The processing of temporal information.
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Summary

The empirical work carried out in this study is founded on two basic propositions. The first of these states that time means information to man. As such, it should be viewed as an independent property of the flow of information that we experience as reality and cannot be distinguished from properties or patterns of information such as size, colour, loudness or spatial location.

The second proposition refers to the relationship between time and memory processes. Over the last few years, experimental studies in the field of memory research have become more focused on the ways in which humans process temporal information. The main aim of the present study is to further this approach and to begin to explore the variables that govern our ability, or lack of it, to distinguish by memory the ordering of events in time.

The particular path followed can be summarized most clearly by reiterating the three important questions raised issues related to the what, when, and how of temporal information processing.

The what issue involves asking what in a stimulus configuration actually constitutes the functional stimulus or temporal attribute which serves as the input for temporal judgments. The second question, the when issue, asks whether the temporal attribute, once identified, is encoded upon acquisition or, instead, constructed during retrieval. Thirdly, the how question asks whether temporal information is processed as an inevitable, automatic byproduct of information processing in general, or whether temporal information processing in itself requires specific cognitive effort.

Chapter 2 discusses the methodological issues involved in exploring the encoding and retention of temporal information. The three types of experimental tasks employed in the present study, namely order judgments, lag estimates and position judgments are described and the difficulties which arise when we try to compare such measures are
The main topic of Chapter 3 relates to the automatic/controlled distinction as it applies to temporal information. Although various theories of attention are mentioned, the main emphases in this chapter are on the positions adopted by Hasher and Zacks in 1979 and Tzeng and his colleagues in 1979 and 1980. Hasher and Zacks consider memory processes as a function of attention and qualitatively different types of processing. They present a list of criteria which are necessary for distinguishing between automatic and effortful processing and also present evidence to substantiate their framework.

Notwithstanding the paucity of the evidence they produce, they reach the firm conclusion that temporal information is automatically encoded. Conceptual confusions in their arguments are discussed and a diametrically opposed viewpoint is put forward, namely "... temporal information is not encoded unless noticed and not noticed unless meaningful!" (Michon & Jackson, 1984, p. 305).

The position adopted by Tzeng and his colleagues also introduces conceptual confusions about what should be called automatic processing. Whereas they claim that their process model follows an automaticity view, we argue that it also seems to incorporate some non-automatic features, namely rehearsal processes.

Since it makes an excellent starting point for our empirical studies, the set of criteria proposed by Hasher and Zacks is used to explore and indeed rebuffer the automaticity viewpoint. These studies are described in Chapters 4-7 and their aim is to provide empirical evidence to answer the what, when, and how questions posed earlier. Given, however, that these three questions are not independent, but are intricately intertwined, we have selected to take as the starting point of our research the how question, and will attempt to integrate the other related questions into our experimental analysis. The first two experiments described in Chapter 4 use a directed forgetting paradigm in which subjects are cued either to remember or to forget each item. The main aim of the experiments is to explore the influence of stimulus characteristics on temporal judgments. Results show that knowledge of temporal
information varies depending on whether the items are cued to-be-remembered or to-be-forgotten but also, and more importantly, depending on whether stimulus material consisted of concrete or abstract items. This latter pattern of results is difficult to fit into the automatic processing framework. The differences found suggest that something extra, possibly related to selective attention demands or processing strategies, plays an important role. Results from the third experiment also show that knowledge of temporal information varies depending on whether stimulus material is concrete or abstract. This experiment explicitly explored the criterion of incidental versus intentional learning. Unlike the previous research quoted by Hasher and Zacks, the results show that explicit instructions do affect the amount of temporal information retained, and that this effect is particularly evident when abstract material is used.

In Chapter 5, a levels-of-processing procedure similar to that of Craik and Lockhart (1972) is used to explore whether a rehearsal set constitutes a necessary condition for the successful performance of temporal judgments, as was suggested by Tzeng et al. (1979). Results confirm this suggestion, since no temporal judgments exceed a random guessing level following an orienting task which simply required a shallow level of processing (i.e. paying attention to the physical structure of words). Results of an orienting task which demanded a deeper level of processing (i.e. paying attention to the semantic structure of a word) are less straightforward, with significant differences in performance occurring between various temporal judgment tasks.

