

## Chapter 11. Contextual Coding in Memory: Studies of Remembered Duration<sup>1</sup>

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Two metatheories have dominated psychological studies of memory and of time during this century. Although the historical pattern of adoption of these metatheoretical approaches overlaps somewhat, one of them is clearly older. The older metatheory has roots in the behavioristic and neobehavioristic psychology of the earlier part of this century, but it extends it; branches into some recent information processing psychology. I refer to this as a *stimulus-based* approach, because it emphasizes memory for stimulus events per se. The newer metatheory originates in some cognitive psychology of the later part of this century. I refer to this as a *context-based* approach, because it emphasizes contextual coding in memory.

Consider first the stimulus-based paradigm. It is implicitly based primarily on a mechanistic root metaphor, or ›world hypothesis‹, discussed so well by Pepper (1942), although it also partially relies on what he called a formistic root metaphor. The prototypical example of the adoption of this approach by memory researchers was the verbal learning tradition of the 1940s, 1950s, and early 1960s, which emphasized stimulus-response associations. It was initially assumed that memory could be adequately characterized in terms of associations between relatively meaningless stimuli and relatively meaningless responses. Later, many researchers realized that this framework was insufficient to describe the complexities of human memory.

In the last decade or two, the mechanistic flavor of this approach has receded somewhat, but the emphasis on memory for stimulus information remains, even if it is sometimes tempered by phraseology such as ›stimulus-as-coded‹. Information processing models of human memory, which implicitly or explicitly adopt a computer metaphor, can be seen to be primarily mechanistic, or perhaps a mixture of mechanistic and formistic root metaphors (Hoffman & Nead, 1983; Pepper, 1942). In theorizing on the experience of duration, Ornstein (1969) explicitly relied on a computer metaphor. He referred to the ›storage size‹ in memory taken up by encoded and retrievable stimulus information as determining the remembered duration of a time period. He assumed that if more stimuli occurred during a time period, or if the stimuli were coded in a more complex way, the experience of duration would lengthen. Indeed, Ornstein conducted several cleverly designed experiments that seemed to support this particular embodiment of a stimulus-based metatheory, his ›storage size metaphor‹ of remembered duration. Fraisse (1984)

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stated that this is the leading account of effects on the estimation of duration in retrospect, although his view would be questioned by some researchers.

Now consider an alternative conceptualization of memory, one which is context-based. It is derived from contextualism, another root metaphor discussed by Pepper (1942). One of the earliest proponents of this approach among memory theorists was Jenkins (1974), who concluded: »What is remembered in a given situation depends on the physical and psychological context in which the event was experienced, the knowledge and skills that the subject brings to the context, the situation in which we ask for evidence for remembering, and the relation of what the subject remembers to what the experimenter demands« (p. 793). In a somewhat similar way, Estes (1980) asserted that human short-term memory is »oriented toward events and their attributes rather than toward the retention of items as units« (p. 65). A contextualist approach, such as that advocated by Jenkins and a few other cognitive scientists, divides the world into two basic ontological categories – events and changes. Contextualism emphasizes that change and novelty are inherent in observer-environment interactions and that every event has a unique quality and texture. It rejects the notion of permanent structures; instead, it emphasizes the »salient or important aspects of events« that depend upon »the observer's particular purposes« (Hoffman & Nead, 1983, p. 519).

In the past I have not adopted a »pure« contextualist approach to remembered duration, but rather a combination of mechanism and contextualism. I wish to explore a more purely contextualist approach in the present selective review and report of my research. To do so entails a rejection of the mechanistic assumption of relatively static memory structures, such as those that comprise Ornstein's (1969) »storage size«. Instead, dynamic terms must be used to describe the encoding of contextual information and its use in judging the duration of a time period in retrospect.

### Review of Previous Studies

A selective review of some of my previous studies on remembered duration is needed as background for the present study. These studies are all characterized by a common methodology. Events occurred during each of two moderately long periods of equal duration (between 54 and 280 s). Then subjects unexpectedly were asked to judge the relative duration of the two time periods. Half of the subjects judged the first time period relative to the second, and the other half judged the second time period relative to the first (see Ornstein, 1969). Table 1 presents a summary of these studies, including a characterization of independent variables as well as main effects<sup>2</sup>. All data reported here are expressed in terms of the ratio of the apparent duration of the first time period ( $D_1$ ) to that of the second time period ( $D_2$ ), even though a different ratio was used in some of the original articles.

<sup>2</sup> The analysis of main and residual (i.e., interaction) effects is based on the methods which have recently been described clearly by Rosenthal & Rosnow (1984, Chapter 21).

