9) = 6.67$, $p < 0.001$, one-tailed). In

[3] Even though subjects were told that the printed list contained an equal number of words originally displayed in standard and large size, most subjects were biased toward responding 'standard' rather than 'large'. Therefore, as previously done by Fabiani *et al.* (in press) we used measures of accuracy based on the actual number of responses of each type emitted by the subjects. These measures are reported in Table 2.

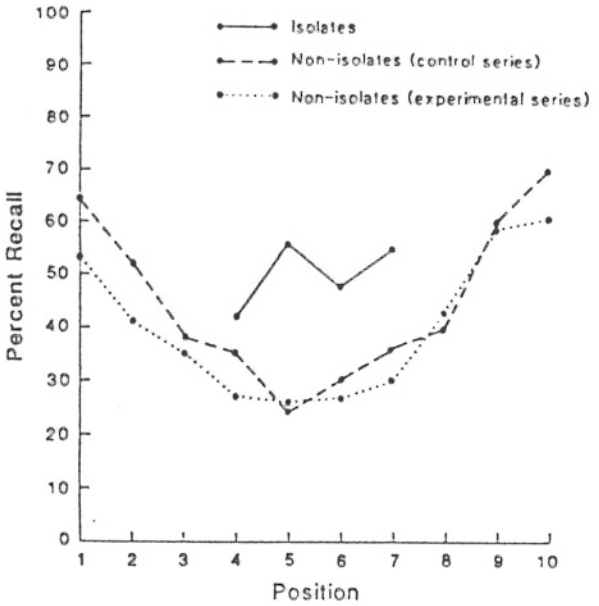

Figure 2 Average free recall curves for isolates (solid line), non-isolates from experimental series (dotted line) and non-isolates from control series (dashed line).

addition, subjects were more accurate in recalling the size of the isolates than in recalling the size of the non-isolates. The mean percent accuracy for isolates was 77.2, while for non-isolates it was 66.1 ($t(9) = 3.13$, $p < 0.01$, one-tailed). The VRI in the free recall was significantly correlated with the overall accuracy of the subject in the size recall ($r = 0.62$, $t(8) = 2.24$, $p < 0.05$, one-tailed). In other words, subjects who recalled more isolates than non-isolates in similar serial positions (high VRI scores) were more accurate in the size recall. Furthermore, the magnitude of the VRI in the free recall was also correlated with the magnitude of the difference in accuracy between the recall of the size of the isolates and the non-isolates ($r = 0.62$, $t(8) = 2.24$, $p < 0.05$, one-tailed).

Table 2 Results of the size recall task.

Subject number	% Correct	Isolates	Non-isolates	Difference
01	59	60	57	+ 3
02	73	85	68	+17
03	80	100	71	+29
04	60	62	59	+ 3
05	78	100	70	+30
06	58	67	56	+11
07	60	67	57	+10
08	78	77	79	− 2
09	70	70	70	0
10	78	84	74	+10
Mean	69.4	77.2	66.1	+11.1
SE	2.9	4.6	2.6	3.6

% Correct = % correct for all stimuli.

Isolates = % large size stimuli correctly identified over total number of large responses emitted.

Non-isolates = % regular size stimuli correctly identified over total number of regular responses emitted.

Difference = Difference in accuracy between large and regular responses (a positive number indicates an advantage for the isolates).

