Attention & Memory

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RED

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ATTENTION AND MEMORY

BY

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PERGAMON PRESS

OXFORD · NEW YORK · TORONTO · SYDNEY · PARIS · FRANKFURT

U.K.	Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England
U.S.A.	Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A.
CANADA	Pergamon of Canada, P.O. Box 9600, Don Mills M3C 2T9, Ontario, Canada
AUSTRALIA	Pergamon Press (Aust.) Pty. Ltd., 19a Boundary Street, Rushcutters Bay, N.S.W. 2011, Australia.
FRANCE	Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France
WEST GERMANY	Pergamon Press GMbH, 6242 Kronberg/Taunus, Pferdstrasse 1, Frankfurt–am–Main

Library of Congress Cataloging in Publication Data

Underwood, G

1. Attention. 2. Memory. I. Title. [DNLM:
1. Attention. 2. Memory. BF321 U56a]
BF321.U5 1975 153.1'2 75–17614
ISBN 0–08–019615–2
ISBN 0–08–018754–4 pbk.

Printed in Great Britain by A. Wheaton & Co., Exeter

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Publisher: Robert Maxwell, M.C.

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PREFACE

How do we select information from the world around us, represent it to ourselves, and use it to guide our behaviour? Stated concisely these are the questions to which this book addresses itself, but given the refined nature of the apparatus which we use to acquire information from the world, and given the enormity of the amount of information available, then the simplified nature of the questions becomes apparent. The inevitable conclusion of a review text such as this must be that psychologists have only just begun to look away from artificial laboratory situations and towards the human being as an interactive element in a very complex environment. The subject matter of the book is biassed very heavily towards our ability to process verbal material, and that is because this is the major source of evidence when we start to consider the questions of the operation of attention and memory. This operational approach engages discussion of both the structural constraints to our knowledge of, and behaviour in, the world, and the processing strategies used within these constraints. As a review of the psychological evidence available about human memory and its major control process, attention, the book is intended for use in conjunction with undergraduate and graduate courses in experimental psychology. The text grew out of a course of lectures which had the same title as the book, and which were delivered to undergraduates here between 1972 and 1974. Revisions and elaborations were performed both in Nottingham and at the University of Waterloo during 1974 and 1975. My own views on the nature of the attention process, on the unitary trace theory of memory, and on the automaticity of word recognition have been influenced by a number of colleagues, many of whom despair at the conclusions reached here. These influences will nevertheless be apparent to the reader.

Deserving of particular thanks for commenting upon discussions now contained in the text are John Brown, Phil Bryden, Chris Darwin, Ian Howarth, Doug Mewhort, Neville Moray, Joel Singer, and Dave Wood. Especial thanks should also go to Jean Underwood for her assistance in the task of organizing the bibliography and indexes.

We wish to thank the following publishers for permission to reproduce figures in the text:
Human Factors Society for Figs. 1.2 and 1.4; the American Association for the Advancement of Science for Figs. 1.5 and 3.6; the American Psychological Society for Figs. 1.7, 1.8, 2.2, 3.2, 3.5, 5.4, 3.8 and 4.2; the North Holland Publishing Company for Fig. 1.10; the Canadian Psychological Association for Fig. 1.11; Academic Press for Figs. 1.13, 1.14, 1.15a, b, 2.3, 2.5a, b, c, 2.8, 2.9, 3.4, 3.9, 4.4 and 4.5; the Experimental Psychology Society for Figs. 2.4, 2.10 and 2.15; the University of Illinois Press for Fig. 2.7; the Psychonomic Society for Figs. 2.12, 3.1; and the American Institute of Physics for Fig. 4.2. Thanks also go to the authors concerned.

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ERRATUM

p. 144 The caption to Fig. 3.4 should read: "Mean percentage of words recalled over trials for lists repeated with the same or with changing quartet groupings. (From Bower, Lesgold and Tieman, 1969.)"

p. 145 The caption to Fig. 3.5 should read: "Mean recall errors over four trials for noise items and for items repeated with the same grouping or with different groupings. (From Bower and Winzenz, 1969.)"

CONTENTS

CHAPTER 1

IMMEDIATE (SENSORY) MEMORY

A resilient view in modern psychology is that human memory can best be described as comprising two systems, short-term and long-term memory. However valid or invalid this distinction may be, we are now compelled to add at least one other system, and this may be described as immediate or sensory memory. The justification of this addition is the subject of the present chapter, together with the consideration of the separation of processes within the concept of sensory memory. The division and sub-division of memory is more than an academic exercise, even though this purpose alone has its merits in the assistance of the development of psychological science. In the description of the representation of knowledge by human memory we shall necessarily draw conclusions about optimal presentation and retrieval procedures, which should be transferable to non-laboratory situations where information processing is presently inadequate. The model-building approach to the investigation of memory, prevalent during the last ten years, is not without its limitations however. Not the least of these limitations is that model-builders have tended to lose sight of the *purpose* of the components which they have been satisfied to include in their flow-charts. Although the present approach will attempt to keep sight of the purposes of the processes to be described, the reader should be aware of this fault with this and with any description of memory and its control processes.

