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LA THÈSE A ÉTÉ
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THE ELECTRODERMAL ORIENTING RESPONSE AND MEMORY:
AN ANALYSIS OF AGE DIFFERENCES IN PICTURE RECALL

Louise M.. A. Plouffe

Thesis presented to the School of Graduate Studies of
the University of Ottawa as partial fulfilment of the
requirements for the degree of Doctor of Philosophy.

Ottawa, Canada, 1983

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ABSTRACT

The Electrodermal orienting response and memory:

An analysis of age differences in picture recall

Information-processing models of orienting response (OR) elicitation (Ohman, 1979) and habituation (Wagner, 1976) were applied to problems in human memory. Specifically, the research attempted to determine whether age differences in picture recall were related to differences in cognitive effort expended in encoding the pictures, as indexed by the electrodermal OR. Within this framework, it was also proposed that pictures with low frequency, unusual names would elicit more frequent and larger magnitude ORs and be better recalled than pictures with high-frequency, common names. A further goal was to explore the priming effects of recall on long-term habituation of the OR.

The experiment consisted of a study phase, a delayed test of free recall, a habituation training session and a test of recognition memory. In the study phase, thirty young (17-25) and elderly (60-88) women were shown a mixed series of high and low frequency pictures while electrodermal activity was recorded. Free recall was tested once, 30 min later. In the

habituation session, subjects received 10 repetitions of a recalled, not-recalled or new (not previously shown) picture. In the recognition memory test, pictures shown in the study phase were presented with an equal number of distractors.

Young subjects recalled more pictures than the elderly and both groups recalled more pictures with high-frequency names. Young and older subjects displayed more frequent and larger skin conductance responses to recalled pictures, especially to recalled low-frequency pictures. Older women, however, displayed consistently smaller electrodermal responses than the young. The overall age differences in recall and skin conductance were largely attributable to a decline displayed by women aged 71-88. Stimulus priming effects were observed on the first trial of the habituation series, where not-recalled pictures evoked smaller responses than pictures not previously shown. There were no age differences in habituation across trials.

In general, the results indicated that the electrodermal OR is functionally related to recall and that the age decline in recall may be attributed to reduced cognitive effort in the elderly. It appeared also that the OR plays a role in the encoding of low frequency, but not high frequency items. It was concluded from the habituation phase that stimulus priming is mediated by recognition rather than by

recall processes in memory and that these processes remain similar across the adult life-span.

Louise M. A. Plouffe, Doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, 1983, i-171 p.

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CURRICULUM STUDIORUM

Louise M. A. Plouffe was born on December 16, 1952 in Noranda, Quebec. She obtained a B.A. (Conc. Religious Studies) in 1974 and an M.A. (Psychology) in 1977, both from the University of Ottawa. Her doctoral studies were supported by the Ontario Ministry of Colleges and Universities (Ontario Graduate Scholarship), the University of Ottawa (Merit Scholarship) and the Social Sciences and Humanities Research Council of Canada (Doctoral Fellowship).

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INTRODUCTION

This research was designed to investigate the role of the electrodermal orienting response (OR) in picture recall for young and elderly adults in the context of Ohman's (1979) information-processing model of the orienting response (OR).

The central question concerned age differences in encoding processes. Recent views of memory have emphasized the role of attention and cognitive effort in memory; according to this perspective, encoding operations that demand a considerable amount of attention, or cognitive effort, lead to superior retention. Accordingly, memory failure in the elderly is attributed to an age-related reduction in the capacity to engage in effortful encoding. Because it incorporates the same constructs of attention and effort, Ohman's (1979) model of the OR provided a convenient framework for exploring age differences in encoding. Specifically, the model suggested that the electrodermal component of the OR would be sensitive to differential encoding in young and older adults. It was thus expected that OR elicitation would be positively associated with recall performance in both age groups, but that poorer recall in the elderly would correspond to reduced OR elicitation to stimuli.

The second question pertained to the influence of picture novelty in OR elicitation and recall. In studies involving the presentation of mixed lists of words which occur with a high or a low frequency in printed English, superior recall for low frequency words has been demonstrated. These effects are consistent with Ohman's model of the OR and it was anticipated that word count would display a similar influence in the encoding of pictures with high and low frequency names. More importantly, the mixture of high and low frequency items was intended to provide a wide variability in skin conductance responses which would facilitate discrimination between groups. This manipulation would confirm the appropriateness of the electrodermal response as a measure of encoding differences between the young and the elderly.

A third goal was to determine the effects of prior encoding on long-term habituation. Habituation of the OR is generally regarded as an indication of memory for a stimulus. It has been further asserted (Wagner, 1976) that the availability of a trace in memory is determined by the degree of processing previously received by the stimulus. On the assumption that pictures which can be recalled have received greater processing than pictures which have not been recalled, it was predicted that recalled pictures would elicit smaller ORs and show greater habituation than pictures that had not been recalled. Furthermore, it was possible to examine age differences in the availability of an encoded stimulus by means of this manipulation.

In the first chapter, the theoretical and experimental literature which provided the rationale for the study is reviewed. Attention is drawn to the heuristic value of information-processing models of the OR in the explication of the problems addressed. The chapter concludes with a statement of the experimental hypotheses:

The second chapter describes the experimental method used to test these predictions. Details concerning the participants, instrumentation and procedures are provided.

In chapters three and four, the results are presented and interpreted in relation to the hypotheses and the theoretical implications of the findings are discussed.

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REVIEW OF THE LITERATURE

This chapter begins with a review of the research conducted mainly within the last twenty years concerning age differences in human memory. Explanations for memory loss in the elderly, which focus on storage, retrieval and encoding operations, are presented and the proposal that memory decline is due to attentional deficits in old age is described. Studies on the electrodermal correlates of learning and memory are then reviewed, and, in the following section, the relationship between electrodermal activity and memory is discussed in the context of the models of orienting response (OR) elicitation (Sokolov, 1960, 1963, 1969; Ohman, 1979) and habituation (Wagner, 1976). The effects of printed word frequency on memory for pictures and words are discussed next. The chapter concludes with a general summary of the problem and a statement of the research hypotheses.

Age differences in memory: An overview

D. O. Hebb, aged 82, and B. F. Skinner, aged 80, currently have more in common than an associationistic view of mind: in recent addresses to professional audiences, both Hebb (1981) and Skinner (1983) have acknowledged that their intellectual abilities have eroded with age. Their comp-

2
laints of slower comprehension and poorer retention are typical among elderly adults; indeed, a close correspondence has been reported between self-assessed and actual decline in memory abilities (Zelinski, Gilewski, & Thompson, 1980).

Some aspects of memory functioning are more affected than others by the aging process. Tasks measuring long-term retention of new information, that is, secondary memory processes, display a larger age-related loss than tasks which assess short-term retention, or what is known as primary memory operations (cf reviews by Botwinick, 1978, and Craik, 1977). Age differences in secondary memory favouring the young have been reported for various types of verbal materials, including serial word lists (Craik, 1968; Laurence, 1967), sentences (Whitbourne & Slevin, 1978), and television programs (Cavanaugh, 1983), as well as for non-verbal materials such as digits (Craik, 1968; Drachman & Leavitt, 1972), line-drawings (Harwood & Naylor, 1969), faces (Smith & Winograd, 1978), film sequences (Farrimond, 1968) and geometric designs (Adamowicz, 1978). The extent of memory impairment is positively (e.g., Craik & Masani, 1967, 1969) or negatively (e.g., Howell, 1972) related to the degree of meaningfulness and familiarity of the materials employed, although, with rare exceptions (e.g., Barratt & Wright, 1981), the elderly are always disadvantaged.

Age differences in memory for pictures

Age differences in memory for pictures have been established with a variety of methods and materials. In the eleven studies examined, the pictorial material consisted of line drawings or photographs of objects, photographs of faces, and, in one study, a short film sequence. Recall and/or recognition memory was assessed and, in four reports, memory for pictures and words was compared.

In studies of immediate and delayed free recall, a consistent age-related decline in performance has been observed. Laurence (1966) presented a series of 16 line drawings of common objects in repeated learning trials to young and aged subjects. Each presentation was followed by a test of free recall. For the older group, recall performance improved more slowly across trials, although, by the final trial, older adults recalled as many pictures as the young.

Farrimond (1968) measured single-trial free recall of scenes from a short film sequence for subjects ranging in age from 23 to 79 years. Fewer scenes were recalled by individuals over 50, but statistical tests for the age comparisons were not reported.

In an experiment described by Harwood & Naylor (1969), free recall of 16 line drawings was tested 4 weeks after learning had been equated for young and aged samples. An

age-related decline in performance was observed, with elderly and young subjects recalling 40% and 54% of the items originally learned.

In the past, all but one investigation of picture recognition have used an absolute-judgment procedure in which a list of target items was presented first, followed by a set of target and distractor items. In the single study using a continuous recognition paradigm, Ferris, Crook, Clark, McCarthy & Rae (1980) presented a long list of items, with some pictures shown only once (new) and others shown more than once (old). In some recognition studies, only the proportion of correct responses is reported; the omission of false alarm data makes interpretation of age differences difficult, since recognition accuracy is confounded with response bias.

Botwinick & Storandt (1974) failed to demonstrate age differences in the proportion of correct responses for a list of 4 familiar pictures. This low level of task difficulty could account for the absence of an age effect on recognition performance. Rabinowitz, Ackerman, & Craik (cited in Craik & Byrd, 1982) similarly failed to find age differences in the proportion of hits for a target list of 16 pictures. In this case, however, recognition scores may have been influenced by an interpolated recall test. Harwood & Naylor (1969) also assessed recognition after recall in the

same sample, yet slight differences favouring young subjects were obtained.

Age group comparisons of error scores (misses and false alarms) were reported by Howell (1972) for meaningless pictures, reproductions from a 1908 Sears-Roebuck catalogue and photographs of common objects. Older subjects made more errors in the recognition of the meaningless material and pictures of common objects; however, recognition performance for the catalogue pictures was equivalent between age groups. In the Ferris et al (1980) continuous recognition experiment for pictures of human faces, elderly subjects made more false alarms and had poorer recognition accuracy (d'). This pattern of higher false alarm rates and lower d' scores corroborated the earlier findings of Smith & Winograd (1978). Thus, it appears that recognition memory for pictures declines to some extent with advancing age.

Recall for pictures and words has been compared in four studies. All of the studies revealed an age-related decline for both types of stimuli. With the exception of one report (Winograd & Simon, 1980), these investigations demonstrated superior recall for pictures in both young and aged groups (Craik & Byrd, 1982; Keitz & Gounard, 1976; Winograd, Smith & Simon, 1982). Overall, it appears that the picture superiority effect in memory (e.g., Paivio, 1971) is maintained in old age.

To summarize, memory for pictures has quite consistently been found to decrease with advancing age. The magnitude of the decline is, however, somewhat less than for verbal materials.

The locus of memory deficits in old age

Woodworth's (1938) original tripartite classification of memory operations into learning, retaining and remembering has been translated with little change in substantive meaning into the contemporary information-processing terminology as encoding, storage and retrieval operations (e.g., Atkinson & Shiffrin, 1968). Researchers have attempted to explain the phenomenon of forgetting generally, and increased forgetting in old age specifically, in terms of deficits in one or more of these processes. Prior to the emergence of information-processing models of cognition, memory loss in older adults was attributed to increased susceptibility to associative interference among stored verbal S-R bonds. This view was replaced in the 1960s with the hypothesis that deficits in the retrieval of stored material were responsible for forgetting in old age. Evidence that the elderly also exhibit poorer learning generated experiments designed to determine whether the primary deficit was one of encoding or retrieval. In recent years, the interdependency of retrieval and encoding operations has been acknowledged and attempts have been made to identify possible age-related changes

which lead to impairments at both the input and output phases of memory functioning. Because the evolution of research hypotheses in the area of aging and memory has been chronicled by several reviewers (Craik, 1977; Hartley, Harker & Walsh, 1980; Salthouse, 1982; Smith, 1980), only the highlights of this literature are discussed here, principally to develop a rationale for the proposal that a general reduction in information-processing capacity, or, more simply, in "mental energy" (Craik & Byrd, 1982) is the primary cause of memory decline in old age.

Storage deficit hypothesis.

Poorer performance of older adults in paired-associate (PA) retention led to the suggestion that vulnerability to interference increases with age (Kay, 1959; Welford, 1958). It was assumed that verbal bonds acquired during a lifetime somehow interfered with the maintenance of new associations, possibly by weakening the associative strength of to-be-remembered word pairs. However, Jerome (1959) and later, Kausler (1970) criticized the early PA research on the grounds that initial learning was not equated between age groups. Studies which have equated the level of learning have typically yielded minimal age differences in both proactive and retroactive interference (cf Arenberg & Tcha-bo-Robertson, 1977; Kausler, 1970; Salthouse, 1982; Winocur, 1982).

The hypothesis of increased susceptibility to interference became less attractive on theoretical grounds as well. Kausler (1970) reasoned that this hypothesis would predict greater vulnerability of young adults to proactive interference, since presumably, the young would acquire stronger associative bonds to the first (interfering) PA list. Yet another difficulty lay in the absence of a unitary theory of interference. Depending upon the researcher's perspective, increased interference could be seen as arising from an unlearning of associations in storage (Melton, 1963) or from response competition during retrieval (Postman & Stark, 1969).

Interference theory has thus not provided a satisfactory account of age differences in human memory. Measures of single list learning (as opposed to PA learning) have similarly not revealed storage differences between young and aged adults. After reviewing experiments which measured retention at varying test intervals, rate of forgetting and cumulative learning, Salthouse (1982) concluded that "we can be fairly confident that age differences in the storage stage of memory are slight to non-existent" (p. 141).

The retrieval deficit hypothesis.

With the emergence of information-processing models in cognition and memory, interference theory was superseded by the notion of retrieval failure to account for forgetting;

the idea was that information was permanently stored in long-term memory but failures could occur in the search and recovery of stored representations (Tulving & Pearlstone, 1966).

Among the experimental paradigms listed by Smith (1980) which have been used to assess the hypothesis that retrieval processes become less efficient with age, the most common involve comparisons between free recall and either recognition or cued recall. Free recall is thought to make maximum demands on retrieval whereas recognition memory and cued recall involve little or no retrieval (e.g., McCormack, 1972; Mandler, 1980).

In an influential study, Schonfield & Robertson (1966) presented a list of 24 words to subjects ranging in age from 20 to 75 years. An independent-groups design was used to test recall and recognition memory. The results indicated an age-related decline in recall scores, but no age differences were observed in the proportion of items correctly recognized. The authors interpreted these findings as an indication that the elderly encoded the words as well as the young but could not retrieve them as efficiently.

The Schonfield & Robertson report generated many more experiments involving age comparisons in recognition memory performance. Most studies, however, do show age differences in recognition as well as in recall, thus weakening support

for the notion that age deficits occur primarily at the retrieval stage. Salthouse (1982) counted 21 out of 29 reports in which recognition scores favouring the young were found. In a recent replication of the Schonfield & Robertson experiment, White & Cunningham (1982) demonstrated age-related decrements on both recall and recognition tests.

Notwithstanding the prevailing evidence of age differences in recognition memory, the view that recognition is a measure of encoding unconfounded by retrieval (Kintsch, 1970; McCormack, 1972) has been challenged by many researchers (Brown, 1976; Craik, 1979; Flexser & Tulving, 1978; Mandler, 1980; Tulving & Thompson, 1973). Since the nature of the retrieval process involved in recognition remains an unsettled issue (McCormack, 1981), it can only be affirmed that the retrieval operations involved in recognition memory are less vulnerable to the aging process than are the operations required for successful recall.

Comparison of cued and free recall performance is the second most common method used to investigate age differences in retrieval. Drachman & Leavitt (1972) tested young and elderly subjects under a standard free recall and a cued recall condition in which the first letter of each word in the learned list served as a test cue. Both age groups benefited equally from the provision of cues at recall. Laurence

(1967) and Hultsch (1975) used word categories as cues; in these experiments, the performance of the elderly was disproportionately enhanced under the cued recall conditions.

Smith (1977) attempted to resolve the discrepancies between the single letter and category cue findings by comparing the effectiveness of both types of cues. First-letter cues did not improve recall for either young or older subjects, but category cues disproportionately increased recall scores for the elderly. Smith concluded that semantic cues provided better access to stored words than did structural cues because word meaning was more likely to have been encoded during learning than structural features of the words.