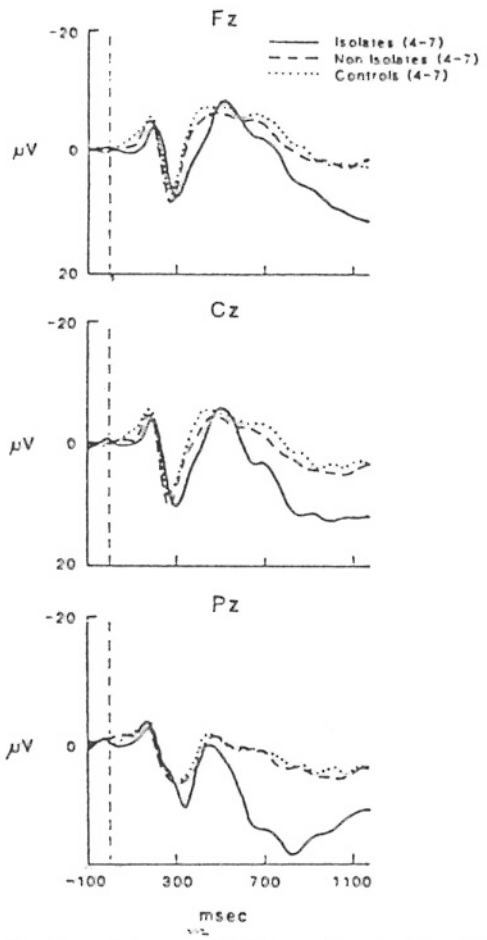

Figure 3 Grand averages ERP waveforms at Fz, Cz, and Pz for isolates (solid line), non-isolates from experimental series (dashed line) and non-isolates from control series (dotted line).

ERP analyses

Effects of word type. Grand average waveforms for isolated words, and for non-isolated words from experimental and control series (position 4–7) from Fz, Cz, and Pz are presented in Figure 3. The main difference between the waveforms for isolates and non-isolates is in a positive component, with an average latency of approximately 800 ms. Since this component is maximal

at Pz and larger for the isolated words, it can be classified as the P300 component. Note that the latency of this component appears to be longer than that recorded in the Karis *et al.* (1984) study (520 ms). However, 11-year-old subjects usually have a longer P300 latency than young adults (Goodin *et al.*, 1978). Two other components appear in the waveforms, an early positive component with a latency of about 300 ms (visual P200), and a negativity preceding the P300 (N200). Neither of these components, however, appears to distinguish between isolates and non-isolates.

These visual impressions were confirmed by statistical analyses. The amplitude of P300 was assessed by measuring the mean amplitude in a latency window from 600 to 1180 ms after stimulus presentation. The amplitude of P300 was positive at all electrodes and largest at Pz ($F(2,18) = 20.54$, $p < 0.001$). Therefore, all the remaining analyses of the P300 were performed on amplitude measures taken at Pz. The P300 elicited by the isolated words was significantly larger than that elicited by the non-isolated words (14.66 microvolts for isolated words, 3.75 microvolts for non-isolated words from experimental series and 2.94 microvolts for non-isolated words from control series), $F(2,18) = 16.21$, $p < 0.001$. Note that the amplitude of P300 for non-isolated words from experimental and control series did not differ significantly ($t(9) = 0.26$).

The amplitude of the P200 component was quantified by computing the mean amplitude in a latency window between 250 and 350 ms after stimulus presentation. The amplitude of this component did not differ significantly across the midline electrodes ($F(2,18) = 2.20$) and was not affected by word type ($F(2,18) = 1.50$).

The amplitude of N200 was quantified by measuring the mean amplitude in a latency window between 350 and 600 ms. The amplitude of N200 was maximum at Fz, $F(2,18) = 20.54$, $p < 0.001$. This component was not significantly different for words written in different size fonts ($F(2,18) = 1.21$).

Memory effects. Grand average waveforms at Fz, Cz, and Pz for isolated words sorted on the basis of subsequent recall are presented in Figure 4.

The amplitudes of P300 for isolated words subsequently recalled or not recalled and the magnitude of the 'memory effect' are presented in Table 3.