Immediate Memory of Visual Events

One of the earliest experiments performed on human memory processes has been revived over the past few years, with a corresponding updating of its interpretation. The amount of visual information which we can apprehend at any one instant was considered by the Scots philosopher Sir William Hamilton (1859). He noticed that if we look at six objects or less we can say how many are present without much difficulty. If the number is increased then increasing difficulty is experienced in judging how many objects are present. This would suggest a limit on the amount of information which we can perceive at a time, and Hamilton's remarks were tested empirically by Jevons in 1871. Jevons threw beans into a tray, never knowing in advance how many would have to be estimated, and quickly judged the number landing in a predefined area. When three of four beans were present no errors were made, but when more than this fell into the test field then errors became more frequent as the number of beans increased. When 10 beans were estimated Jevons was correct about 50% of the time, but with fifteen beans he was correct in his estimate on only 18% of trials. As recently as 1954 Woodworth and Schlosberg described these results as indicating the upper limit to the span of attention, that is, the amount of information which we may perceive at any one time, and hence suggesting a perceptual limitation explanation. Use of the tachistoscope, giving accurate and short exposures of visual displays enabled replication of the span of attention result for the case of written material. Erdmann and Dodge (1898) found that 4 or 5 unrelated letters could be reported when the letters were exposed for 100 msec.These data have been used traditionally as support for a theory of behaviour in which information is said to be perceived, stored in memory, retrieved from memory, and used to guide the response. Hence the profusion of compartmentalized courses in Psychology under the headings of "Perception", "Memory", "Skills", etc. That perception and memory are interrelated rather than serial processes has been demonstrated convincingly by Sperling (1960), in an experiment which challenged the traditional interpretations of Hamilton, Jevons, and Erdmann and Dodge. Sperling pointed to the fact that subjects often claimed that they saw much more than they could report in these experiments, and went on to show that the subject can perceive almost all of the items presented in a short exposure. The limitation to the "span of attention" must occur at some other stage than the layman's notion of "memory". In this experiment subjects were shown three rows of unrelated letters with four letters in each row, a typical stimulus array being shown in Fig. 1.1. Displays of this type were shown for 50 msec. and shortly after termination of the display the subject

S N T R

P K L A

D Q J M

Fig. 1.1. A display of the type used by Sperling (1960).

heard a tone. This tone indicated which one of the three rows of letters the subject was to report. A high tone instructed the subject to recall the letters from the top row of the display, a medium tone the centre row, and a low tone the bottom row. The important feature of the experimental design is that the tone is presented after the display has been removed from sight, so the subject must attempt to remember all 12 letters until the tone is heard, at which point a part of the display is reported. From the "span of attention" data provided by Erdmann and Dodge we might have expected that subjects would only have 4 or 5 letters available from the 12 presented. As these letters would be distributed over three rows then only 4/3 or 5/3 letters, on average, would be reported from any one row. However, Sperling found that subjects were able to remember about 3 letters out of the 4 required on each test trial (i.e. about 75% recall, on average). They could report about 3 letters from any of the 3 rows, and since they did not know which row would be cued for recall then this must mean that they could have recalled about 75% of any row. Hence the subjects must have had 75% of the total display available for recall after the presentation had finished. That is, about 9 of the 12 letters were in some form of memory after the display had been terminated and before presentation of the tone which cued recall. Whereas the early experiment had suggested that the span of attention is 4 or 5 letters, the Sperling experiment shows clearly that this is not the case. It is this sort of counter-intuitive result which distinguishes Psychology as an experimental science.

An explanation of the discrepancy between results from the 'whole report' procedure of Erdmann and Dodge on one hand and the 'partial report' procedure of Sperling on the other hand is provided by recall data when the tone, whichever the row required, is delayed. With a cue which follows immediately after the display we infer that about 9 letters are available, but if the cue is delayed for 1 second then only 4·3 letters are available from the whole display – a figure similar to that reported by Erdmann and Dodge. What is happening in this 1 second interval that affects recall to such an extent? Sperling has argued that his experiments provide evidence for the existence of a visual memory system in which items decay extremely rapidly and are lost from this system within 1 second. This decay function can be seen in Fig. 1.2, which shows the result of an experiment reported by Sperling (1963) in which the total