Table 1. Summary of main effects in previous studies

	Description of treatment	Treatment effect <sup>a</sup>	Time-Order effect <sup>b</sup>
Block (1978)			
Experiment 1	Complex (C) vs. simple (S) stimuli	$C \approx S \pm 0.00$	$D_1 > D_2 + 0.21^*$
Experiment 2	Complex (C) vs. simple (S) sequence	$C > S \pm 0.11^*$	$D_1 > D_2 + 0.14^*$
Block & Reed (1978)			
Experiment 1	Deep (D) vs. shallow (S) processing	$D \approx S \pm 0.01$	$D_1 > D_2 + 0.12^*$
Experiment 2	Mixed (M) vs. unmixed (U) processing	$M > U \pm 0.09^*$	$D_1 > D_2 + 0.15^*$
Block (1982)			
Experiment 1	Disruption only Disruption & change		$D_1 > D_2 + 0.12^*$ $D_1 \approx D_2 + 0.03$
Experiment 2	No Disruption Disruption only Disruption & change		$D_1 > D_2 + 0.19^*$ $D_1 > D_2 + 0.07^*$ $D_1 \approx D_2 - 0.04$
Experiment 3	Mixed (M) vs. unmixed (U) processing Disruption only Disruption & change	$M > U \pm 0.09^*$ $M \approx U \pm 0.01$	$D_1 \approx D_2 + 0.05$ $D_1 \approx D_2 + 0.04$

Note. Significant effects are indicated by an asterisk (\*). <sup>a</sup>Treatment effects are shown as plus or minus the amount by which the mean in each condition differed from the overall mean. An effect of  $\pm 0.11$ , for example, indicates that *remembered duration* was 22 percent longer in the first condition listed than in the second condition listed. <sup>b</sup>Time-order effects are shown as the amount by which the mean  $D_1/D_2$  judgment ratio differed from 1.00 (the theoretical mean).

### Event and Sequence Complexity

Two experiments on effects of complexity (Block, 1978) gave me the first indication that Ornstein's (1969) stimulus-based storage size metaphor was fundamentally incorrect. In the first experiment, the complexity of individual stimuli did not affect remembered duration, as would be predicted by Ornstein's hypothesis. In the second experiment, a more complex *sequence* of stimuli was remembered as being about 22 percent longer in duration than a less complex sequence. The nature of the entire sequence of events – the »texture« of the whole experience – seemed to be much more important than the nature of the individual stimuli.

In addition, a positive time-order effect was observed in both experiments: with all other factors equal or controlled by counterbalancing, the first duration was remembered as being longer than the second duration. Discussion of this important effect is postponed until a later section.

### *Levels of Processing and Changes in Processing*

The results of another study (Block & Reed, 1978) also supported a context-based, rather than a stimulus-based, account. In the first experiment, subjects spent a 64 s duration processing 32 words at either a *shallow*, structural level or a *deep*, semantic level. Then they performed the other kind of processing during a second 64 s duration. The remembered duration of the deep processing task was not greater than that of the shallow processing task. However, recognition of the stimulus words was considerably greater for those that were deeply processed. Thus, a measure of the »storage size« of stimulus information »remaining in storage« showed that more stimuli were retained as a result of the deeper, semantic processing. Ornstein's (1969) hypothesis – as well as other similar hypotheses like those of Block (1974) and Fraisse (1984) – simply cannot explain these data.

In order to clarify these findings, we conducted a further experiment. Subjects either performed structural or semantic processing (as in Experiment 1) or alternated between the two kinds of processing during the first of two 80 s durations; they performed the other kind of task during the second time period. The duration containing alternating, or *mixed*, kinds of processing was remembered as being about 18 percent longer than the *unmixed* duration, regardless of whether the unmixed processing was structural or semantic. Again, a stimulus-based storage-size hypothesis would not predict and cannot easily explain this finding, because later recognition of words from the mixed task was intermediate between recognition of words from the shallow processing task and recognition of words from the deep processing task.

These findings seemed to support a *contextual-change hypothesis*, a more dynamic explanation which asserts that remembered duration is based on »memory for the overall change in cognitive context« during a time period (Block & Reed, 1978, p. 664; see also Block, 1979). In these experiments, a major kind of contextual change was assumed to be produced by variations in process context; that is, because the mixed-processing task required different kinds of cognitive processes, dynamic changes in the internal context resulted (see B.J. Underwood, 1977). The quality of the mental events that occurred during the whole duration apparently caused changes in memory in a fairly direct way, perhaps as a byproduct of the particular processing of stimulus information. It is on this quality – what we referred to as the amount of contextual change rather than on memory for stimulus information *per se* that subjects apparently rely in order to judge the duration of a time period in retrospect. If this is the case, judgments of duration may be expected to play a central role in any contextualist account of memory: »Retrospective judgment of duration may serve... as an index of the overall amount of change in cognitive context« during a time period (Block & Reed, 1978, p. 665).