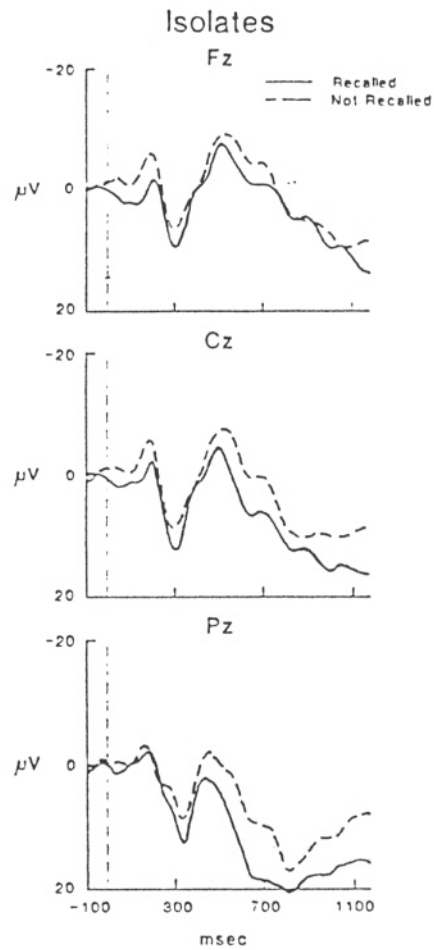

Figure 4 Grand average ERP waveforms at Fz, Cz, and Pz for isolates subsequently recalled (solid line) and not recalled (dashed line).

The average P300 amplitude for isolated words subsequently recalled was 17.91 microvolts, and 11.38 microvolts for isolates not recalled ($t(9) = 3.94$, $p < 0.01$).

Analysis of the P200 did not reveal any significant difference between the amplitude of this component elicited by isolates subsequently recalled or not recalled ($t(9) = 1.68$). The same was true for the N200 ($t(9) = 0.49$).

Discussion

Fifth-grade children's self-reports of rehearsal strategies showed less pronounced individual differences in the use of rehearsal strategies than those of adults. Furthermore, the children in this study exhibited a pronounced isolation effect, and a large difference between the amplitudes of

Table 3 P300 amplitude for isolates recalled and not recalled (microvolts).

Subject number	Isolates		
	Recalled	Not recalled	Memory effect*
01	7.37	2.86	4.51
02	21.53	12.90	8.63
03	12.37	11.38	0.99
04	14.71	1.03	13.68
05	32.35	28.06	4.29
06	16.58	9.54	7.04
07	10.42	−0.91	11.33
08	12.92	9.38	3.54
09	28.34	14.86	13.48
10	22.52	24.71	−2.19
Means	17.91	11.38	6.53
SE	2.55	3.00	1.67

*The memory effect is calculated by subtracting the amplitude of isolates not recalled from the amplitude of isolates recalled.

the P300's elicited by those isolated words that were subsequently recalled and those that were not. These results suggest that the encoding processes immediately following stimulus presentation influenced subsequent recall performance in this group.

These data support our model of the von Restorff effect. We predicted that children would show little elaborative rehearsal, and that therefore their recall performance would be based primarily on the nature of the traces created by the initial presentation of the stimulus. The model we proposed assumes that retrieval depends on processes that may take place in two different phases of the study period. In the first phase, which is related to the initial encoding of the word's features, the distinctive size feature assumes primary importance for the isolates, as this is the feature that makes these words stand out in comparison to the background. The isolated words also elicit large P300's, whose variance is hypothesized to index the degree to which the deviant feature was processed, and the memory representation updated. In other words, we are assuming that the amplitude of the P300 is a measure of the distinctiveness of the eliciting event. The updating process, triggered by distinctive events, facilitates the subsequent recall of the isolated words, presumably because it provides useful retrieval cues.

Karis *et al.* (1984) and Fabiani *et al.* (in press) observed a strong negative correlation between measures of overall memory performance and of the magnitude of the isolation effect. This negative correlation was attributed to the role of elaborative rehearsal strategies that produce an overall enhancement in recall performance, but reduce the magnitude of the isolation effects. No such correlation was observed in the present experiment (the correlation was −0.08 and was not significant). The absence of this correlation is consistent with the fact that most subjects in this study did not use elaborative rehearsal strategies.

We derived our prediction of a relationship between the amplitude of P300 and subsequent recall from the assumption that this component may manifest the 'updating', or 'refreshing' of the memory representation of the eliciting event. In this respect, it is noteworthy that, in the Karis *et al.* study, all isolated words elicited, besides a large P300, also a large N200.[4] However, the amplitude of the N200 did not predict recall. That is, subsequently recalled and unrecalled words elicited N200's of similar amplitudes. Thus, it is not sufficient that the information processing system 'notices' the isolation (as indicated by a large N200): some further operation is required, that is signaled by an enhanced P300 amplitude.