These results therefore challenge the view that all temporal coding takes place automatically but do, on the other hand, support earlier findings from our laboratory which show that while order judgments reflect some automatic encoding of intrinsic order, such coding is not sufficient to enable subjects to perform more complex temporal judgment tasks adequately. These tasks require more deliberate processing. Taken together, results from these three experiments begin to tackle the what issue: they suggest that intrinsic order is indeed a suitable candidate to serve as the functional stimulus or temporal attribute for temporal judgments. Furthermore, they give some answers to the when issue: intrinsic order is acquired at time of encoding.
In Chapter 6 the fifth criterion discussed by Hasher and Zacks, namely developmental trends, is explored. If, as these authors suggest, the processing of temporal information is automatic, it should follow that performance on temporal tasks is relatively insensitive to developmental variables. While experiments 5 and 6 studied the performance of young children (5- and 11-year olds) on various temporal judgment tasks, Experiment 7 compared the performance of two adult groups (24- and 60-year olds). The results from these three experiments appear at first sight to be somewhat contradictory: with some temporal judgment tasks, no developmental effects are found but with others, significant developmental differences are observed. They are, however, in line with evidence we have cited previously which claimed that different temporal tasks require different qualitative levels of processing. If words are indeed attended, intrinsic order is encoded without further processing and this leads to above chance responding on order judgment tasks in 5- as well as 11-year olds, and in older as well as younger adults. Other temporal judgment tasks on the other hand, require additional deliberate processing in order to produce accurate levels of performance. Since it is precisely with this deliberate type of processing that developmental effects occur, we predicted that developmental effects would be found with position as well as with lag judgment tasks. Our predictions are met in these three experiments.

In Chapter 7, both the discontent which arose as a result of always relying on group data, and the cognitive strategy approach which developed as a result of this discontent, are discussed. A small in-depth study (Experiment 8) used protocol analyses to discover the strategies which individuals use when carrying out various judgment tasks. These protocols are then used to construct a fairly extensive list of the various strategies which could be adopted. In two of the experiments described in this chapter, Experiments 9 and 10, a simplified coding system which involves grouping strategies into two main clusters, simple or elaborative rehearsal, is adopted. During the study and test phase of the experiment subjects in each condition are treated as a uniform group. Prior to statistical analyses, however, they are assigned to one of the two strategy groups. Although dramatic changes depending on either list structure or task demands had been expected, these expectations are not fulfilled. Instead, subjects tended to continue with their original choice of strategy.
An important research question which was explored in these experiments asks whether there is a relationship between strategy use and performance. Results from all three experiments reveal positive effects, with subjects who use elaborative strategies performing better. Performance on temporal tasks is therefore closely related to the strategies subjects use. In addition, performance also reveals a considerable 'effect of practice'. These criteria are, however, among those cited by Hasher and Zacks as being indicative of the deliberate information processing mode.

Chapter 8 summarizes our position and gives answers to the three important questions posed in Chapter 1. We adopt the stance that time is an inherent property of nature justifying in an objective way the distinction between earlier and later. Our task as a psychologist is therefore described as one of establishing how this order is coded and represented. The experimental results support our belief that intrinsic order constitutes the functional stimulus which serves as the input for temporal judgments. Furthermore, this order is acquired at time of encoding. The third issue relating to the how question is not so straightforward. Using their own criteria, we have collected a considerable amount of data which directly challenges Hasher and Zacks (1979) automaticity stance.

We have also found experimental results which suggest that encoding intrinsic order relationships is a necessary but not sufficient condition to produce adequate temporal retention in all tasks. Instead, we suggest that a hierarchy exists such that different temporal judgment tasks demand different levels of processing: simply being available in working memory for further processing is a necessary condition to lay down old-new relationships, and these in turn are in the main sufficient to produce above-chance levels of performance on order judgments. In contrast, both position and lag judgments require further deliberate processing of these old-new relationships in order to produce high levels of performance.

The position adopted assumes that the temporal information which is coded relates to sequential information and that other temporal information, such as interval information, is derived from this coded information. Unless attended to and processed further, however, such information loses validity. While a loss of validity affects position and
lag judgments, order judgments can still be made fairly adequately.

The final issue discussed relates to the representation of order information. The ideas expressed in this study fit well within the representational system described by Anderson (1983). He proposes a separate representational code for temporal information and suggests that "temporal strings" record the sequential structure of events. Our data also lend some credibility to a further (preliminary) suggestion raised by Anderson, namely that positional and interval information may and can be deliberately encoded as extra features.