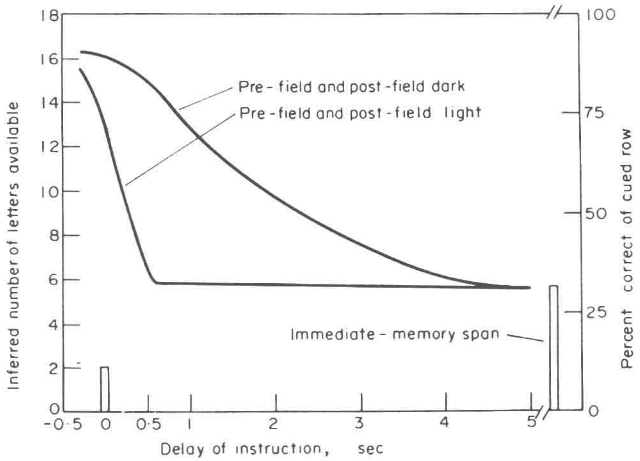

Fig. 1.2. Recall of briefly presented visual displays with whole and partial report cues. The immediate memory span corresponds to the number of items recalled from the whole display. When the subject is instructed to recall part of the display, and the cue follows with a short delay, then a large proportion of the target set may be recalled. This implies that for a short period a large proportion of the whole display is available. (From Sperling, 1963.)

numbers of letters in the display was 18. As the delay between termination of the display and onset of the tone is increased from 0 seconds to 0·5 seconds the number of letters reported drops from about 75% of the number presented to about 30%. Thereafter the delay of cue makes little difference to the number of letters reported: the partial report had been asked to recall items anywhere in the display. The proportion of items reported would be the same for any row, cued or uncued.

Sperling explains this result by postulating the use of a memory system in which all of the visual display is stored in the form in which it is presented, that is, as a series of visual images rather than a series of meaningful symbols. This visual representation, which Neisser (1967) described as the "icon", has a very short life and so information must be extracted from it very quickly if the original stimulus is exposed for a short time. In very general terms, Sperling considers that estimates of a span of apprehension of 4 or 5 items reflect not the capacity of the first system of storing information which is presented to us, but the number of items which can be extracted from this visual memory before the icon has decayed. In support of this notion a number of experiments have been reported which suggest that physical cues may be used to advantage in the partial report situation, but that semantic cues give no advantage if items are sorted in visual memory prior to being processed for meaning we would not expect their meaning to be of any use in selecting which items from the total set are to be recalled from the visual store, and this is the case. Clark (1969) found that subjects could selectively retrieve from visual memory items of one colour in multi-colour presentations, with the same effect as Sperling's subjects could selectively retrieve items on the basis of their spatial location in the display.Turvey and Kravetz (1970) were also able to use the shape of the items as a basis for selection. Semantic information cannot be used as a selection cue in the same way. Sperling (1960) presented mixed displays of letters and digits, with the tone cueing recall of letters or digits. In this situation subjects were unable to recall the same proportion of digits or letters as they did when recalling items from the whole display, digits and letters. This reaffirms Sperling's view that visual memory is a precategorical store, that information is stored in visual memory prior to being analysed for semantic content. Our ability to select information on the basis of physical rather than semantic features is a debatable issue, however, a number of experiments suggesting that non-selected (and presumably selected) sources of information are processed to some extent and not simply rejected following the analysis of physical characteristics. This particular debate is also a feature of work on the problem of selective attention: given competing auditory inputs (the "cocktail party" situation) and the need to listen to one at the exclusion of others then what cues do we use to select the relevant message? The simple answer is, again, that we use the physical characteristics of the message, but it is apparent that the semantic content of relevant and irrelevant messages may also be effective.

What could be the purpose of a literal memory of a visual scene which persists for a quarter of a second or so? It is a useful facility to have when engaged as a subject in a tachistoscope experiment, but its usefulness elsewhere may be justifiably questioned. Buswell (1922) reported that skilled readers fixate for above a quarter of a second, and Mackworth and Morandi (1967) found that duration of eye-fixations whilst looking at a picture was not much greater than this figure. Thus, we do present ourselves with a tachistocopic view of the world, fixating briefly on different aspects of the environment to synthesize our perceptions. The purpose of the icon in this process is to ensure that we always have a stimulus representation which persists long enough for us to extract the important information from it.