The idea that a retrieval cue is effective only if it has been originally encoded is essentially the principle of encoding specificity enunciated by Tulving & Thompson (1973). According to this principle, learning involves the formulation of effective retrieval plans while remembering involves the implementation of these plans. Since retrieval cannot be assessed independently of encoding, deficits displayed by older adults may reflect ineffective encoding rather than faulty retrieval alone. For this reason, several reviewers have judged that studies claiming to show a retrieval deficit in old age yield, at best, ambiguous results (Botwinick, 1978; Burke & Light, 1981; Hartley et al, 1980; Smith, 1980; Salthouse, 1982).

Buschke (1974) provided evidence of a retrieval deficit in the aged which could be more clearly distinguished from inadequate encoding. In this experiment, subjects repeatedly recalled a word list presented for study once. The finding that older adults were less consistent than the young in the pool of items recalled from trial to trial suggested that they had encoded the words but could not retrieve them efficiently.

The encoding deficit hypothesis.

Potential age-related deficiencies in the acquisition of information have been examined by manipulating learning instructions known to have differential effects on retention. The effects of organization, verbal and visual mnemonics and processing depth are considered here.

Organization refers to the imposition of structure, or the establishment of a relation among items presented for learning. The extent to which subjects spontaneously organize information has been determined either by varying the degree of inherent structure among list items or by measuring the amount of subjective organization revealed in repeated recall trials. The relative benefits of instructions to organize have also been measured.

Older adults tend to be less effective in imposing structure on a list presented for learning. Craik & Masani (1967)

and Craik (1968) observed larger age decrements in recall of verbal material amenable to organization, while Denney (1974) reported that older adults displayed less clustering of words from the same category in their recall protocols. Studies measuring repetitions in the order of items on successive recall trials have yielded less consistent results, with some authors (e.g., Laurence, 1966) indicating no age differences and others reporting less subjective organization among the elderly (Hultsch, 1974; Smith, 1980). The lack of agreement among these studies may be attributed to the use of different measures of subjective organization.

Laurence (1967) and Smith (1977) gave subjects a list of categories from which the words to be learned were drawn prior to learning. In the first experiment, older subjects did not benefit from the category information, but in the second study, provision of word categories eliminated age differences in free recall performance.

In yet another type of experimental manipulation, Hultsch (1971) instructed one group of young and elderly subjects to sort words into categories before testing recall; a second group inspected the words, but did not do the sorting task. The sorting condition improved recall for the elderly relative to the inspection condition. In an earlier study, Hultsch (1969) compared the effects of specific organizational instructions ("arrange the words in alphabetical ord-

er") and non-specific instructions ("try to organize"). Only older adults with poor verbal skills benefited disproportionately from the the specific organizational instructions.

The use of verbal mnemonics and relational imagery in paired associate learning has been examined in adults of different ages. Although older people typically report less frequent use of mediational techniques in learning new information (Hulicka & Grossman, 1967; Hulicka, Sterns & Grossman, 1967; Rowe & Schnore, 1971), instructions to use mediators have attenuated age differences in memory.

Hulicka & Grossman (1967) presented a list of paired associates to young and elderly adults under one of four conditions: 1) subjects were asked to form an image that included both items in each pair; 2) the experimenter provided a word linking the item and instructed the subject to form an image that included the given word and the pair; 3) a linking word was given without instructions to generate an image; 4) no mediator was provided. Both the imaging and word-alone mediational conditions improved recall for the elderly relative to the no-instruction condition. Comparable effects were reported by Canestrari (1968) and by Treat & Reese (1976).

Robertson-Tchabo, Hausman & Arenberg (1976) trained one group of elderly subjects to learn a word list using the method of loci, a mnemonic device which involves association

of material to-be-learned with objects in a familiar location. The remaining subjects learned the list under standard conditions. The trained group recalled more words than the control group on a test of immediate recall; however, on the following day, the trained subjects did not use the mnemonic to recall the list unless instructed to do so.

In summary, it is quite clear that older adults do not engage in organizational or mediational strategies which enhance retention of new information. When induced to use these strategies, the elderly demonstrate an improvement in recall performance, although age differences typically remain.

The levels-of-processing framework proposed by Fergus Craik and colleagues (Craik & Lockhart, 1972; Craik & Tulving, 1975) has also been applied to the study of age differences in memory. According to this perspective, older adults exhibit poorer retention because they do not process information as deeply as the young. White (cited in Craik, 1977) guided the processing depth of a word list by requiring subjects to make structural, phonemic or semantic decisions. Comparison of recall performance following a deep, semantic processing task or a standard learning task revealed considerable benefits of semantic processing for the young subjects but not for the elderly. On a subsequent test of recognition memory, however, age differences in re-

tention were eliminated after the semantic task. Craik & Simon (1980) later replicated these results, using a between-groups design for recall and recognition.

Research from other laboratories has confirmed the semantic processing deficit in recall, although, contrary to the findings of Craik and his co-workers, age differences in recognition memory following semantic processing have also been found (Eysenck, 1974; Mason, 1979; Simon, Dixon, Nowak, & Hultsch, 1982; Yokubynas, 1979). Thus, it appears that older persons either cannot or can, but do not, engage in the deep, semantic levels of processing which enhance retention.

Memory loss and processing capacity

The age-related decline in memory functioning has been attributed to a general psychobiological degeneration, although specific brain-behaviour relationships have been difficult to establish (Adams, 1980). Nevertheless, it is known that neurological changes characteristic of old age are concentrated in the frontal and temporal regions of the cortex (Bondareff, 1980; Petit, 1982). Neuropathology in these areas is associated with deficits in the direction and maintenance of attention (e.g., Kinsbourne, 1980) and in the consolidation of memory traces (e.g., Milner, 1970). In light of this evidence as well as of reported parallels in the me-

memory performance of elderly adults and of brain-lesioned patients, a number of investigators have proposed a neurological basis for memory decline in old age (Albert & Kaplan, 1980; Kinsbourne, 1980; Parkinson, 1982; Squire, 1980; Winocur, 1982).

At the behavioural level, changes in the senescent nervous system may be reflected in a general decrease in mental capacity. This decrease would be manifested particularly in cognitive tasks which demand a great deal of attention for successful performance. With respect to memory, there is mounting evidence that tasks which require deep or "effortful" processing lead to enhanced retention (e.g., Craik, 1981; Tyler, Hertel, McCallum & Ellis, 1979). Memory deficits in the elderly might therefore stem from a biologically-based inability to engage in memory-enhancing processing. This hypothesis has been advanced recently by Hasher & Zacks (1979) and by Craik & Byrd (1982).

Hasher & Zacks (1979) propose that encoding operations in memory vary in their demand for processing resources or attentional capacity, from those that demand minimal attention (automatic processes) to those that consume a maximum amount of available attention (effortful processes). Effortful encoding operations include rehearsal, organization and verbal or visual mnemonics. Automatic processes remain intact across the lifespan, but effortful processes undergo system-

matic developmental changes: they emerge later in childhood and drop out earlier in old age. Hence, performance of older persons is expected to suffer most on tasks requiring effortful operations; since recall is influenced more than recognition by rehearsal, list organization, etc., recall is expected to show greater age impairment than recognition.

Craik and his co-workers (Craik & Simon, 1981; Craik & Byrd, 1982) have applied the notion of a continuum of attentional demands to the levels-of-processing framework. They suggest that deep, semantic processing requires greater attentional capacity than superficial processing. When attentional resources are limited, as in old age, events are less likely to be encoded in sufficient depth and detail for lasting retention. In support of this hypothesis, Craik & Byrd (1982) and Rabinowitz, Craik, & Ackerman (1982) have reported that conditions which reduce attentional capacity in young subjects, such as alcoholic intoxication, fatigue and divided attention tasks, result in memory performance deficits similar to those observed in sober, alert, elderly adults under full attention conditions. Parenthetically, it may be added that when older persons are subjected to divided-attention conditions, their memory performance is more penalized than that of young adults.

Salthouse (1982) has challenged the assumption that poorer performance resulting from the inclusion of a secondary

task necessarily occurs because processing demands exceed available capacity. Essentially, his argument is that the manner in which attention is allocated to each task is at least as important in determining performance as the total amount of attention available. A similar view was expressed by Wingfield (1980), who cautioned that:

the question is whether one should see the problem in terms of limited resources per se, or in terms of differential allocation strategies as the elderly attempt to distribute finite resources among several potential inputs and/or cognitive operations (p. 138).

The age-related decline in memory performance may thus be due to insufficient processing resources, to inefficient allocation of available resources, or to both. To the extent that memory performance in the elderly is remediated by learning instructions and other techniques which induce the elderly to process information more effectively, age decrements can be attributed to inefficient allocation of processing resources. However, the fact that age differences are rarely eliminated, regardless of the remedial strategy, suggests that the capacity for mental work becomes increasingly limited with advancing age.

Electrodermal correlates of learning and memory

In cognitive research, the number and difficulty of mental tasks are manipulated to determine the association between the allocation of attention and memory. Attentional factors underlying retention have also been assessed by measuring the covariation between autonomic responses to stimuli and subsequent memory performance. In most of the work reported in the following section, the amplitude of the skin conductance response has been positively associated with measures of delayed retention. In early reports, this association was interpreted in the framework of arousal theory. The use of arousal as an explanatory construct has largely been abandoned, however, not only because of the loose reference made to tonic and phasic response changes or to emotional and cognitive factors (Eysenck, 1977; Raskin, 1973), but also because of the growing evidence that arousal is a multidimensional phenomenon involving distinct responses and response systems (Fowles, 1980; Lacey, 1967; Routtenberg, 1968). Instead, electrodermal responses to stimuli have been employed as measures of attention, mental effort and the orienting response interchangeably (Craig & Blankstein, 1976; Kahneman, 1973; Maltzman & Raskin, 1965; Ohman, 1979). By considering the electrodermal response as an index of attention, it is possible to investigate age differences in attention and memory using psychophysiological methods.

In an early experiment, Brown (1937) recorded skin resistance over successive presentations of a list of nonsense syllables which were terminated when all items were recalled in serial order. A positive association was found between GSR magnitude and the order in which items were learned. Moreover, the correlation was stronger for learning trials preceding the first correct recall of each item than it was for succeeding trials when the item was recalled consistently. Kintsch (1965) later reported comparable results in a study involving PA learning. Both studies thus implicated a relation between electrodermal response elicitation and the learning process.

Investigations of the correspondence between electrodermal activity and memory differ from the studies mentioned above in that skin conductance is recorded only during the initial presentation of the material to be remembered; subsequent memory performance is analyzed in relation to responses elicited during presentation.

Kleinsmith & Kaplan (1963) measured skin resistance while presenting a short PA list, then tested retention of the list after delays ranging from 2 min to one week. Items which evoked the largest responses (high arousal) were less well recalled than low arousal items after no delay, but were better recalled at later intervals. Subsequent PA experiments confirmed these effects (Kleinsmith & Kaplan, 1964; Kaplan & Kaplan, 1969).

An a priori selection of stimulus words on the basis of arousal value was made by Walker & Tarte (1963), who presented either homogeneous or mixed lists of high and low arousal word-digit pairs. Associates of stimulus items from both arousal categories were equally well recalled on a test of immediate retention, but after 20 min, the recall of low arousal items declined while the recall of high arousal associates remained constant. Butter (1970) chose concrete-high imagery and abstract-low imagery nouns as PA stimulus terms. Compared to the concrete-high imagery words, the abstract items were associated with larger electrodermal responses and with poorer short-term but better long-term retention.

Although the interaction between skin conductance and retention interval is a robust finding in PA learning, contradictory results have been reported in studies of free recall; in these investigations, larger electrodermal responses are associated with increased immediate as well as long-term recall.

Maltzman, Kantor & Langdon (1966) challenged the Walker & Tarte findings by testing free recall after presentation of the same high and low arousal words. High arousal items elicited larger GSRs and were better remembered after short and long retention delays. Zelinski, Walsh, & Thompson (1976) measured retention after requiring subjects to process words

either semantically or non-semantically. Semantic processing generated larger skin conductance responses and led to improved immediate and long-term recall relative to non-semantic processing.

A free recall paradigm was used by Corteen (1969) as well, although in this experiment, the list items were not classified beforehand. Recall scores obtained immediately following list presentation or after delays of 20 min or 2 weeks were correlated with electrodermal response magnitude. A weak positive relation was found after no delay but over time, the correlation became progressively stronger.

Finally, Warren & Harris (1975) assessed word recall in relation to the presence or absence of skin potential responses (SPR). After a 2 min delay, words that evoked an SPR were better recalled than no-response words. However, there was no association of SPR with retention after 45 min. The poor reliability of the SPR (Venables & Christie, 1980) and the unusual procedure of dichotomizing physiological data may account for this anomalous finding.

With the exception of the Warren & Harris report, all studies have indicated a positive correlation between electrodermal response magnitude and delayed retention. Nevertheless, the effects of arousal on immediate recall remain controversial. Levonian (1972) and Eysenck (1977) have pointed out methodological differences between the PA and

the free recall studies which may explain the discrepant findings.

Similarities in the experimental procedures used to obtain release from proactive inhibition in recall and OR dishabituation have suggested that OR elicitation may be implicated in enhanced short-term recall. In the first study of this line of investigation, Grush, Coles, Ferguson & McGee (1973) presented a 25-item list consisting of either positively or negatively evaluated words; on the 21st trial, a change to a word of the opposite evaluative meaning was introduced. Habituation of the skin conductance response to similar words and dishabituation to the contrasting word were observed. Moreover, the increase in electrodermal responding following the evaluative change was paralleled by an increased probability that the contrast word would be recalled.

Performance on a Brown-Peterson (Peterson & Peterson, 1959) task and concurrent changes in skin conductance have been assessed in four recent investigations. This paradigm involves presentation of 3 to 4 words from the same taxonomic category over successive trials; recall of the items in each trial is preceded by a brief (15-30 sec) interference task. The decline in recall over trials is attributed to the build-up of proactive inhibition (PI). However, a shift in word category after PI build-up results in improved recall, or release from PI.

Siddle & Kroese (1983) recorded skin conductance while visually presenting 4 trials of 4 to-be-recalled words from the animal category followed by a change to words representing body parts or vice versa. Memory performance and SCR declined over Trials 1-4 and the category shift produced both enhanced recall and an increase in SCR magnitude. Magliero, Gatchel, & Gortney (1980) observed a similar covariation between recall and SCR on trials involving auditory presentation of words from animal and sports categories. These investigators also noted that items from the trial that elicited the largest SCR were recalled first on a test of final free recall. In a similar vein, Yuille & Hare (1980) found that the best recalled words elicited larger SCRs when electrodermal responses for the best and worst recall trials were compared, independent of category shifts. Nevertheless, the authors failed to observe a correspondence between release from PI and SCR dishabituation. Finally, Wilson (1982) did not observe any association between skin conductance and the build-up and release from PI. Although SCR and recall declined in parallel over trials, individual differences in SCR habituation were not matched by differences in recall performance. Furthermore, as in the Yuille & Hare (1980) report, the category shift did not result in increased SCR.

In summary, the hypothesis that the build-up and release of proactive inhibition in short-term memory reflects the

extinction and reinstatement of attention as manifested by the OR has received equivocal support. Nevertheless, of the 4 studies cited, 3 did yield a generally positive relation between SCR magnitude and short-term recall.

The literature relating recognition memory to autonomic response measures is sparse. Heart rate changes have been examined in two studies (Jennings & Hall, 1980; Spence, Lugo & Youdin, 1972), both of which indicated an association between heart rate deceleration and item recognition. Skin conductance measures have not been employed, possibly because SCR habituation occurring during presentation of the long lists of stimuli typically used in recognition studies would reduce the sensitivity of the SCR to recognition memory performance.

Stelmack, Plouffe & Winogron (1983) circumvented this difficulty by presenting stimuli found to have either a high or low frequency of correct recognition in an independent analysis of recognition memory. High recognition pictures evoked larger initial SCRs in a stimulus habituation sequence than low recognition pictures. When subjects who had participated in the recognition memory task were presented items they had either recognized or failed to recognize, the recognized stimuli elicited smaller initial responses than the not-recognized items. This study clearly indicated that the OR plays a complex role in memory.