We hypothesize that the processing operation manifested by the P300 marks in some fashion (attaches a 'flag' so to speak) to the memory representations of the event. This 'flag' signals the deviation of one (or more) of the stimulus features from the standard value set by the context. The size-recall data provide some support for this hypothesis, as the information about the size with which the word was originally presented is preserved. In fact, in the present study, the children's performance in the size-recall task was significantly above chance. A similar finding was reported by Fabiani *et al.* (in press), who also found that, when subjects used elaborative rather than rote rehearsal strategies, they did not readily recall the size of the words.

In both the Fabiani *et al.* (in press) and the present study, subjects were more accurate when they identified a word as being originally presented in large rather than standard size. This finding suggests that the subject's processing in

[4] This finding was not replicated in the present study. However, in this study, all isolated words (either recalled or not-recalled) elicited a larger P300 than non-isolated words.

the size-recall task involves checking whether or not the memory representation of the word is 'flagged' for the deviant size. In other words, subjects will respond 'standard' unless a flag is detected, in which case they will respond 'large'. So, although many large stimuli may be missed, when subjects respond large they are likely to be correct. The probability of losing the flag would be higher when elaborative rehearsal strategies are used, as it is not used as a retrieval cue in the free recall. This model of the size-recall task has some similarities with models of memory-search tasks (Sternberg, 1969) and visual-search tasks (Neisser, 1963; see also Treisman and Gormican, 1988). In all these tasks, the *presence* of a target feature is easier to detect than its *absence*.

Several models of the von Restorff effect have been proposed. They can be categorized into two broad classes: models that stress the influence of special encoding processes, such as those triggered by the 'surprise' value of the stimulus (e.g. Green, 1956, 1958a, 1958b), and models that claim that the increased recall of the isolates is mainly due to increased rehearsal (e.g. Cooper and Pantle, 1967; Rundus, 1971). A crucial assumption of the models invoking augmented rehearsal of the isolates is that, as the total time available for rehearsal is fixed, the recall of the non-isolates from series containing an isolate (experimental series) will be inhibited with respect to the recall of the non-isolates coming from control series, because more time is devoted to rehearsing the isolates than non-isolates in the experimental series (total time hypothesis). This hypothesis did not gain support in the present study, in the Karis *et al.* (1984) and Fabiani *et al.* (in press) studies, as well as in a number of other experiments (e.g. Bird, 1980; Bruce and Gaines, 1976). Thus it appears that, at least for free recall memory tasks, there is more to the processing of the isolates than increased processing time. Note that this does not imply that an increased rehearsal is *never* a consequence of the isolation, or that, if increased rehearsal does occur, it will not have any effect on the recall of the isolates or of the background items.[5] It is quite possible that, especially when the isolated event has an arousing character (such as a picture of a nude, or a loud shout—see Detterman, 1975; Detterman and Ellis, 1972; Ellis, Detterman, Runcie, McCarver and Craig, 1971) it may lead to increased processing, and thus to a decrement in the recall of the surrounding items. However, given that when rehearsal time is equated (Gibbons and Leicht, 1970) the isolates are still recalled better than the non-isolates, there must be some differential processing, beyond the effect of increased rehearsal time, that facilitates the recall of the isolates.

In summary, the data from the present experiment indicate that the children we tested in this study behave in a manner consistent with the model of the von Restorff phenomenon developed by Karis *et al.* (1984) and Fabiani *et al.* (1986) using young adults as subjects. Since children do not rely spontaneously on elaborate rehearsal strategies, their recall performance is largely dependent on the first phase identified by the model (initial processing of the word). For this reason they show an enhanced isolation effect and a clear relationship between P300 and recall. The reduced number of factors influencing memory performance in young children suggests that they may be ideal subjects to study the relationship between encoding processes and subsequent memory retrieval.

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[5] Three of the subjects in the present study may have used differential rehearsal in addition to differential encoding for the isolated items. These are subjects for whom the recall of the non-isolates in the experimental lists appears to be inhibited (see Table 1, subjects 8–10).