Sperling, in 1967, described how he evolved a model to handle results concerning the inter-relation of sensory and short-term memory systems. It may be useful to follow Sperling's reasoning here, both as an exercise in the method of theory-building prevalent in experimental psychology, and for the purposes of comparison with other models of memory which are to appear in later chapters. The basic question asked by this series of models was: "Why is there a limitation to the amount of information reported following a brief exposure?". The answer offered by the first model suggests that only 4 or 5 items are usually recalled because after these items have been read out of the visual store the icon has faded, and items are no longer extractable. The limit here is due directly to the fading of the visual image. Figure 1.3a indicates the stages of processing which would be sufficient to describe such an explanation. This model may be rejected quite simply because by the time the subject begins to execute the response of writing or speaking the icon has already disappeared. The icon has a very fast decay function, and the latencies between the end of the presentation and the response greatly exceed the period of life of the visual image (VIS in Fig. 1.3).

The second model postulates intervening processes between visual storage and output (Fig. 1.3b). The major modifications are the introduction of a process of auditory coding and a process of auditory rehearsal. Auditory coding is implicated in memory experiments by the

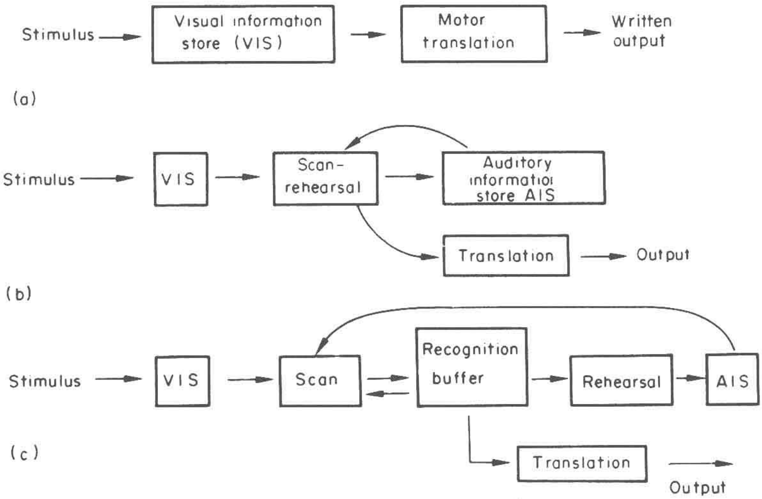

Fig. 1.3. a-c. Sperling's (1967) successive approximations to a model of storage and response to briefly presented visual stimuli.

occurrence of acoustic confusion errors with visual presentations: items sounding the same (e.g. "P,B,G,D,T") are recalled less well than items which are acoustically distinct (Conrad, 1964). Items are said to be transferred from visual memory to auditory memory by means of subvocal rehearsal, and the response is facilitated via the rehearsal loop from a form of auditory storage. As the cued items are read out of iconic memory they are subvocally rehearsed, and thereby stored in auditory memory. The limit to the number of items reported would therefore be a function of the rate of decay of the iconic image *and* upon the rate of reading items out of iconic memory into auditory memory. The problem with this model is that the speed of rehearsal cannot keep up with the speed of extraction of information from the display. Fig. 1.4 indicates the rate at which items can be extracted from visual displays.

In this experiment Sperling (1963) found the number of items which can be reported with varying exposure durations. At the end of exposure a "visual noise" mask was presented, thus preventing the formation of an

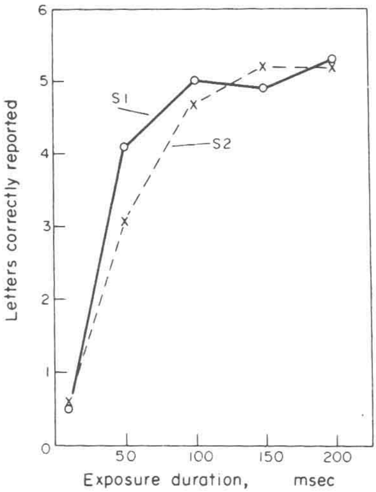

Fig. 1.4. The number of letters reported correctly as a function of the exposure duration. The pre-exposure field was dark, and the post-exposure field was a random dot pattern ("visual noise"). The two curves are for the two subjects.(From Sperling, 1963.)

image which would persist after termination of the display. Fig. 1.4 indicates that the first few items are processed at a rate of between 10 msec and 20 msec per item. Thus the model would have to allow transfer from iconic to acoustic memory at this rate, which may be the same as the subvocal rate of rehearsal. However, it is not possible to rehearse words at such a fast rate, and Landauer (1962) has found that it takes more than 100 msec to rehearse subvocally a single syllable. Hence either the model is inadequate in that subjects could not have been encoding items in auditory memory immediately as they read them out of visual memory, or the supposition that rehearsal rates are identical to read-out rates is incorrect, and so Landauer's data would not be pertinent.

The third model retains the rehearsal process, but gives it several functions (Fig. 1.3c). The "scan" function represents the subject's strategy of acquisition of information from the iconic image available to him, and is evidently restricted to the use of information about the physical