The role of the orienting response in learning and memory

In general, phasic changes in electrodermal activity reliably predict learning and memory performance. The sensitivity of the electrodermal response to mental events was recognized in the nineteenth century and was specifically associated with the construct of arousal (Neumann & Blanton, 1970; Raskin, 1973). However, its functional importance in learning and memory has stemmed mainly from its identification as a component of the orienting response (OR), which is intimately linked with selective attention and conditioning (Hultstijn, 1979; Kahneman, 1973; Lynn, 1966; Maltzman & Raskin, 1965; Ohman, 1979; Pribram & McGuiness, 1975; Sokolov, 1963, 1969; Waters, McDonald & Koresko, 1977).

As defined by Sokolov (1960, 1963), the OR is a complex of behavioural, autonomic and electrocortical responses elicited by novel or signal stimuli. The properties that distinguish the OR from other reflexive responses to environmental stimulation are: 1) the OR is non-specific with regard to sensory mode and direction of change; 2) it habituates to stimulus repetition; and 3) the OR enhances rather than limits the action of the eliciting stimulus. The common purpose of the component responses is to optimize stimulus reception and analysis by lowering sensory thresholds and by increasing the efficiency of transmission in the central nervous system.

In Sokolov's theory, the mechanisms and neural substrates of the OR are inextricably linked with memory processes; indeed, in subsequent elaborations of his early (1960, 1963) proposals, Sokolov (1969, 1975) articulated more fully the connections between the OR and memory.

Elicitation and habituation of the OR are based upon a cortical modelling system (Sokolov, 1960, 1963). Current stimulus input is compared with traces of previous stimulation stored in a neuronal model. Any detected mismatch between present and previous stimulation triggers the OR which continues to be elicited until all the information contained in the novel stimulus is extracted and registered in an updated neuronal model. The magnitude of the OR is proportional to the degree of stimulus novelty and the rate of habituation to repeated presentations of the stimulus is an inverse function of the time required to establish a model incorporating all the features of the eliciting stimulus. Thus, elicitation and habituation of the OR reflect the registration of an event and the formation of a lasting neural representation of the event:

the orienting response is a reaction which is determined by the absence of an acting signal in stored experience... the extinction of the orienting reflex is a process of transformation of the new into the old, i.e., of some trace formation (Vinogradova, 1975, p. 153).

In a later theoretical statement, Sokolov (1969) addressed the OR from an information-processing perspective, ascribing a role to short and long-term memory stores in response elicitation and habituation. According to this view, the OR is elicited by improbable or unexpected stimuli, that is, by stimuli for which there is no representation in operative (immediate) memory. The occurrence of an unpredicted stimulus generates a number of equiprobable hypotheses or predictions concerning the nature, frequency and duration of the event, arising from the organism's permanent record of past experience. These hypotheses become active in operative memory, and, as information is accumulated from repeated stimulation, some of these predictions acquire higher probability while others are excluded. When the next stimulus can be accurately predicted, the information-gathering, hypothesis-testing OR ceases to be required.

Western researchers have generally endorsed Sokolov's proposals regarding the parameters of stimulus input that are effective in eliciting an OR (cf Graham, 1973). The assertion that OR magnitude is a direct function of the amount of stimulus change or novelty has been supported in independent inquiries which have considered changes along such dimensions as acoustic intensity (Siddle & Heron, 1976, 1977) and degree of predictive certainty in a concept-identification task (DeSwart & Das-Smaal, 1979). The OR is also known to be sensitive to changes in the semantic characteristics

of verbal stimuli, including denotative meaning (Luria & Vinogradova, 1959; van Olst, 1971), evaluative meaning (Grush et al, 1973) and taxonomic category (Magliero et al, 1980; Siddle & Kroese, 1983; Siddle, Kyriacou, Heron, & Matthews, 1979). In addition, OR habituation has been found to coincide with the establishment of learning (Kintsch, 1965) and with response discovery in a problem-solving task (Maltzman, 1971). In brief, Sokolov's model of the OR has provided a useful framework for investigating encoding processes in memory.

Since problems in selective attention, learning and memory have been of central interest in Western cognitive psychology, contemporary researchers, in particular, Ohman (1979) and Wagner (1976), have attempted to integrate Sokolovian theory with information-processing models of attention and memory (e.g., Atkinson & Shiffrin, 1968; Kahneman, 1973; Shiffrin & Schneider, 1977). This approach is germane to the present study because it facilitates the application of the OR to explore hypotheses relating memory decline in old age to deficits in attention.

Ohman's (1979) model represents an amalgam of interrelated constructs borrowed from the information-processing literature; it has been described by one reviewer (Coles, 1980) as a fairly orthodox synthesis of current cognitive theories. While Ohman accepts the Sokolovian premises he de-

fines more clearly the changes that occur in an information-processing system as a consequence of OR elicitation. Ohman's model is shown in Fig. 1.

According to this view, an OR is elicited when initial, pre-attentive analysis fails to find a match for current stimulus input in the short-term store (STS). The OR initiated by this unexpected, novel event represents a "call for processing" in a capacity-limited central channel. In other words, the OR signals a re-allocation of processing capacity towards the stimulus. The processing induced by the OR involves an effortful, controlled search of the long-term store (LTS) to retrieve associated representations in order to identify the stimulus. The cognitive effort expended in stimulus analysis and retrieval of associated traces results in the registration of the stimulus in LTS. In Ohman's words, "the OR is a pre-requisite for learning, because information can be stored in long-term memory only through processing in the central processing channel" (p. 445).

Ohman proposes that the extent of processing received by the stimulus varies directly with the magnitude of the OR. This suggestion is based upon the assumption that the magnitude of the OR is proportional to the degree of mismatch between stimulus input and the contents of STS: as the likelihood of a stimulus in a given context decreases, there is an increase in the amount of processing required to analyze

Figure 1. Ohman's information-processing model of the OR, in which the OR is considered to be the "call" which initiates processing in the central channel when pre-attentive mechanisms fail to find a "match" for the incoming stimulus in the short-term store.

and identify the stimulus. Increased processing demands result in a greater expenditure of cognitive effort, the physiological concomitant of which is arousal. The empirical data reviewed previously supports the prediction from the model that stimuli which evoke larger ORs are more likely remembered than stimuli which evoke smaller responses.

While the OR as a "call" for attention is conceptually distinct from the cognitive processing it induces, the autonomic responses from which the OR is inferred cannot be so readily distinguished. Ohman acknowledges this difficulty, conceding that the call can be separated from actual processing only in instances where the OR is elicited but the stimulus is not consciously identified. Nevertheless, the response manifestation to an identified and subsequently remembered stimulus should be included in the OR concept. Ohman states that:

Skin conductance responses may be quite straightforwardly identified with the call, but because this measure is regarded as highly sensitive to cognitive effort, a skin conductance OR may be affected by processing in the central channel. In other words, it may reflect not only the call but part of the answer to the call. However, as long as this central processing does not result in clearly identifiable additional responses, it must be included in the OR (p. 434).

In his model, Ohman is principally concerned with specifying the nature of the information-processing initiated by the OR. The mechanisms responsible for response habituation described by Ohman draw heavily from Wagner's (1976) theory of stimulus priming. For present purposes, only those aspects of Wagner's model which pertain to long-term or between-session habituation are discussed.

Wagner's (1976) proposals evolved from experimental work in compound conditioning of the eye-blink response in rabbits, where he observed that the rate of post-training habituation to a conditioned stimulus was inversely proportional to the frequency of the CS-UCS pairings during training. From these apparently paradoxical observations, Wagner concluded that the availability of a stimulus trace in STS (pre-representation or priming) determines the extent of processing received by the stimulus. Unexpected stimuli which are not "primed" in STS receive greater processing than expected stimuli, and hence are more likely to leave a memory trace which can be readily accessed from LTS to STS on a test trial. When these processed stimuli are then presented on a test trial, the corresponding LTS traces are activated and primed in STS, resulting in reduced OR magnitude and faster habituation. Briefly stated, the more accessible the memory trace is to STS, the smaller the OR on a test trial.

Wagner & Pfautz (1978) tested predictions from the theory in a study of habituation of the vasoconstrictive OR in rabbits. In a paradigmatic analogue of a recognition memory task, the animals received several presentations of a 5-item series consisting of auditory, visual, electrotactile and vibrotactile stimuli. In the test phase, conducted 15 min after the stimulus series, the magnitude of the vasoconstrictive response to isolated stimuli was assessed; these stimuli had consistently occupied the first, middle or last position in the series. The response pattern paralleled the bowed-position curve observed in human memory, with smaller responses occurring to stimuli placed in the initial and last list positions. The authors interpreted this decrement in OR magnitude as an indication of stimulus retention.

Comparable findings were obtained in the study by Stelmack et al (1983) mentioned earlier. These investigators reported that smaller electrodermal ORs were elicited by picture and word stimuli that had been correctly recognized in a prior recognition memory task than by stimuli that had not been recognized.

The Stelmack et al (1983) and Wagner & Pfautz (1978) studies explored predictions from Wagner's (1976) model in relation to recognition memory. No experiment exploring the relationship between priming mechanisms underlying habituation and recall processes has yet been undertaken. Since a

memory representation must be accessible to STS for a stimulus to be recalled, it could be predicted that a stimulus which had been recalled would elicit smaller ORs and show greater habituation than would stimuli which had not been recalled.

Wagner's (1976) and Ohman's (1979) elaborations of OR theory rely extensively on contemporary information-processing models of encoding and retrieval in memory. In both accounts, autonomic components of the OR are considered to be reliable indices of the extent of processing received by a stimulus. If aging is indeed accompanied by a reduction in processing capacity, then older adults would be expected to produce fewer and smaller magnitude skin conductance ORs to stimuli presented in a learning task. Furthermore, if stored information is not as readily accessible to STS in older adults (Buschke, 1974), one would expect that priming effects would be less evident on a test trial for this age group than for the young; that is, a previously recalled stimulus might not induce the same degree of OR decrement on a test trial.

Word frequency as an index of picture novelty

The stimuli employed in this investigation were 20 simple line drawings of concrete objects. Half of the pictures represented nouns with high Thorndike-Lorge (1944) word

counts (HF) and the remainder depicted nouns which have a low frequency of occurrence (LF) in English usage. On the strength of the evidence cited below, it was assumed that these stimulus categories would be differentially effective in eliciting the OR and would be differentially recalled.

There are precedents in the experimental literature for categorizing stimuli a priori on some dimension assumed to influence autonomic arousal. In the studies by Walker & Tarte (1963) and Maltzman et al (1966), emotional and neutral words were used. Butter (1970) manipulated word concreteness and imagery, although little explanation was given for the prediction that abstract-low imagery nouns would induce greater arousal than concrete-high imagery nouns.

Lists comprising equal numbers of words with high, moderate and low Thorndike-Lorge frequencies were presented by Corteen (1969). Differences in skin conductance responses were not considered, however, and word frequency was not found to be related to recall.

The absence of a relationship between word frequency and recall in the Corteen study was an atypical result in the verbal learning literature, where a paradoxical effect of frequency on recall and recognition is consistently demonstrated (e.g., Kintsch, 1970; McCormack, 1972). In comparisons of memory scores obtained with homogeneous HF or LF word lists, HF words are better recalled than LF words, whi-

le the reverse holds true for recognition memory. Among the explanations offered for HF superiority in recall (Gregg, 1976), it has been suggested that, by virtue of their familiarity, HF words have priority of access from semantic memory, and generate many more associations which can serve as retrieval cues. Furthermore, HF words are more amenable to organization during encoding. Rare, LF words are more readily recognized for precisely the opposite reason -- the absence of close associates renders them more distinctive among distractor items.

Studies in which HF and LF words are mixed in single lists have yielded results which conflict with findings obtained with homogeneous word lists. May & Tryk (1970) asked subjects to memorize word lists consisting of homogeneous HF or LF words or a mixed list of alternating HF and LF items. Rare, LF words were better recalled than common HF words in the mixed list. These findings were subsequently confirmed in a study by Gregg (1976). May & Tryk explained the effect in terms of enhanced orienting responses to the HF/LF stimulus change.

Word frequency can reasonably be understood as a form of stimulus novelty, if novelty is defined in probabilistic terms. Low frequency words have a low probability of occurrence in written and, presumably, in spoken language. Also, they tend to be acquired at an older age and to be identi-

fied more slowly than common, HF words (Gregg, 1976; Oldfield & Wingfield, 1965).

The encoding of pictures almost certainly depends upon a host of perceptual variables, such as complexity of detail and uniqueness of the representation. Nevertheless, there is evidence which suggests that the characteristics of verbal labels also play a role in memory for corresponding pictures. The rated familiarity of pictures shows a moderate positive correlation with the frequency count of their verbal labels (Snodgrass & Vanderwart, 1980). Moreover, the naming latency of pictures varies inversely with the logarithm of the picture names (Oldfield & Wingfield, 1965); that is, semantic memory codes for pictures with LF names are accessed more slowly than are the codes for pictures with HF names. Paivio (1971) has proposed that pictures engender both perceptual and verbal codes; the expectation that word frequency would exert a similar influence on the recall of pictures and of words representations is consistent with this view.

It is reasonable to suppose, therefore, that a mixed series of pictures with HF and LF names would give rise to superior recall for LF pictures. These pictures are assumed to be relatively more novel than the common, HF pictures; hence, enhanced memory for these pictures is considered to depend upon increased OR elicitation.

Summary and statement of hypotheses

The present chapter has endeavoured to develop a rationale for using the electrodermal OR to assess age differences in picture recall and, secondarily, to determine the role of recall in long-term habituation of the OR. The research hypotheses were derived from an integration of information-processing models of the OR with current research in human memory.

Older adults consistently display poorer retention of verbal and pictorial material. Explanations of the age decline in memory have attempted to localize the loss in storage, retrieval or encoding stages of memory; generally, the emphasis on deficits in one stage or another has followed shifts in theoretical accounts of forgetting. Recently, it has been proposed that the deterioration of memory in the elderly is attributable to a biologically-based decline in attention or information-processing capacity.

There is considerable evidence that the magnitude of the skin conductance response is a reliable index of performance on learning and memory tasks. This association is interpreted with reference to the orienting response, which has been formally linked with processes underlying attention and memory. By emphasizing contemporary constructs of attention and cognitive effort in explicating the role of the OR in memory, these models offered a new perspective and methodology for investigating memory decline in old age.

In Ohman's (1979) model, the OR signals a call for processing in a capacity-limited channel; this processing entails an analysis of incoming stimulus features and an effortful search of LTS to retrieve associated representations. The expenditure of cognitive effort results in registration of the stimulus in LTS. Hence, stimuli which elicit ORs are more likely to be remembered than stimuli which do not elicit ORs and individual differences in the capacity for OR elicitation to stimuli are likely to be reflected in differences in stimulus retention.

Stimulus novelty, defined in terms of a low probability of stimulus occurrence, is a pre-condition for OR elicitation. In studies of recall of mixed lists of words with high and low frequencies of occurrence, differential OR elicitation has been invoked to explain the superior recall of LF words. Since the encoding of pictures appears to depend at least partly on the characteristics of the picture-names, it was supposed that similar effects would be obtained with a mixed set of pictures with HF and LF names.

In Wagner's (1976) model of OR habituation, the magnitude of the OR is inversely related to the availability of a stimulus trace in STS. Thus, a stimulus which has left a trace in memory as a result of previous processing produces smaller OR magnitude and greater habituation on a test trial than does a stimulus which has not received prior process-

ing. Wagner's (1976) proposals have been successful in accounting for the effects of recognition memory on OR elicitation.

In the first phase of this study, a series of pictures with familiar, HF word names and rare, LF verbal labels was presented to young and elderly adult women while electrodermal activity was recorded. Free recall was measured 30 min after presentation of the stimuli. This procedure was designed to test the following predictions.

If OR elicitation reflects the degree of cognitive effort expended in the registration of a novel stimulus in LTS, then stimuli which elicit skin conductance ORs would be better recalled than stimuli which do not elicit an OR.

On the premise that word frequency is an index of stimulus novelty for pictures, it was predicted that pictures with LF names would elicit larger skin conductance ORs and would display enhanced recall in comparison to pictures with HF names.

If poorer recall in older adults is due to insufficient encoding effort, then age differences in recall performance would be mirrored by differences in the magnitude of skin conductance responses elicited by elderly and young subjects.

In the second phase of the study, OR elicitation to recalled, not-recalled and novel (i.e., not previously presented) pictures was examined in a simple habituation paradigm. The following hypotheses were formulated.

If the registration of an item in LTS facilitates subsequent retrieval of the item (stimulus priming), then recalled stimuli would elicit smaller responses than not-recalled pictures and pictures not previously shown.

If older adults are deficient in the ability to consistently retrieve stimulus traces from LTS to STS, they would be expected to display less evidence of stimulus priming to previously recalled pictures than the young.

METHOD

The research methodology is described in this chapter. Details concerning the participants are given first, then the stimulus materials and equipment used to present the stimuli are described. In the following section, the experimental procedure and electrodermal recording method are presented; briefly, the experiment consisted of a study phase, during which each subject viewed the pictures, a delayed test of free recall, a stimulus habituation session and a test of recognition memory. It should be noted here that no hypotheses were specifically formulated regarding age differences or SCR in relation to recognition memory; rather, this procedure was included simply to assess whether the picture stimuli were perceived as well initially by young and aged groups. In the final section of the chapter, the method used to score the electrodermal data is discussed.

Subjects

The participants were 30 young adult females ranging in age from 17-24 years ($\bar{X}$ age = 19.9) and 30 elderly females aged 60-88 years ($\bar{X}$ age = 71.0). The young women were undergraduate students at the University of Ottawa and the older

women were local community residents recruited through seniors' centres as well as through friends and relatives of the author. The older volunteers received \$5.00 for their participation and their transportation to and from the university was provided if requested.

Prior to the experiment, each participant was questioned about her present health, recent medical history and visual and auditory acuity during a structured interview. Older subjects who required undue repetition or elaboration of standard experimental instructions were replaced. One older participant was replaced for this reason. All subjects whose data were retained for analysis reported no serious physical or sensory impairment and rated themselves as being normally healthy.

The young women had received more formal education ($\bar{X}$ = 14.6 years) than the older adults ($\bar{X}$ = 12.3 years). However, the older sample obtained slightly higher W.A.I.S. vocabulary scaled scores ($\bar{X}$ = 13.0, S.D. = 1.8) than the young participants ($\bar{X}$ = 12.0, S.D. = 2.0), $t(58) = 2.09$, $p < .05$. Thus, the groups displayed an equivalent level of verbal ability.

Materials and apparatus

Picture stimuli

The stimuli presented in the study phase were 20 photographic slides of unambiguous black and white line drawings of simple objects (Dacko, 1973). These pictures were categorized as being common (HF) or unusual (LF) on the basis of the Thorndike-Lorge (1944) frequency count of their corresponding names. The names of the 10 HF pictures had a usage frequency in the AA range (more than 100 times per million words), whereas the names of the 10 LF pictures had a low word-count (less than 30 times per million words). The contemporary accuracy of the word categories was determined with reference to the Kucera-Francis (1967) word-count and to the Toglia-Battig (1978) word-familiarity ratings (Appendix A). An additional 20 pictures were selected according to the same word frequency criteria to serve as distractors in the recognition memory test. The slides which were presented for recall and which also served as target items in the recognition test are shown in Fig. 2. The distractor slides are shown in Fig. 3.

Stimulus presentation apparatus

A Kodak carousel projector (model 850 H) was used to project the slides onto a wall in the main laboratory; the projected image was relayed by means of an RCA camera (model

Stimulus Frequency			
High		Low

Figure 2. Picture stimuli presented in the study phase.

Stimulus Frequency	
High	Low

Figure 3. Picture stimuli presented as distractors on the recognition memory test.

TC1000) to a video monitor placed in an experimental chamber adjacent to the stimulus presentation and response recording equipment. The chamber was dimly lit, sound-attenuated and temperature-controlled (20° C). The video monitor had a 19 x 14 cm screen area and was positioned at eye-level approximately 1.5 m from the subject. A Lafayette timer (model 5431 A) and counter (5812) were used to initiate and terminate presentation of the stimulus sequence. A moderately intense (86 db SPL) .1 sec burst of white noise produced by a Lafayette white noise generator (15012) and transmitted through earphones was presented as a standard stimulus for range-correction (Lykken & Venables, 1971).

Procedure

Experimental procedure

Study phase. After washing her hands in running water and wiping them with a paper towel, the subject was seated comfortably in the experimental chamber. She was instructed to watch the TV screen and to "try to learn" the pictures that would appear one by one. To minimize possible rehearsal of the items during the retention interval, the subject was not explicitly told that a memory test would follow. After a 5 min delay, the stimuli were exposed for a duration of 1 sec at random interstimulus intervals of 15, 20, 25 and 30 sec to prevent anticipation of the stimuli. The order of stimulus presentation was arranged according to one of 30

computer-generated random sequences, so that the order was unique for every subject within an age category.

All 10 LF and 10 HF stimuli were shown to 20 subjects in each age group; the remaining 10 young and 10 elderly participants saw all but one LF picture, which was presented in the habituation phase as an item not previously shown. (This selection procedure was required in order for the same stimuli to be presented in each of the three conditions in the habituation phase). After the last slide was shown, earphones were placed on the subject's head and the white noise stimulus was presented.

During presentation of the pictures and white noise stimulus, skin conductance was measured by applying a constant voltage of 0.05 V across Beckman miniature Ag-AgCl electrodes filled with a 0.05 molar NaCl electrolyte (Johnson & Johnson K-Y jelly) placed on the distal phalange of the index and second fingers of the non-dominant hand. Responses were recorded on a Watanabe polygraph (model MC611) with a sensitivity of 0.03 μ mho for a 1 mm pen deflection and a chart speed of 5 mm/sec. The constancy of electrode polarity was checked at the beginning and in the middle of each recording session. The recording equipment and method conformed to the most recent recommendations for electrodermal measurement (Fowles, Christie, Edelberg, Lykken, & Venables, 1981).

Retention delay. Following presentation of the stimuli, the subject went to an adjacent room where she remained for 30 min. During this time, the experimenter administered the W.A.I.S. vocabulary subtest orally, then gave the subject a self-report personality inventory (Sensation-Seeking Scale) to complete alone. This questionnaire was included to fill the time before retention testing and to prevent rehearsal of the pictures.

Retention test. After 30 min had elapsed from the presentation of the last picture stimulus, the participant was given a sheet of paper with instructions to write the names of as many pictures as she could recall. If she remembered a particular picture but could not identify it, she was asked to either describe the picture or to draw it. The recall test was unpaced.

Stimulus habituation session. Once the subject had completed the recall task, she returned to the testing room where the electrodes were replaced in preparation for a stimulus habituation session. She was instructed to relax and to simply watch the TV screen. After 5 minutes, the subject received 10 presentations of a single LF slide for a duration of 1 sec at randomly varied intervals of 20, 25 and 30 sec.

Of the 20 individuals in each age group who saw all the pictures initially, half were chosen at random to receive a

picture they recalled; the other half saw a picture they had not recalled on the memory test. The remaining 10 young and 10 elderly subjects received the LF picture which had been omitted from the original series. Thus, all 10 LF pictures were represented in each of the three conditions.

Recognition memory test. Following the habituation session, a recognition memory test was administered in the adjacent room. A Kodak projector (model 800) was used to project the slides on a wall about 1.5 m away from the subject. The 20 slides shown in the learning phase and 20 distractor slides were exposed in a random sequence for 5 sec with a 1 sec interval between slides. The subject indicated the pictures which had been shown earlier by saying "yes" or "no" to each picture while the experimenter recorded her responses. A signal detection analysis of recognition memory (d') and response bias (β) was applied to the data (Green & Swets, 1966).

Electrodermal scoring procedure

The electrodermal records were manually scored in accordance with standard practice (Venables & Christie, 1981). Skin conductance level (SCL) was sampled at 1 min intervals during the 5 min baseline period preceding stimulation and at the onset of each stimulus. Any increase in conductance from SCL at stimulus onset greater than 0.03 μmho (1 mm pen

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deflection) occurring within 1-4 sec of stimulation was considered a stimulus-evoked skin conductance response (SCR). Skin conductance changes greater than 0.03 μ mho relative to SCL which occurred in the interstimulus interval were scored as spontaneous fluctuations (SF).

Stimulus-evoked changes in conductance were analyzed first in terms of raw score SCR, then in terms of range-corrected values. Range-correction is a data-transformation procedure designed to reduce variation in SCR magnitude attributable to individual differences in physiological, biochemical or structural substrates of electrodermal activity which are assumed to be unrelated to the psychological variables of interest (Lykken & Venables, 1971). Raw score values are transformed to range-corrected scores by expressing the SCR observed on each trial as a proportion of the subject's maximum response as follows:

$$SCR_{rc} = SCR_{ix} / SCR_{max}$$

To obtain an estimate of SCR max, Lykken & Venables (1971) recommend the presentation of a brief, intense stimulus, such as a loud noise or shock sometime during the recording session. The decision regarding when to present the range-correction stimulus poses some difficulty, however, since there may be interactive effects of the stimulus and experimental treatments (Siddle, Turpin, Spinks, & Stephenson, 1980). Presentation of the stimulus early in the session may

contaminate responses in the experimental condition, while the experimental condition may affect the response to the range-correction stimulus presented at the end of the recording session.

The white noise burst used as a range-correction stimulus was presented at the end of the recording session because it was judged that the presentation of a loud, startling noise at the beginning of the recording session might detrimentally affect the learning performance of the experimentally naive and possibly apprehensive elderly subjects.

Temporal measures of the SCR elicited during the first stimulus trial in the learning phase were obtained. Response latency was determined from the onset of the stimulus to the onset of SCR. Rise-time of the response was defined as the time from SCR onset to response peak. Finally, response recovery was measured by means of the half-recovery time method suggested by Edelberg (1970). Using a transparent overlay, the time required to attain a 50% recovery from peak amplitude to base SCL was measured. Since there was little precedent in the literature for examining age differences in the time-related features of the SCR, no predictions were made.

RESULTS

The first section of this chapter presents the results of the memory tests and the electrodermal data recorded during the picture study phase. In the course of data analysis, it was noted that subjects over 70 years of age ($n = 14$) differed from women under 70 ($n = 16$) and from young subjects with respect to both recall and electrodermal activity; these differences are explored in the latter part of the first section. In the second section, the electrodermal response data obtained in the stimulus habituation session are described.

Statistical analyses were performed with the aid of programs contained in the BMDP-79 Biomedical Computer Programs, P Series (Dixon & Brown, 1979) and the Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). A .05 level of confidence was adopted for all statistical tests; for factors and interactions involving repeated measures, the Greenhouse-Geisser correction factor was applied to the degrees of freedom (Kirk, 1968). Post-hoc comparisons were done using the Newman-Keuls procedure. The ANOVA summary tables for the principal analyses are provided in Appendix B.

Memory performanceFree recall

Recall of HF and LF pictures. To assess differential recall of HF and LF pictures, the proportion of items correctly recalled was subjected to a 2 x 2 analysis of variance in which the factors were Age and Stimulus Frequency. Young women recalled more pictures overall (.72) than the older women (.59), $F(1,58) = 12.96$, $MSe = 0.04$. Subjects in both age groups recalled a greater proportion of HF than of LF pictures, $F(1,58) = 18.52$, $MSe = 0.02$. For young and aged samples, the proportion of recalled HF pictures was .77 (SD = .17) and .65 (SD = .17), and the proportion of remembered LF items was .67 (SD = .18) and .54 (SD = .14).

Recall, age and vocabulary. Relationships between recall, age and verbal ability, as indicated by the W.A.I.S. Vocabulary standard score were also considered. Recall performance and verbal ability were not associated in the young adult sample, $r = -0.20$, NS; for the elderly group, however, a significant positive correlation was observed, $r = 0.44$, $p < .05$. Since the range of recall and vocabulary scores was similar for both age groups, the absence of an association in the young sample could not be attributed to insufficient variability in either score. Age was negatively correlated with recall for the older women, $r = -0.39$, $p < .05$; the combination of age and vocabulary scores predicted 30% of the

variance in the recall performance of the elderly sample, $R^2 = 0.30$, $F(2,27) = 5.69$, $M_{res} = 0.01$.

Serial position effect in recall. When recall of each item in a list is examined as a function of presentation order, serial position effects are invariably observed (Murdock, 1962); in immediate free recall, the most recently presented items are recalled best (recency effect), followed by the initial 3 to 4 items (primacy effect). In delayed recall, the recency effect is absent, leaving only superior retention of the first items in the list. In the present data, serial position effects were determined by averaging recall frequency at each ordinal position into 4 position blocks, each comprising an equal number of items. These data are shown in Fig 4.

A 2 (Age) x 4 (Serial Position) ANOVA yielded significant differences for both factors, and no interaction, $F < 1$. Items in the first position were better recalled than items in any other position, $F(3,174) = 21.11$, $MSe = 0.05$. Trend analysis of the retention curve indicated a significant linear $F(1,58) = 44.83$, $MSe = 0.06$, and quadratic trend, $F(1,58) = 12.25$, $MSe = 0.04$. The increase in recall for the last few items suggests that these pictures may have been rehearsed during the interval preceding the presentation of the white noise; however, this effect is not remarkable.

Figure 4. Proportion of pictures recalled by young and elderly groups, plotted according to serial position of the items.

Recognition memory

The proportion of hits and false alarms as well as the d' and B scores obtained on the test of recognition memory are reported in Table 1. The similar d' scores indicate that young and elderly adults recognized the target pictures equally well, $t(58) = 1.44$, NS. A comparable response criterion (β) also was adopted by both age groups, $t(58) = 0.74$, NS. The high degree of recognition accuracy may be a "ceiling effect", reflecting the relatively low level of difficulty of the recognition task. Because of these ceiling scores and the absence of differences between age groups, further analysis of SCR in relation to recognition memory and aging was not warranted. In any event, these findings suggest that the older women perceived the target pictures as well as the young when they were presented in the study phase.

The effects of age on electrodermal activity

Skin conductance level

Baseline SCL sampled at 1 min intervals during the 5 min delay prior to stimulus presentation was analyzed by means of a 2 (Age) x 5 (Trials) analysis of variance. Young women displayed generally higher resting SCL ($3.4 \mu\text{mho}$) than the elderly ($1.9 \mu\text{mho}$), $F(1,58) = 22.68$, $MSe = 9.58$. A decline in SCL over Trials also was observed, $F(1,58) = 8.38$, $MSe =$

Table 1

Proportion of Correct Recognitions (Hits), False Alarms, d' and β Scores Obtained by Young and Elderly Groups

Group	Recognition Score			
	Hits	False alarms	d'	β
Young (SD)	0.96 (0.06)	0.02 (0.21)	5.01 (1.19)	2.73 (0.59)
Old (SD)	0.92 (0.09)	0.01 (0.05)	4.59 (1.08)	2.75 (0.57)

0.16; the non-significant interaction confirmed that the decline was parallel in both groups.

A 2 (Age) x 19 (Trials) design was used to evaluate SCL measured at stimulus onset using the 19 trials received by all subjects. Again, the young displayed higher SCL (3.36 μ mho) than the elderly (1.92 μ mho), $F(1,58) = 13.82$, $MSe = 42.79$. SCL remained constant over trials for both groups, $F < 1$.

Spontaneous fluctuations

The number of SFs produced by each group over the stimulus trials was compared. Fewer SFs were emitted by the elderly women (23.8) than by the young women (31.4), but the difference was not statistically significant, $t(58) = 1.37$, NS.

Stimulus-evoked skin conductance responses

Raw score skin conductance responses to the picture stimuli presented in the study phase were subjected to a 2 (Age) x 19 (Trials) ANOVA. A significant main effect of Age was observed, $F(1,58) = 4.15$, $MSe = 0.36$, with young subjects displaying larger magnitude SCRs to the pictures than older adults. As shown in Fig 5, there was a general decline in SCR from the first to the last stimulus trial, $F(1,58) = 17.18$, $MSe = 0.05$. SCR decreased at a similar rate in both groups, $F(1,58) = 1.24$, $MSe = 0.05$, NS.

Figure 5. Mean SCR magnitude over 19 picture trials. Perpendiculars indicate s_{em} .

SCR to the white noise stimulus

The white noise stimulus, which was intended to produce an estimate of the upper limit of electrodermal responsiveness, elicited an SCR of $0.61 \mu\text{mho}$ ($SD = 0.39$) in the young sample and $0.55 \mu\text{mho}$ ($SD = 0.38$) in the elderly group, $t(58) = 0.57$, NS. A scanning of the electrodermal records showed that the SCR to the white noise was generally not the largest response; attenuated responding to this moderately intense stimulation conceivably resulted from response habituation induced by the picture sequence.

The largest response produced on individual records was therefore used as an estimate of SCR max for range-correction of SCRs on stimulus trials. The maximum SCR was somewhat larger for the young ($0.99 \mu\text{mho}$, $SD = 0.55$) than for the aged ($0.72 \mu\text{mho}$, $SD = 0.51$), but the difference was not significant, $t(58) = 1.95$, NS.

Range-corrected SCR over stimulus trials

The analysis performed on the raw SCR values was repeated using range-corrected scores. These data are plotted in Fig 6. Range-correction effectively eliminated age differences in SCR over trials, $F(1,58) = 1.56$, $MSe = 0.28$, NS. In subsequent analyses relating recall to electrodermal responding, raw score SCR values are used. The appropriateness of range-correcting data obtained from subjects of different ages will be discussed later in light of these findings.

Figure 6. Range-corrected SCR magnitude over 19 picture trials.

Time-related measures of the initial SCR

Measures of response latency, rise-time to peak amplitude and half-recovery time for the initial stimulus-evoked SCR are presented in Table 2. Because these measures were found to be intercorrelated (Table 3), a between-groups analysis of multiple dependent variables (Hotelling's T^2) was performed before comparing groups on single measures. The overall T^2 value of 7.83 approached statistical significance, $F(3,36) = 2.47$, $p < .10$. Among the individual comparisons, only the difference in response latency was reliable, $t(51) = -2.92$, $p < .01$, with older subjects responding more sluggishly after stimulus onset. Age-group comparisons for rise-time, $t(51) = -0.12$, NS, and for half-recovery time measures, $t(51) = -0.92$, NS, were not significant.

Summary of age differences in electrodermal activity

In general, older women displayed lower SCL both before and during stimulus presentation. As indicated by the number of SFs, subjects in each age group exhibited a similar degree of electrodermal lability. The elderly displayed a slightly longer latency of response to the initial stimulus, but did not differ from the young with respect to response rise-time or half-recovery time. The magnitude of SCR elicited by the picture stimuli was smaller in the older group; however, age differences in SCR were eliminated when a range-correction transformation was applied.

Table 2

Mean and (SD) Temporal Measures of the Initial
SCR for Young and Elderly Groups

Group	n	Response Component (sec)		
		Latency	Rise-Time	Half-Recovery Time
Young	30	1.81 (0.52)	1.86 (0.73)	2.37 (1.55)
Old	30	2.24 (0.56)	2.17 (1.21)	2.81 (1.87)

Table 3

Intercorrelations Among Latency (lat), Rise-Time (rit) and Half-Recovery Time (hrt) Measures of the Initial SCR for the Total Sample (N = 60) and for Young and Elderly Groups (n = 30)

Group		Response Component	
		lat	rit
Total	lat		
	rit	0.44*	
	hrt	0.24	0.30*
Young	lat		
	rit	0.25	
	hrt	0.14	0.38*
Old	lat		
	rit	0.52*	
	hrt	0.31	0.26

*p < .05

Age, recall and SCR by serial list position

Serial order effects are typically observed in both the SCR to repetitive stimulation and in the recall of a list of items; that is, initial stimuli elicit larger SCRs than subsequent stimuli and initial list items are better recalled than later items (cf Craik & Blankstein, 1975). Because these parallel effects were evident in the present data as well, serial position was considered as an independent variable in the analysis of the degree of correspondence between SCR elicitation and picture recall. The stimulus series was divided into 4 consecutive positions, comprising 5, 5, 5, and 5 (or 4) stimuli. The proportion of SCRs elicited in each serial position (that is, the ratio of the number of SCRs elicited to the number of stimuli included in the position) and the mean SCR magnitude in each position were the dependent measures to which three-way analyses involving Age, Memory (recalled or not-recalled) and Position were applied.

Since all 5 pictures occupying the first serial position were successfully recalled by many subjects, measures for the not-recalled category were missing in several cases. As a check on the accuracy of these analyses, the ANOVA programs were repeated using only complete cases, i. e., cases in which there were electrodermal response frequency and magnitude values for recalled and not-recalled picture cate-

gories at every position. Thirteen cases ($n = 13$) in each age group met this requirement.

Proportion of SCRs elicited: total sample

As indicated in Fig 7, pictures which were recalled evoked a larger proportion of SCRs (.59) than pictures which were not recalled (.53), $F(1,58) = 5.12$, $MSe = 0.08$. The frequency with which SCRs were elicited by the picture stimuli decreased from the first to the last position, $F(1,58) = 19.79$, $MSe = 0.10$, and no interaction between Memory category and Position was evident, $F(1,58) = 1.83$, $MSe = 0.07$, NS. The Age variable did not contribute any significant effects, either alone or in interaction with Memory or Position, $F < 1$. Thus, older and young adults were found to display a greater number of SCRs to pictures they recalled than to pictures they did not recall.

Mean SCR magnitude: total sample

The analysis of SCR magnitude revealed significant main effects due to Memory, $F(1,58) = 13.03$, $MSe = 0.01$, and to Position, $F(1,58) = 28.92$, $MSe = 0.03$. The interaction of these variables also was significant, $F(1,58) = 10.40$, $MSe = 0.01$. Pictures that were recalled evoked larger magnitude SCRs than pictures that were not recalled. As indicated in Fig 8, the difference in SCR magnitude between remembered

Figure 7. Proportion of SCR's elicited by recalled and not-recalled pictures, plotted according to serial position of the items.

Figure 8. Mean SCR magnitude elicited by recalled and not-recalled pictures, plotted according to serial position of the items.

and not-remembered items was maximal for stimuli presented at the beginning of the series. The Age factor did not interact with Memory, $F < 1$, Position, $F < 1$, or with the combination of these variables, $F(1,58) = 1.48$, $MSe = 0.01$, NS. It is evident from the figure that SCR magnitude effectively differentiated recalled from not-recalled pictures for both young and older adults, despite the generally reduced SCR in the latter group.

Proportion of SCRs elicited: complete cases

The analysis of the 13 cases for which no cell values were missing yielded results comparable to the analysis using all cases. Briefly, the increased SCR elicitation by recalled pictures was maintained, $F(1,24) = 7.01$, $MSe = 0.08$, as were the effects of serial Position, $F(1,24) = 12.61$, $MSe = 0.09$. No differences due to Age or to the interaction between Age and other variables were demonstrated, $F < 1$.

Mean SCR magnitude: complete cases

Analysis of SCR magnitude also revealed effects in the same direction as the analysis based on all subjects for Memory, $F(1,24) = 7.24$, $MSe = 0.01$, and Position, $F(1,24) = 15.25$, $MSe = 0.03$, as well as for the Memory x Position interaction, $F(1,24) = 4.11$, $MSe = 0.01$. However, no age differences in SCR magnitude were found in the analysis of this restricted sample, $F < 1$.

SCR and recall for HF and LF pictures

Electrodermal responsiveness to HF and LF pictures was assessed by applying a 2 (Age) x 2 (Stimulus Category) x 2 (Memory) ANOVA to the proportion of SCRs elicited (i.e., the proportion of SCRs elicited by HF or LF stimuli that were recalled or not recalled) and to mean SCR magnitude. In these analyses, 6 cases (5 young and 1 old) were omitted because of a missing cell value. Since the data employed in these analyses were the same as in previous analyses, although categorized differently, the overall age effects reported earlier were the same; that is, the elderly did not differ from the young with respect to the proportion of SCRs elicited, but they did produce SCRs of smaller magnitude.

Proportion of SCRs elicited

The mean values used in this analysis are displayed in Fig. 9. LF pictures elicited a larger proportion of SCRs (.60) than HF pictures (.54), $F(1,52) = 4.19$, $MSe = 0.05$. More frequent SCR elicitation to LF stimuli was equally evident in young and elderly groups, as indicated by the absence of an Age x Stimulus Category interaction, $F < 1$. The non-significant interaction between Memory and Stimulus Category, $F(1,52) = 1.38$, $MSe = 0.06$, NS, revealed that SCR elicitation was not associated with recall for either type of picture.

Figure 9. Proportion of SCR's elicited by recalled and not-recalled high (HF) and low (LF) frequency pictures.

SCR magnitude

The analysis of SCR magnitude yielded a significant interaction involving Memory with Stimulus Category, $F(1,52) = 6.36$, $MSe = 0.01$. As shown in Fig 10, recalled LF pictures elicited substantially larger SCRs than either recalled HF pictures or LF items that were not recalled. There were no differences in SCR magnitude between recalled and not-recalled HF pictures.

Memory and skin conductance in elderly subgroups

Because the elderly sample represented a wide age range (60-88 years), memory performance and patterns of electrodermal activity were re-examined for subsamples aged 60-70 ($n=16$) and 71-88 ($n=14$). A group of 15 young subjects was randomly selected for comparison with the elderly subsamples.

Recall

A 3 (Age) x 2 (Stimulus Frequency) analysis of variance was applied to the free recall scores obtained by each group; these scores are presented in Table 4. A significant Age effect was observed, $F(2,42) = 5.46$, $MSe = 0.03$; post-hoc comparisons indicated that young subjects recalled more pictures than the very old (71-88) group. The difference in recall scores between the young and the 60-70 year-old group

Figure 10. Mean SCR magnitude elicited by recalled and not-recalled high (HF) and low (LF) frequency pictures.

Table 4

Mean and (SD) Proportion of Pictures Recalled by
Young, Moderately Old (60-70) and Very Old (71-88) Groups

Group	n	Stimulus Category	
		High frequency	Low frequency
Young	15	.77 (.13)	.65 (.18)
60-70	16	.67 (.17)	.55 (.14)
71-88	14	.62 (.16)	.52 (.15)

was marginally less than the critical value for a .05 level of significance. Notwithstanding these age differences in total recall, all groups recalled a higher proportion of HF than of LF picture, as revealed by the significant Stimulus Category effects, $F(1,42) = 12.56$, $MSe = 0.02$, and the absence of an Age x Stimulus Category interaction, $F < 1$.

Recognition memory

The recognition memory protocols were re-analyzed according to the tripartite age classification. A one-way ANOVA on d' scores revealed that all groups displayed equivalent recognition accuracy. The d' scores obtained by the young and by subjects aged 60-70 and 71-88 were 5.22, 4.62, and 4.55, with corresponding SDs of 1.24, 1.11, and 1.07. All groups adopted a similar response criterion, $F(2,42) = 1.56$, $MSe = 0.03$, NS; for the young, moderately old and very old samples, the B scores were 2.79, 2.70 and 2.81, with corresponding SDs of 0.55, 0.64, and 0.49.

Electrodermal activity

Skin conductance level. A 3 (Age) x 5 (Trials) analysis of resting SCL yielded significant effects for Age, $F(1,42) = 12.76$, $MSe = 6.17$. Over the 5 trials, subjects over 70

years displayed lower SCL ($1.42 \mu\text{mho}$) than subjects aged 60-70 years ($2.32 \mu\text{mho}$) and both older groups exhibited lower levels than young adults ($3.49 \mu\text{mho}$).

Age group comparisons for the 19 pre-stimulus SCL values also showed reliable differences, $F(2,42) = 9.52$, $MSe = 31.4$, with the oldest subjects displaying lower average SCL ($1.31 \mu\text{mho}$) than either the moderately old ($2.46 \mu\text{mho}$) or young subjects ($3.39 \mu\text{mho}$).

Spontaneous fluctuations. The number of SFs produced by the very old group (15.3 , $SD = 16.2$) was smaller than the number emitted by moderately old (31.3 , $SD = 24.4$) or by young subjects (30.0 , $SD = 19.1$). However, owing to the wide variability of SFs, this difference did not reach statistical significance, $F(2,42) = 2.76$, $MSe = 415.77$, $p < .10$.

Time-related measures of the initial stimulus-evoked SCR. Response latency, rise-time and half-recovery time measures for subjects in the three age categories are presented in Table 5. Pairwise comparisons using t-tests for independent samples revealed a significantly longer latency of response for women aged 71-88 relative to the young subjects. No other significant differences were noted.

SCR magnitude over stimulus trials. Age-group differences in the magnitude of stimulus-evoked SCRs also were observed, $F(2,42) = 5.57$, $MSe = 0.27$. As shown in Fig 11, the

Table 5

Mean and (SD) Temporal Measures of the Initial
SCR for Young, Moderately Old (60-70)
and Very Old (71-88) Groups

Group	n	Response Component (sec)		
		Latency	Rise-Time	Half-Recovery Time
Young	15	1.81 (0.52)	1.86 (0.73)	2.37 (1.55)
60-70	16	2.13 (0.59)	2.36 (1.44)	3.08 (2.19)
71-88	14	2.40 (0.49)	1.88 (0.75)	2.28 (1.01)

Figure 11. Mean SCR magnitude elicited by recalled and not-recalled pictures for young ($n = 15$), moderately old ($n = 16$) and very old ($n = 14$) groups.

oldest group displayed smaller SCRs than the other groups, who displayed SCRs of equivalent magnitude over trials.

SCR, recall and stimulus frequency. Of the two analyses which considered the number of SCRs elicited and SCR magnitude in relation to memory performance and either serial list position or the HF/LF stimulus categories, only the latter is repeated here, since it is assumed that both analyses would yield the same overall age effects.

Differences among the three age groups were observed in the analysis of the proportion of SCRs elicited by HF and LF stimuli which were either recalled or not recalled, $F(2,41) = 3.24$, $MSe = 0.28$. Specifically, the oldest group displayed fewer responses (.42) than the moderately old group (.66) or the young sample (.61); these latter groups did not differ from each other. These results are shown in Table 6.

Significant age effects were noted in the analysis of SCR magnitude, $F(2,41) = 5.28$, $MSe = 0.05$. As well, the effects of Memory, $F(2,41) = 12.28$, $MSe = 0.01$, and the interaction of Age and Memory, $F(2,41) = 4.44$, $MSe = 0.01$, were significant. While all age groups tended to exhibit larger SCRs to recalled stimuli, the most conspicuous difference between

Table 6

Mean and (SD) Proportion of SCRs Elicited by HF and LF
 Pictures that were either Recalled or Not-Recalled by Young,
 Moderately Old (60-70) and Very Old (71-88) Groups

Group	n	Recalled		Not-Recalled	
		HF	LF	HF	LF
Young	15	.58 (.32)	.65 (.32)	.59 (.38)	.60 (.36)
60-70	16	.68 (.29)	.78 (.29)	.61 (.30)	.56 (.36)
71-88	14	.45 (.26)	.50 (.32)	.31 (.33)	.41 (.32)

the LF and HF categories occurred in the group aged 60-70. Although LF stimuli which were recalled elicited slightly larger SCRs (0.19 μ mho) than recalled HF items (0.15 μ mho) or not-recalled LF pictures (0.10 μ mho) and HF pictures (0.12 μ mho), the Memory x Stimulus Category interaction did not reach the .05 level of significance, $F(1,41) = 2.57$, $MSe = 0.01$, $p = .12$.

Summary of memory performance and electrodermal activity

In general, young and elderly adults displayed a similar pattern of superior recall for HF pictures; they also exhibited a comparable differentiation of electrodermal responses to recalled and not-recalled items and to HF and LF picture categories. However, elderly adults recalled fewer pictures and produced smaller magnitude SCRs to stimuli. Pictures that were recalled generally elicited more frequent and larger SCRs than pictures that were not recalled. Pictures with LF names elicited more frequent SCRs than HF name pictures, and recalled LF items evoked the largest responses.

The breakdown of the older adult sample into groups aged 60-70 and 71-88 revealed that poorer recall performance and reduced SCL and SCR elicitation in the over-70 group largely contributed to the overall differences between the old and the young adults, since the under-70 group did not differ

appreciably from the young group on measures of recall or electrodermal activity.

SCR habituation to recalled and not-recalled pictures

The electrodermal responses recorded during the habituation training phase were analyzed by means of an independent-groups design in which there were 2 Age levels, 3 Stimulus groups (recalled, not-recalled and not previously shown) and repeated measures on the Trials factor. Responses to the 10 trials were collapsed into 5 blocks of 2 averaged trials.

Skin conductance level

A 2 (Age) x 3 (Groups) x 5 (Trials) analysis of SCL recorded prior to the stimulus sequence yielded significant Age effects, with older women displaying lower SCL than young adults, $F(1,54) = 16.75$, $MSe = 5.32$. No differences among Stimulus Groups were observed, $F(2,54) = 1.42$, $MSe = 5.32$, NS, and the Age x Groups interaction was not significant, $F < 1$.

Parallel findings were obtained for SCL measured at stimulus onset over the 10 trials. Young adults consistently displayed higher SCL, $F(1,54) = 14.39$, $MSe = 15.55$, and SCL was equivalent among Stimulus groups, $F(2,54) = 1.36$, $MSe = 15.55$, NS.

SCR to the initial trial of the habituation series

A between-groups comparison of the SCR elicited on Trial 1 of the habituation session was performed. Differences among Stimulus Groups were noted, $F(2,54) = 5.30$, $MSe = 0.18$. Newman-Keuls comparisons of the group means shown in Table 7 indicated that a stimulus which had not been shown in the original series elicited a larger SCR than did a picture which had been seen but not recalled. None of the other group comparisons was significant. There were no differences due to Age or to the interaction involving Age and Stimulus Groups, $F < 1$.

SCR habituation

A decline in SCR magnitude over the 5 Trial Blocks was observed, $F(1,54) = 13.28$, $MSe = 0.01$. However, there were no differences in SCR habituation as a function of Age, $F < 1$, or of Stimulus Groups, $F(2,54) = 2.12$, $MSe = 0.06$, NS. The habituation curves for young and elderly groups are plotted in Fig 12.

Summary of results for the habituation phase

A picture which had not been shown in the study phase elicited differential responses only in comparison to a not-recalled picture; this effect, however, was limited to the first stimulus trial of the habituation series. The rate of

Table 7

Mean and (SD) of the Initial SCR Elicited During
 Habituation Training by Young and Elderly Groups in
 Recalled, Not-Recalled and Control (New) Picture Condition

Group	Stimulus Groups (n = 10)		
	Recalled	Not-Recalled	Control
Young	0.21 (0.32)	0.09 (0.19)	0.39 (0.38)
Old	0.24 (0.37)	0.13 (0.17)	0.31 (0.29)

Figure 12: Mean SCR magnitude elicited under recalled, not-recalled and control (new) stimulus conditions, plotted against blocks of two consecutive habituation trials.

response decrement over trials did not differ as a function of either prior recall for the stimulus or, indeed, prior presentation. Young and elderly samples displayed SCRs of similar magnitude over the stimulus trials.

DISCUSSION

The principal aim of this study was to apply Ohman's (1979) information-processing model of the OR to the problem of age differences in human memory; by explicating the role of the OR as a mechanism subserving the allocation of attention and cognitive effort, this model offered a framework for exploring the current hypothesis that deficits in attentional processes in old age are responsible for memory decline. Within this context, it was expected that electrodermal OR elicitation and memory for picture stimuli would vary as a function of the relative novelty of the stimulus, which was defined in terms of word frequency. The first issue to be addressed in this discussion is the overall relation between SCR-OR elicitation and recall performance for HF and LF pictures. Age differences in recall and in electrodermal response are then interpreted in light of the functional role of the OR in encoding processes. Similarities between electrodermal and late-evoked potential correlates of memory and of aging are highlighted to support the proposal that deficits in orienting behaviour underlie the age-related memory loss. Anatomical and neuropsychological evidence relevant to the electrophysiological data is also considered, in an attempt to specify the biological factors which contri-

bute to deficits in orienting and in memory. This chapter concludes with a discussion of the rôle of memory in OR elicitation in light of the results obtained in the habituation phase of the study.

The role of the orienting response in memory

As predicted, SCR elicitation was positively related to recall performance, with recalled pictures eliciting more frequent and larger SCRs than not-recalled items. Differences in electrodermal responding between recalled and not-recalled items were most pronounced for stimuli presented at the beginning of the picture series; poorer differentiation for items presented later may be attributed to overriding habituation of responses to successive stimulation. This parallel between response habituation and serial position effects has been signalled by other authors (e.g., Craik & Blankstein, 1975; Levonian, 1972) as a potential confound in the association of psychophysiological measures and memory for serial lists. Including serial order as an independent variable made it possible to more clearly discriminate responses elicited by remembered and not-remembered items across the stimulus series.

Notwithstanding the effects of serial position, the results concur with the majority of studies which demonstrate a positive relation between electrodermal response amplitude

and performance on delayed recall tests (e.g., Corteen, 1969; Kleinsmith & Kaplan, 1963; Maltzman et al, 1966; Walker & Tarte, 1963). The consistency of these findings suggests that the formation of lasting and retrievable traces is facilitated by phasic changes in centrally controlled electrodermal response mechanisms. These phasic changes are regarded as indices of the orienting response, an attentional reflex which facilitates stimulus reception and analysis. Within the context of Ohman's (1979) information-processing view of the OR, the positive relation between SCR elicitation and picture recall can be adduced as evidence that the SCR-OR initiates extensive cognitive processing which enhances stimulus memorability.

Elicitation of the OR signals the absence of a memory trace corresponding to current stimulus input. As Ohman (1979) points out, however, few stimuli are totally unfamiliar to human subjects; thus, the "absence" of a memory for the stimulus must be restricted to the context in which the stimulus occurs; that is, the OR indicates that the stimulus is unfamiliar within the given context. The function of the autonomic, behavioural and electrocortical components of the OR is to remedy this memory deficiency by "opening up" afferent channels in order to analyze the stimulus features thoroughly and register them in memory. In Sokolov's (1969) view, the OR operates as a memory updating system, constantly creating and modifying the organism's internal represen-

tations of the external world. Similarly, for Pribram & McGuinness (1975), the occurrence of an OR reflects the registration of a previously un-represented stimulus in memory.

According to Sokolov (1969) the processing generated by the OR leads to stimulus identification or recognition, which occurs when the neuronal model accurately matches the current stimulus or correctly anticipates future stimulation. Ohman (1979) also considers stimulus identification to be the principal consequence of OR-induced processing, but his model describes in greater detail the mechanisms by which stimulus identification leads to memory formation. In his view, the OR initiates an effortful search of long-term memory for representations associated with the stimulus; since a serial comparison between stimulus features and memory representations is made, this search requires extensive analysis of the stimulus event. Storage of the stimulus trace results from the cognitive effort expended in this search.

This model is compatible with current memory theory, which emphasizes the role of effortful processing in retention. At this point, it may be useful to consider the factors which are thought to lead to retention and how these factors are related to the notion of cognitive effort and to physiological activity. Storage models of memory propose

that information is transferred from STM to LTM by means of rehearsal (Waugh & Norman, 1965) and coding (Atkinson & Shiffrin, 1968). Coding processes include inter-item organization and the use of language and image mediators which serve to elaborate and transform the material to be learned. The levels-of-processing approach (Craik & Lockhart, 1972; Jacoby & Craik, 1979) asserts that retention varies with the depth of perceptual analysis, with deeper, semantic processing yielding better retention than shallower analysis at a structural or phonemic level. Memory is also influenced by the degree of elaboration or extensiveness of processing at any given level. Deep and extensive analysis of information has been termed elaborative rehearsal (Craik & Watkins, 1973) or attending (Darley & Glass, 1975). Whether these encoding processes are conceptualized in terms of breadth, depth or complexity, it is generally agreed that operations that lead to good retention require attentional capacity or cognitive effort (Craik, 1981; Hasher & Zacks, 1979; Tyler et al, 1979).

Electrodermal responses have been associated with at least one factor implicated in retention, that of processing depth. Siddle, Kyriacou, Heron, & Matthews (1979) examined the effects of semantic and non-semantic change in an SCR habituation-dishabituation paradigm. Presentation of a word from a different taxonomic category on a change trial elicited larger dishabituated SCRs than did a word which dif-

ferred in sound but not category (i.e., a phonemic change). These results may be interpreted as an indication that semantic levels of encoding require more cognitive effort than shallower encoding.

The relation between SCR, processing depth and recall was explored in two studies by Zelinski et al (1976; 1978). In the earlier report, deep semantic processing was associated with larger magnitude SCR and with enhanced recall. In the second study, tasks which demanded "active" processing, regardless of depth, induced larger SCRs than passive attending. However, of these "active" processing tasks, only semantic analysis and intentional memorization led to superior retention.

In this research, subjects were given standard intentional learning instructions, which do not specifically guide processing depth. Nevertheless, as the Zelinski et al (1978) study demonstrates, the effort to memorize was associated with enhanced retention. Elsewhere (Craik, 1977), it has been suggested that under "learn" instructions, young subjects encode items semantically, while older subjects merely rehearse items. In the present study, it was noted informally that young subjects reported using categorization (a semantic strategy) to learn the pictures, while older adults typically repeated the pictures to themselves (maintenance rehearsal). It would appear, then, that elicitation of the

SCR-OR reflects effortful encoding operations; it may be also possible that, deep, semantic encoding may underlie the association between the SCR magnitude and enhanced recall.

Orienting and recall as a function of picture novelty

The sensitivity of the OR to stimulus novelty (Sokolov, 1963; 1969) has been invoked to explain the superior retention of LF words in mixed LF and HF word lists (May & Tryk, 1970). In line with this suggestion and with predictions made by others (Snodgrass & Vanderwart, 1980), it was expected that pictures of LF words would elicit more frequent and larger electrodermal responses than pictures with HF names and consequently, that LF words would elicit more frequent and larger electrodermal responses than pictures with HF names and consequently, that LF pictures would be better recalled. As predicted, LF pictures did evoke a larger number of SCRs than HF items. Contrary to expectations, however, HF pictures were better recalled than LF items, and the SCR did not differentiate HF pictures that were recalled from those that were not recalled. Nevertheless, the SCR was sensitive to memory performance for LF pictures.

The first question raised by these findings concerns the superior retention of HF pictures: why are pictures with common word-names better recalled than pictures with infrequent verbal referents when the reverse is observed with mixed lists of HF and LF words? It should be noted that di-

rect comparisons of effects obtained in different experiments are hazardous, owing to the varied and limited samples of items used (Gregg, 1976). Moreover, it cannot be determined in this study whether the ~~opposite~~ effects of word frequency in picture recall are, in fact, due to the peculiar nature of pictures because recall for the corresponding names was not assessed. In a related study reported by Paivio (1976), which presumably involved a set of pictures with varied word frequencies, word frequency was positively related to picture recall, but only under incidental learning conditions; under intentional conditions, no correlation was found between recall scores and the frequency of the picture labels. While it is conceivable that recall effects attributed to word frequency in the present study may be confounded with the effects of other dimensions, such as elaborateness of pictorial detail (e.g., Nelson, Reed, & Walling, 1976) or name agreement (Snodgrass & Vanderwart, 1980), the picture stimuli were not apparently dissimilar with respect to these dimensions. In light of these considerations, it can only be surmised that frequency effects observed in mixed word lists do not apply to pictorial representations. Further research using homogeneous and mixed lists of pictures and corresponding word-names is required to determine the effects more precisely.

A second point of interest is the relation between recall for HF and LF items and SCR elicitation. The greater number

of SCRs to LF pictures relative to HF items may reflect a slower, more laborious access to the semantic memory code for LF pictures (Oldfield & Wingfield, 1965); within Ohman's (1979) perspective, a more effortful search of LTM is required to identify an LF picture stimulus. The differentiation of recalled and not-recalled LF pictures on the basis of SCR magnitude suggests that effortful processing induced by OR elicitation is needed to establish a lasting and retrievable memory trace for these novel stimuli. Recall of HF pictures, however, appears to be less dependent on the degree of processing effort expended in encoding; factors such as associative ease and guessing advantage have been invoked to account for recall of familiar material (Gregg, 1976). Thus, it appears that item recall is not predicated solely on OR elicitation; rather, recall depends more generally on the accessibility of a memory trace to STM, either as a result of well-established associative connections, as in the case of HF items, or as a consequence of OR-initiated processing, as in the case of LF items.

Age differences in picture recall

Like their younger counterparts, elderly women recalled proportionately more HF than LF pictures; it seems that aging does not influence sensitivity to the dimension of word frequency in learning tasks. Indirect support for this conclusion was provided in a recent study of metamemory abili-

ties by Bruce, Coyne & Botwinick (1982), in which older and younger adults similarly predicted that they could recall a greater number of words from high frequency than from low frequency lists.

The age-related decline in total recall scores for pictures also concurs with previous research (Craik & Byrd, 1982; Harwood & Naylor, 1969; Keitz & Gounard, 1976; Winograd & Simon, 1980; Winograd et al, 1982). The extent of the age decrement was mitigated by high verbal ability as indexed by W.A.I.S. Vocabulary scores. These differential effects of aging on memory performance as a function of verbal skill are evidenced in earlier reports as well (Craik & Masani, 1967, 1969; Farrimond, 1968; Hultsch, 1969; Kausler, Hakami, & Wright, 1982). While it is not surprising that verbal intelligence should correlate with performance on verbal memory tasks, the fact that this association is stronger for older than for young adults requires some comment. One explanation is that the further away one is from the constant exercise of learning skills in educational settings, the greater the dependency of memory performance on one's level of intelligence; because laboratory learning tasks closely resemble formal learning situations, they may discriminate intellectual differences in older adults more than in young college students. On the other hand, intelligence test scores have been associated with the integrity of brain function in old age. Verbal subtests in particular have

been found to differentiate normal controls from senile patients (Botwinick & Birren, 1951) and individuals who survived five years after the testing period from those who died (Birren, 1968).

Electrodermal activity and memory in older adults

The correspondence between recall performance and electrodermal responses to stimuli was equivalent in both age groups: young and older adults displayed more frequent and larger magnitude SCRs to pictures they subsequently recalled. In addition, poorer recall in the elderly was paralleled by diminished SCR magnitude. These results appear to support the hypothesis that memory decline in old age is attributable to reduced capacity for effortful processing of information (Craik & Byrd, 1982; Craik & Simon, 1980; Hasher & Zacks, 1979). Before such an assertion can be endorsed, however, it is necessary to consider the relative contribution of changes in peripheral end organ functioning and in central autonomic processes on electrodermal activity in the aged. To pose the question squarely: Is the age-related decrement in SCR magnitude an indication of changes in epidermal structure and functioning or is it indeed a reflection of deficits in OR-initiated stimulus processing?

Perhaps it should be noted first that the lower SCL displayed by the elderly group is consistent with the litera-

ture (Eisdorfer, Doerr, & Follette, 1977; Garwood, Engel, & Quilter, 1979; Lykken, 1982; Powell, Milligan, & Furchtgott, 1980); this phenomenon has been associated with an age-related decrease in the number of active sweat glands on the palmar surface (Catania, Thompson, Michalewski, & Bowman, 1980; Juniper & Dykman, 1967). Moreover, the observation of longer SCR latency in the elderly concurs with the findings of Surwillo & Quilter (1965).

The literature is far less consistent regarding the pattern of stimulus-evoked SCR in the aged. In experiments involving classical conditioning, older adults have displayed restricted electrodermal responses. Botwinick & Kornetsky (1960) found that GSRs to mild shock UCS were more slowly acquired and more rapidly extinguished in older men. Similar results were reported by Shmavonian, Yarmat, & Cohen (1965) using shock and by Shmavonian, Miller, & Cohen (1968) in discrimination conditioning to auditory tones. These investigators concluded that diminished GSR conditioning in the elderly stemmed primarily from reduced autonomic reactivity, due possibly to hypothalamic deterioration. Morrow, Boring, Keough, & Haesly (1969) challenged this hypothesis by demonstrating that older adults displayed a similar degree of differential conditioning despite reduced SCR magnitude; these authors argued that aging affects peripheral end organ activity rather than autonomic conditionability.

Studies of electrodermal activity during reaction time tasks have yielded results consistent with the hypothesis of autonomic under-arousal in old age (Garwood et al, 1979; Powell et al, 1980). Research involving serial learning tasks, however, has shown either reduced SCR magnitude only in subjects over 70 years of age (Zelinski et al, 1978) or no age differences in SCR (Powell et al, 1980).

Similar inconsistencies are found in experiments which have used a simple habituation paradigm. Eisdorfer et al (1977) recorded electrodermal activity while subjects exhaled against 40 mm Hg for 12 sec (Valsalva maneuver) during a 30 min period. No differences in SCR between young and elderly groups were observed. Catania et al (1980) also failed to find age differences in SCR elicited by repeated presentations of a 1000 Hz tone. In contrast with these reports, Lykken (1982) obtained a negative correlation between age and SCR magnitude; range-correction, however, eliminated this association.

The electrodermal research fairly consistently indicates an age-related decrement in tonic levels and possibly in the speed of sudomotor activation which can be attributed to peripheral organ deterioration. The collage of discrepant findings regarding phasic response measures, however, makes it difficult to disentangle changes in central nervous system activity which may underlie cognitive deficits from ex-

traneous epidermal factors. Contradictions in the data cannot be explained with reference to differences in recording technique (constant current versus constant voltage), since varying results have been obtained with both methods. Differences in research paradigm may partially account for the discrepancies; an age decrement in SCR was observed in most conditioning experiments but not in habituation paradigms. The age of the elderly subjects employed in electrodermal research should be considered, particularly since both the present study and the Zelinski et al (1978) report revealed a noticeable decline in responses emitted by persons over 70 years of age. Nevertheless, as most of the work cited here used subjects with approximately the same age distribution (60-75), this factor cannot explain the lack of concordance in the SCR data. Elderly people tend to be less homogeneous than the young with respect to physical health (Botwinick, 1978); it is therefore possible that varying health in the samples used contributed to differences in SCR elicitation. Clearly, further research is needed to delineate the influence of age, health and task conditions on electrodermal responsiveness in elderly populations.

Although the nature and degree of the relationship between electrodermal responsiveness and cognitive functioning in the aged remain to be fully specified, the correspondence observed here between SCR magnitude and memory performance is not coincidental; while peripheral factors cannot be ig-

nored, it is clear that central mechanisms are implicated in the differential sensitivity of the SCR to recalled and to not-recalled HF and LF pictures observed here. It is thus reasonable to suppose that the mechanisms which mediate orienting and memory function less efficiently in old age. There is ample evidence of an age-related deficit in the acquisition of learning phase of memory (e.g., Salthouse, 1982; Smith, 1980); if acquisition corresponds biologically to the registration of information in the nervous system and if the OR indexes this registration (Pribram & McGuinness, 1975), then acquisition deficits in the elderly should be mirrored by deficits in the orienting response.

Separate analysis of memory performance and electrodermal measures for subgroups of older adults aged under and over 70 years showed that the more senior group displayed both smaller SCRs and poorer recall than the young adults. Women aged 60-70 displayed SCRs comparable to those of the young and did not differ significantly from the young in recall performance. Zelinski et al (1978) also examined SCR and recall for subgroups of elderly subjects aged 55-70 and 71-85. As in this study, very old adults displayed smaller SCRs than the young or the moderately old; also, the very old performed more poorly than either group on a test of immediate recall. Young and moderately old subjects did not differ in SCR magnitude nor in immediate recall, but after a 48 hour delay, moderately old subjects recalled fewer items

than the young. Differences in the length of the retention interval may account for the discrepancy between the present findings and those of Zelinski et al regarding SCR and retention in a moderately old group; Salthouse (1982) has noted that older adults have a slightly higher rate of forgetting than the young after 24 hour retention periods.

In any event, the observed differences between younger and older subgroups of elderly subjects lend support to Neugarten's (1974) suggestion that the elderly comprise in reality two distinct generations: the young-old (55-75) who are active, healthy and intellectually intact, and the old-old (75+) who show signs of physical and mental deterioration. Other investigators have noted a decline in intellectual test performance up to 5 years prior to death (Birren, 1968; Riegel & Riegel, 1972). This "terminal drop" in cognitive functioning is attributed to organic deterioration (Riegel & Riegel, 1972). In the context of the present study, it may be inferred that optimal learning and memory functioning in the elderly is accompanied by a sustained capacity to display ORs to environmental stimulation.

Range-correction and age differences in SCR

Because the present data indicate a functional correspondence between electrodermal responsiveness and memory in old age, the value of range-correction as a means of attenuating

individual variation in electrodermal activity is questioned. In both this research and Lykken's (1982) study, range-correction eliminated age differences in SCR magnitude. In the present instance, the association between SCR and memory performance for the elderly would be nullified by using range-corrected SCR values. In earlier statements (Lykken & Venables, 1971; Lykken, 1972) Lykken suggested that central autonomic and peripheral influences on SCR were additive; more recently, however, (Lykken, 1982), he proposed that these effects are interactive in populations in which variation in both factors can be presumed. Hence, range-correction is probably inappropriate in electrodermal research on aging, since some of the effects due to central nervous processes as well as peripheral epidermal influences may be eliminated by this method of data transformation.

Cortical evoked-potentials, orienting and memory

The emerging research on the relation of the late positive evoked-potential P300 component to memory bears a striking resemblance to studies of electrodermal response and memory. These avenues of psychophysiological research appear to complement each other both empirically and theoretically. Moreover, the growing evidence of age differences in cortical evoked potentials promises to shed light on the neural processes underlying cognitive deficits in old age.

In a comparative review of the evoked-potential and electrodermal literature, Roth (1983) has enumerated the similarities in experimental conditions used to elicit the P300 and the SCR. First, both are elicited by novel, or task-relevant stimuli; in the case of unexpected stimuli, the magnitude of the response is inversely related to the probability of stimulus occurrence. Second, P300 and the SCR-OR are non-specific with respect to stimulus modality or direction of stimulus change. Third, repetitive stimulation leads to habituation of both responses. Schandry and his co-workers, in particular, have reported that P300 habituates to the same degree as the SCR to varying conditions of stimulus intensity and interstimulus interval (Lutzenberger, Schandry, & Birbaumer, 1979; Schandry & Hoefling, 1979; Schandry, Sparrer, & Elton, 1982). Moreover, parallels exist between interpretations of the role of P300 and of the SCR. The P300 is identified with the detection of a matching or a mismatching stimulus, or, in Donchin's (1981) terms, with the updating of a contextual schema. The SCR, in turn, is regarded as a component of the orienting response, which is implicated in the formation of a neuronal model (e.g., Sokolov, 1969). Both P300 and the SCR-OR are thought to initiate effortful, controlled processing of the eliciting stimulus (Donchin, 1981; Ohman, 1979). Not surprisingly, researchers have attempted to incorporate interpretations of P300 within the framework of OR theory or vice versa (e.g., Donchin,

1981; Ohman, 1979; Roth & Kopell, 1973; Roth, 1983; Schandry et al, 1979).

Recent work from Donchin's laboratory (Donchin, 1981; Karis, Fabiani, & Donchin, 1982) has defined a link between P300 evoked by verbal stimuli and memory. In the Karis et al study, single words printed in larger or smaller type than surrounding words evoked larger P300 components and were better recalled. The research paradigm is quite similar to that used in electrodermal studies of memory and suggest that the late positive component may bear the same relationship to memory as the SCR-OR.

To date, research focussing on adult age differences in cortical potentials has been largely descriptive in nature, and inferences regarding the association of age-related changes in averaged evoked potentials and cognitive performance in the elderly have been limited (Marsh & Thompson, 1977; Smith, Thompson, & Michalewski, 1980; Woodruff, 1982). A systematic increase in P300 latency to auditory stimuli with advancing age has been reported by Squires, Chippendale, Wrege, Goodin, & Starr (1980). Patients with dementia exhibit longer P300 latencies than do normal older persons or non-demented patient groups, and increases in P300 latency are associated with progressive deterioration in the mental status of demented patients. Increasing P300 latency with age is interpreted as an indication of the slowing of

cognitive processing. An age-related decrease in the auditory evoked P300 (Brent, Smith, & Michalewski, 1977) and in the emitted P300 to stimulus omission (Michalewski, Patterson, Bowman, Litzleman, & Thompson, 1982) also has been observed; amplitude reduction is attributed by these investigators to orienting deficits in older adults.

In summary, the SCR-OR and the P300 evoked potential component seem to be closely associated psychophysiological phenomena. Although additional research is needed to clearly establish the role of P300 in memory, the available evidence suggests that P300, like the SCR-OR, may be functionally related to memory and may be differentially sensitive to memory decline in old age.

Aging and the neural substrates of memory and the OR

There is some convergence in the literature concerning the neural substrates implicated in the orienting response and memory, as well as in the aging of the central nervous system which may be helpful in pinpointing the mechanisms that contribute to the age-related decline in memory.

Since Scoville & Milner's (1957) now classic description of the severe anterograde memory deficits exhibited by an epileptic patient who sustained a bilateral removal of the medial temporal lobes, this area of the brain, and specifically, the hippocampus, has been ascribed a central role in

memory formation. Although the hippocampus has not been identified with certainty as the sole structure critical to memory (e.g.; Squire, 1982), it is clear that the degree of memory impairment is associated with the severity of hippocampal damage (Milner, 1970); since patients exhibit marked impairment on tests of delayed recall or recognition of new material, the hippocampus has been implicated in memory consolidation, or the transfer of transient traces in STM to permanent storage in LTM. Because the hippocampus regulates the excitatory influence of the reticular formation on the cortex, it is suggested that memory consolidation results from reticular activation induced by hippocampal slow wave activity (Bloch, 1976; Lhermitte & Signoret, 1976).

Soviet investigators have claimed that the hippocampus plays a central role in OR elicitation and habituation (Grastyan, 1959; Sokolov, 1975, 1976; Vinogradova, 1975). Using electrophysiological recording techniques, Vinogradova (1975) has demonstrated that the modulatory effect of the hippocampus on cortical arousal varies as a function of stimulus probability. Similar findings were reported in the West by O'Keefe & Nadel (1978), who identified cells in the hippocampus which fire when an animal encounters an unfamiliar object or when an expected object is missing. In light of these observations, Sokolov (1975) concluded that the hippocampus acts as the "model comparator" which detects a change in environmental stimulation and which induces corti-

cal arousal to facilitate stimulus reception and analysis. Further, he suggested that the hippocampus may play a role in memory as a consequence of its role in OR elicitation.

The neuropathological changes accompanying both normal aging and dementia are predominant in the hippocampus and in frontal and temporal regions of the cortex (Adams, 1980; Bondareff, 1980), with normal and disease-related degeneration differing mainly in degree (Petit, 1982). The link between memory impairment and the deterioration of hippocampal and adjacent brain tissue in humans is primarily correlational (Adams, 1980), although it has been found that hippocampal damage in senescent rats limits the long-term potentiation of neural firing, an example of brain plasticity which is construed as a neural model of memory (Barnes, 1979). In research focussing on human memory loss, the tactic has been to compare deficits exhibited by amnesics and lesioned animals with those displayed by the normal aged and seniles. Albert & Kaplan (1980) have noted similarities in cognitive performance between older normals and patients with lesions in the frontal system, an area extending from the reticular formation to the frontal cortex via the limbic structures and the thalamus. Winocur (1982) observed parallels between institutionalized elderly persons and hippocampal amnesics in the pattern of recall deficits displayed in a proactive-interference task.

Abnormalities in OR elicitation and habituation among seniles were reported in two studies by Jonsson, Malhammer, & Waldton (1976, 1977). In the 1977 paper, SCR and motor OR (head turning) elicitation thresholds were positively correlated with the degree of mental deterioration in the senile group. Moreover, many of the seniles did not display any SCR-OR to light stimuli. In the earlier study, the motor ORs of seniles to auditory stimuli did not habituate over repeated trials and SCR-ORs to light stimuli were not displayed by half of the patient group. Jonsson et al concluded that deterioration of structures responsible for neuronal model formation underlie memory deficits in senile dementia. A related suggestion was put forward by Albert & Kaplan (1980), who interpreted changes in SCR and P300 with aging and dementia in terms of impaired functioning of the frontal structures implicated in selective attention and anticipation.

In summary, the hippocampus appears to be involved in orienting and in memory; indeed, the role of the hippocampus in memory consolidation may result from its role in OR elicitation. Learning and memory deficits displayed by normal aged persons and to a greater extent, by senile patients, coincide with the extent of hippocampal damage. It seems reasonable to conclude that the OR deficits indexed by reduced SCR elicitation and possibly by decreased P300 amplitude are functionally related via the hippocampus to memory decline in old age.

The role of memory in SCR habituation

There is a general consensus among both neurophysiologically oriented researchers (e.g., Kandel, 1976; Thompson, Berry, Rinaldi, & Berger, 1979) and cognitively oriented researchers (Sokolov, 1963; 1969; 1976; Ohman, 1979; Wagner, 1976) that response habituation is indicative of stimulus memory. At the cellular level, habituation is thought to reflect more or less stable synaptic changes (Groves & Thompson, 1972; Kandel, 1976; Thompson et al, 1979); cognitively, habituation denotes the presence of a complete neuronal model of the stimulus. Recent approaches to habituation have emphasized information-processing constructs in an attempt to explicate the relationship between OR habituation and memory processes (Ohman, 1979; Wagner, 1976). However, few investigators have applied an information-processing model of habituation to problems in human attention and memory (Goldwater & van Dorén, 1982; Kroese & Siddle, 1983; Stelmack et al, 1983).

According to Wagner (1976), habituation reflects the availability of a stimulus representation in STM. Within a training session, habituation to an iterated stimulus occurs because the stimulus event is still active in STM (primed) when the next stimulus is presented. Response decrement to a previously presented stimulus on a test trial, i.e., long-term habituation, occurs as a result of prior extensive cen-

tral processing of the stimulus which leaves a trace accessible to STM. The extent of prior central processing determines the rate of habituation to the stimulus on a subsequent presentation.

In this study, it was reasoned that, as a result of greater central processing, a recalled picture would elicit a smaller SCR-OR on the first trial of a stimulus series and would habituate more readily than would a picture that was not recalled, or a picture that was not shown in the learning phase. Of further interest was the comparison of habituation rates for the different stimulus conditions between young and elderly groups. There is some evidence (Buschke, 1974) which suggests that older adults are less consistent in their ability to recall learned material; it was expected here that retrieval inefficiency in the elderly would be manifested by a larger initial SCR and slower habituation to a previously recalled stimulus relative to young subjects.

The effects were limited to the SCR displayed on the initial stimulus trial, with new pictures eliciting larger responses than not-recalled pictures. The fact that these not-recalled pictures were subsequently identified correctly on the recognition memory task suggests that the decrement in SCR-OR is mediated by recognition processes in memory; that is, presentation of an "old" stimulus readily accesses a stored representation in memory with minimal cognitive ef-

fort. This would suggest that the decision (Mandler, 1980) or matching processes in recognition memory are relatively automatic or effortless (e.g., Schneider & Shiffrin, 1977). In this respect, the effects observed here are consistent with those obtained by Stelmack et al (1983), in which stimuli that were recognized on a recognition memory task elicited smaller magnitude initial SCR-ORs than did stimuli that were not recognized.

Neither Wagner (1976) nor Ohman (1979) differentiate recall from recognition processes in their explanations of habituation. Ohman has recently expressed the view (personal communication, 1983) that recognition processes are more relevant to the OR than recall. In the present study, recall may have been confounded with recognition in the habituation paradigm, since all recalled pictures were subsequently recognized as well. One would have expected, therefore, that the presentation of recalled items would induce at least the same degree of OR inhibition as the presentation of not-recalled, but recognized items. It is not clear why the SCR-OR to recalled stimuli did not differ from the response elicited by the new stimulus items.

In brief, the data fail to support the prediction that recalled items would induce smaller SCR-ORs and greater habituation than not-recalled items as a function of the more extensive processing received by recalled items. It is no-

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teworthy that Goldwater & van Doren (1982) - also failed to find evidence that more extensive initial processing induces faster habituation; in their experiment, no differences were observed in habituation of responses to stimuli which had been presented in the "attend" or "ignore" channel in a prior dichotic listening task.

In the present study, no age differences in SCR habituation were found under any stimulus condition. At one level of interpretation, these results suggest that memory mechanisms involved in long-term habituation are similarly efficient in young and elderly adults. At another level, the contrast between the absence of age differences observed in the habituation session and the presence of an age-related decline in SCR observed in the learning phase is consistent with the suggestion made earlier that differential SCR elicitation in young and aged groups may be a function of task conditions. The distinction proposed by Zelinski et al (1978) between active and passive processing requirements may be applicable here; that is, tasks which explicitly engage subjects in effortful stimulus processing may be more effective in producing age differences in electrodermal response than tasks which do not make cognitive processing demands. In any event, the failure to find age differences in SCR in a simple habituation paradigm concurs with the findings reported by Catania et al (1980) and Eisdorfer et al (1977).

Conclusion

This study clearly demonstrated that SCR elicitation is positively related to recall performance: recalled items elicited more frequent and larger responses than not-recalled pictures. The results generally concur with earlier studies and may be adduced as evidence in support of Ohman's (1979) view that the OR signals a call for effortful processing which enhances stimulus memorability.

Contrary to predictions based on memory studies using mixed lists of high and low frequency-words, superior recall for HF pictures was observed. While it would appear that the frequency attribute and the representational form have interactive effects on recall performance in mixed lists, further research using mixed and homogeneous picture and word lists is required to determine these effects more precisely.

The SCR was found to be differentially sensitive to memory for HF and LF pictures; SCR elicitation was positively associated with recall for LF items but not for HF stimuli. In light of this finding, some refinement of predictions derived from OR theory regarding human memory is in order. Stimulus recall cannot be predicated solely on OR elicitation; rather, it seems that item recall depends more generally on the availability of a stimulus trace in STM, either as a result of a priori familiarity, as in the case of HF

items, or as a consequence of OR-initiated effortful processing, as in the case of LF pictures.

The general age-related decline in picture recall observed here is consistent with the literature on picture memory in the aged. The observation that older persons with high vocabulary skills maintain a higher level of recall performance than do people with poor vocabulary also concurs with earlier reports, and suggests an association between cognitive functioning and the integrity of the central nervous system in old age. Furthermore, since the elderly displayed larger SCRs to items they recalled, it may be inferred that the dependency of recall on effortful encoding remains similar across the lifespan.

Although SCR elicitation was positively associated with recall performance in elderly as in young adults, the magnitude of stimulus-evoked SCRs in the elderly was smaller. To the extent to which OR-initiated cognitive effort determines stimulus memorability, poorer memory performance in older subjects can be attributed to reduced cognitive effort. Thus, the present results support the attentional-deficit explanation of memory decline in old age advanced by Craik (Craik & Bryd, 1982; Craik & Simon, 1980) and by Hasher & Zacks (1979).

Lower skin conductance level and possibly also the decrease in the speed of sudomotor response activation may be

attributed to changes in epidermal structure and functioning which accompany aging. However, the relative contribution of peripheral epidermal and central autonomic factors to stimulus-evoked SCR in the elderly has not yet been clearly defined, although there is some indication in the literature that these factors may be interactive. While peripheral influences cannot be ignored in accounting for the age differences in SCR magnitude obtained here, it is reasonable to infer that central mechanisms responsible for the differential sensitivity of the SCR to remembered stimuli operate somewhat less efficiently in old age. This suggestion is supported by evidence from the evoked-potential literature, where it is found that P300 amplitude is similarly predictive of memory performance and that older adults display reduced P300 amplitude.

Neuropathological changes in the aging nervous system occur principally in regions implicated in selective attention and memory consolidation, notably the hippocampus and frontal and temporal cortex. Since the hippocampus is considered to play a crucial role in OR elicitation and may be involved in memory as a consequence of its role in orienting, deterioration of this structure in senescence may account for the diminished capacity of older adults to generate ORs and to register information adequately in memory.

In the habituation phase, SCR-OR decrement to a not-recalled relative to a new stimulus was demonstrated, but no differential effects of recall on SCR elicitation and habituation were noted. It is tentatively proposed that long-term habituation is mediated by recognition processes in memory which involve a matching of current stimulus input with a stored trace. The absence of SCR-OR decrement to a recalled stimulus fails to support the prediction that more extensive stimulus processing facilitates subsequent long-term habituation. Furthermore, the failure to find age differences in the SCR to the different stimulus conditions suggests that memory processes assumed to underlie OR habituation are equivalent in young and elderly persons. Overall, the results obtained in the habituation phase indicate that further research is needed to clarify the memory processes that determine response habituation in humans.

In conclusion, the results reported here endorse Ohman's (1979) assertions that the OR initiates the allocation of attentional resources or cognitive effort to encode incoming stimuli, and that the memorability of novel stimuli is dependent upon OR elicitation. The functional relationship linking the OR to memory is evident for both young and elderly adults. More importantly, the age-related decline in memory is indexed by reduced OR elicitation. This finding bears directly upon the attentional-deficit explanation of age differences in human memory and further suggests that

age-related changes in attentional processes may be usefully examined in the context of OR theory.

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APPENDIX A

Thorndike-Lorge (T-L) and Kucera-Francis (K-F) Word Frequency Counts
(Per Million Words) and Toglia-Battig (T-B) Word Familiarity Ratings
(1-7) for the Picture Stimuli

Stimuli	T - L	K - F	T - B
Stimuli presented in study phase			
Arm	100+	94	6.4
Dice	8	14	-
Door	100+	312	6.8
Chair	100+	66	6.7
Cane	19	12	-
Harp	20	1	-
Cigar	16	10	6.1
Vase	12	4	5.7
Shoe	100+	44	6.4
Tricycle	1	-	-
Star	100+	25	6.5
Hat	100+	56	6.6
Needle	34	15	6.1
Octopus	2	1	-
Kite	10	1	6.0
Hand	100+	431	6.6
Book	100+	193	6.8
Tree	100+	59	6.5
Trumpet	17	7	5.8
Dress	100+	67	6.3

APPENDIX A (cont'd)

Thorndike-Lorge (T-L) and Kucera-Francis (K-F) Word Frequency Counts
(Per Million Words) and Toglia-Battig (T-B) Word Familiarity Ratings
(1-7) for the Picture Stimuli

Stimuli		T - L	K - F	T - B
Distractors presented in recognition memory task	Arrow	37	14	-
	Sled	8	-	-
	House	100+	591	6.3
	Foot	100+	70	6.3
	Ring	100+	47	6.1
	Alligator	6	4	5.3
	Table	100+	198	6.4
	Bird	100+	31	6.3
	Fish	100	35	6.2
	Teepee	0	-	-
	Cactus	2	-	-
	Scissors	8	1	6.4
	Cat	100+	23	6.4
	Rocket	4	7	5.9
	Cross	100+	55	5.9
	Car	100+	274	6.8
	Carrot	9	1	6.4
	Bed	100+	127	6.5
	Kettle	27	3	6.0
	Lobster	7	1	6.1

APPENDIX B

ANOVA Summary Tables for the
Principal Statistical Analyses

APPENDIX B-1

Summary of Analysis of Variance for the Proportion
of HF and LF Pictures Recalled by Young and Elderly Groups

Source	df	MS	F	Prob.
Age				
Between groups	1	0.49	12.96	.001
Error	58	0.04		
Picture Frequency				
Between types	1	0.31	18.52	.001
Types X Age	1	0.01	0.10	.76
Error	58	0.02		

APPENDIX B-2

Summary of Analysis of Variance for the Proportion
of Items Recalled by Young and Elderly Groups Over Serial List Position

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.89	10.55	.002	
Error	58	0.08			
Serial Position					
Between positions	3	1.04	21.17	.001	.001
Positions X Age	3	0.04	0.83	.48	.48
Error	174	0.05			

APPENDIX B-3

Summary of Analysis of Variance for Pre-Stimulation
SCL Sampled Over 19 Stimulus Trials for Young and Elderly Groups

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	591.36	13.82	.001	
Error	58	42.80			
Trials					
Between trials	18	0.06	0.91	.56	.50
Trials X Age	18	0.05	0.70	.82	.67
Error	1044	0.07			

APPENDIX B-4

Summary of Analysis of Variance for SCR Elicited
by 19 Picture Trials for Young and Elderly groups

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	1.49	4.15	.05	
Error	58	0.36			
Trials					
Between trials	18	0.83	17.18	.001	.001
Trials X Age	18	0.06	1.24	.22	.28
Error	1044	0.05			

APPENDIX B-5

Summary of Analysis of Variance for Range-Corrected SCR
Elicited by 19 Picture Trials for Young and Elderly Groups

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.44	1.56	.22	
Error	58	0.28			
Trials					
Between trials	18	0.89	19.87	.001	.001
Trials X Age	18	0.04	0.83	.66	.67
Error	1044	0.04			

APPENDIX B-6

Summary of Analysis of Variance for Frequency of SCRs
Elicited by Recalled and Not-Recalled Pictures Over Serial List
Position for Young and Elderly Groups (Total Sample)

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.37	0.74	.39	
Error	58	0.50			
Recall					
Between outcomes	1	0.42	5.12	.03	
Recall X Age	1	0.06	0.72	.40	
Error	58	0.08			
Position					
Between positions	3	1.99	19.79	.001	.001
Position X Age	3	0.07	0.71	.71	.55
Error	174	0.10			
Recall X Position	3	0.14	1.83	.14	.15
Recall X Position X Age	3	0.02	0.23	.88	.86
Error	174	0.07			

APPENDIX B-7

Summary of Analysis of Variance for SCR Magnitude
Elicited by Recalled and Not-Recalled Pictures Over Serial List
Position for Young and Elderly Groups (Total Sample)

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.57	5.13	.03	
Error	58	0.11			
Recall					
Between outcomes	1	0.19	13.03	.001	
Recall X Age	1	0.01	0.10	.75	
Error	58	0.01			
Position					
Between positions	3	0.81	28.92	.001	.001
Position X Age	3	0.02	0.79	.79	.50
Error	174	0.03			
Recall X Position	3	0.15	10.40	.001	.001
Recall X Position X Age	3	0.02	1.48	.22	.23
Error	174	0.01			

APPENDIX B-8

Summary of Analysis of Variance for Frequency of SCRs
Elicited by Recalled and Not-Recalled Pictures Over Serial List
Position for Young and Elderly Groups (Complete Cases)

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.13	0.22	.64	
Error	24	0.57			
Recall					
Between outcomes	1	0.57	7.01	.01	
Recall X Age	1	0.01	0.08	.78	
Error	24	0.08			
Position					
Between positions	3	1.17	12.61	.001	.001
Position X Age	3	0.09	0.98	.41	.39
Error	72	0.09			
Recall X Position	3	0.09	1.20	.32	.32
Recall X Position X Age	3	0.04	0.50	.68	.67
Error	72	0.08			

APPENDIX B-9

Summary of Analysis of Variance for SCR Magnitude
Elicited by Recalled and Not-Recalled Pictures Over Serial List
Position for Young and Elderly Groups (Complete Cases)

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	0.001	0	.96	
Error	24	0.13			
Recall					
Between outcomes	1	0.08	7.24	.01	
Recall X Age	1	0.001	0.09	.77	
Error	24	0.01			
Position					
Between positions	3	0.49	15.25	.001	.001
Position X Age	3	0.01	0.18	.91	.76
Error	72	0.03			
Recall X Position	3	0.05	4.11	.01	.02
Recall X Position X Age	3	0.002	0.20	.90	.85
Error	72	0.01			

APPENDIX B-10

Summary of Analysis of Variance for Frequency of SCRs
Elicited by Recalled and Not-Recalled HF and LF Pictures
for Young and Elderly Groups

Source	df	MS	F	Prob.
Age				
Between groups	1	0.25	0.83	.37
Error	58	0.30		
Recall				
Between outcomes	1	0.70	13.88	.001
Recall X Age	1	0.02	0.32	.57
Error	52	0.05		
Stimulus Frequency				
Between frequencies	1	0.22	4.19	.05
Frequency X Age	1	0.01	0.15	.70
Error	52	0.05		
Recall X Stimulus Frequency	1	0.08	1.38	.25
Recall X Stimulus Frequency X Age	1	0.01	0.15	.70
Error	52	0.06		

APPENDIX B-11

Summary of Analysis of Variance for SCR Magnitude
Elicited by Recalled and Not-Recalled HF and LF Pictures
for Young and Elderly Groups

Source	df	MS	F	Prob.
Age				
Between groups	1	0.32	5.15	.03
Error	58	0.06		
Recall				
Between outcomes	1	0.29	15.30	.001
Recall X Age	1	0.01	.30	.59
Error	52	0.02		
Stimulus Frequency				
Between frequencies	1	0.03	2.43	.13
Frequency X Age	1	0.002	.20	.66
Error	52	0.01		
Recall X Stimulus Frequency	1	0.08	6.36	.01
Recall X Stimulus Frequency X Age	1	0.05	3.52	.07
Error	52	0.01		

APPENDIX B-12

Summary of Analysis of Variance for Proportion of HF
and LF Pictures Recalled by Young, Moderately Old (60-70)
and Very Old (71-88) Groups

Source	df	MS	F	Prob.
Age				
Between groups	2	0.15	5.46	.01
Error	42	0.03		
Stimulus Frequency				
Between frequencies	1	0.27	12.56	.001
Frequency X Age	2	0.001	0.02	.98
Error	42	0.02		

APPENDIX B-13

Summary of Analysis of Variance for Prestimulation SCL
 Measured over 19 Stimulus Trials for Young, Moderately Old (60-70)
 and Very Old (71-88) Groups

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	2	298.98	9.52	.001	
Error	42	31.40			
Trials					
Between trials	18	0.03	0.53	.95	.83
Trials X Age	36	0.04	0.65	.95	.84
Error	756	0.07			

APPENDIX B-14

Summary of Analysis of Variance for SCR
Elicited by 19 Picture Trials for Young, Moderately Old and Very Old Groups

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age					
Between groups	1	1.50	5.57	.007	
Error	42	0.27			
Trials					
Between trials	18	0.53	13.38	.001	.001
Trials X Age	36	0.05	1.24	.16	.27
Error	756	0.04			

APPENDIX B-15

Summary of Analysis of Variance for Frequency of SCRs
Elicited by Recalled and Not-Recalled HF and LF Pictures
for Young, Moderately Old and Very Old Groups

Source	df	MS	F	Prob.
Age				
Between groups	2	0.92	3.24	.05
Error	41	0.28		
Recall				
Between outcomes	1	0.38	10.09	.002
Recall X Age	2	0.07	1.89	.16
Error	41	0.04		
Picture Frequency				
Between types	1	0.10	1.86	.18
Types X Age	2	0.01	0.18	.83
Error	41	0.05		
Recall X Picture Frequency	1	0.03	.75	.39
Recall X Picture				
Frequency X Age	2	0.03	.74	.49
Error	41	0.04		

APPENDIX B-16

Summary of Analysis of Variance for SCR Magnitude
Elicited by Recalled and Not-Recalled HF and LF Pictures
for Young, Moderately Old and Very Old Groups

Source	df.	MS	F	Prob.
Age				
Between groups	2	0.28	5.28	.009
Error	41	0.05		
Recall				
Between outcomes	1	0.16	12.28	.001
Recall X Age	2	0.06	4.44	.02
Error	41	0.01		
Picture Frequency				
Between types	1	0.01	0.72	.40
Types X Age	2	0.01	0.94	.40
Error	41	0.01		
Recall X Picture Frequency	1	0.03	2.57	.12
Recall X Picture Frequency X Age	2	0.02	1.13	.33
Error	41	0.01		

APPENDIX B-17

Summary of Analysis of Variance for Prestimulation
 SCL Elicited over 10 Stimulus Habituation Trials
 for Young and Elderly Groups in Recalled, Not-Recalled
 and Control (New) Picture Conditions

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age	1	223.81	14.39	.001	
Conditions	2	21.13	1.36	.27	
Age X Conditions	2	5.12	0.33	.72	
Error	54	15.55			
Trials	9	0.12	1.20	.28	.31
Trials X Age	9	0.08	0.73	.71	.53
Trials X Conditions	18	0.12	1.15	.28	.33
Trials X Conditions X Age	18	0.10	0.98	.48	.43
Error	486	0.10			

APPENDIX B-18

Summary of Analysis of Variance for SCR Magnitude
Elicited on Trial 1 of the Stimulus Habituation Trials for
Young and Elderly Groups in Recalled, Not-Recalled
and Control Picture Conditions

Source	df	MS	F	Prob.
Age	1	0.001	0.01	.92
Conditions	2	0.30	3.27	.05
Age X Conditions	2	0.02	0.22	.81
Error	54	0.09		

APPENDIX B-19

Summary of Analysis of Variance for SCR Magnitude
Elicited on Trial Blocks 1-5 of the Stimulus Habituation Series
for Young and Elderly Groups in Recalled, Not-Recalled
and Control Picture Conditions

Source	df	MS	F	Prob.	Greenhouse Geisser Prob.
Age	1	0.01	0.21	.65	
Conditions	2	0.12	2.12	.13	
Age X Conditions	2	0.05	0.88	.42	
Error	54	0.06			
Trials	4	0.17	13.28	.001	.001
Trials X Age	4	0.01	0.39	.82	.72
Trials X Conditions	8	0.02	1.66	.11	.15
Trials X Conditions X Age	8	0.01	0.88	.54	.50
Error	276	0.01			