### *Changes in Environmental Context*

Three more recent experiments investigated environmental context as another potential source of contextual changes (Block, 1982). In the first two experiments, 15 stimulus words were processed in the same way during each of two 150 s durations. Thus, both the number of words and the complexity of coding of the words were held constant. The experimental manipulation simply concerned the room, or environmental context, in which the two tasks were performed. If subjects spent the second time period in a room which was different from that in which they spent the first time period – that is, if the environmental context was both disrupted and changed – the remembered duration of the second time period was relatively longer (i.e., about 23 percent longer than it would have been judged had the environmental context not been changed). The remembered duration of the second time period was also slightly lengthened if subjects simply were asked to leave the room (and then to return to the same room) in between the two time periods – that is, if there was simply a disruption of context between the two durations. Thus, the remembered duration of the second time period was relatively longer to the extent that the encoding of the environmental context during the second time period was assumed to be changed in some way. As before, these experiments reveal effects on remembered duration that simply cannot be explained by a stimulus-based hypothesis, such as Ornstein's (1969) storage size hypothesis or Fraisse's (1984) adaptation of it.

A third experiment explored the possibility of interacting effects of environmental- and process-context changes. The environmental context manipulation was the same as that in the first two experiments; the process context manipulation was similar to that used by Block and Reed (1978, Experiment 2), which was discussed earlier. This experiment revealed a main effect of process context which replicated that found in the earlier experiment.

More importantly, there was an interaction of the two kinds of contextual factors: If there was no change in environmental context between the two durations, the effect of process context was substantial; but if the environmental context was changed, the effect of process context was eliminated. One possible explanation is that the changes in environmental context were more salient aspects of the experimental situation than the changes in process context. In other words, different kinds of contextual factors do not necessarily produce additive effects on remembered duration, so that the person's subjective reaction to the quality – the »total meaning« (Jenkins, 1974, p. 786) – of the situation is of critical importance.

### *Results of Present Study*

The results of four recent experiments (Block, Note 1) enable us to distinguish between two versions of a contextual-change hypothesis. The findings also rule out any sort of explanation in terms of the storage size of stimulus information. In these

experiments, subjects performed a different kind of imagery task involving the 32 words presented during each of two equal durations between 224 and 280 s in length. One task, the *environmental imagery* task, was assumed to require the deliberate encoding of environmental stimuli. It involved imagining the referent of each presented word interacting in some way with a unique object or location in the room. The other task, the *internal imagery* task, was assumed to restrict the deliberate encoding of environmental stimuli. It involved imagining the referent of each word either in a single location (Experiment 1) or interacting in an internal image with the referent of the preceding word (Experiment 2). Table 2 shows that the results in either case were the same: The internal imagery task was remembered as about 18 percent longer in duration than the environmental imagery task.

Two additional experiments (Experiments 3 and 4) clarify the possible cause of this difference. Before performing the imagery tasks, subjects either wrote a description of the experimental room or a description of a familiar room, relying on internal imagery. The combined results shown in Table 3 reveal that the main effect of imagery task on remembered duration was replicated. More importantly, there was an interaction between the preceding description condition and the subsequent imagery task. Simply stated, the kind of cognitive processing assumed to be required in order to perform the preceding description task caused a relative lengthening of the remembered duration of the imagery task which did require a *different* kind of cognitive processing.

Thus, the results of Experiments 1 and 2 rule out a contextual explanation in terms of the encoding of varied environmental associations, because the environmental imagery task was remembered as being shorter in duration than the internal imagery task. The results of Experiments 3 and 4 suggest another kind of contextual explanation: the factor that is critical in determining remembered duration in this situation involves the more holistic changes in process context that resulted from the performance of an imagery task.

Table 2. Summary tables of means and effects in present study, experiments 1 and 2

Experiment	Imagery-task order		
	Environmental-internal	Internal-environmental	Average
Table of means			
Experiment 1	1.04	1.22	1.13
Experiment 2	1.02	1.20	1.11
Table of effects			
Experiment 1	- 0.09*	+ 0.09*	+ 0.13*
Experiment 2	- 0.09*	+ 0.09*	+ 0.11*

Note. Significant effects are indicated by an asterisk (\*). The overall means (column at right) reveal the time-order effect. Data are from Block (Note 1).

Table 3. Summary tables of means and effects in present study, experiments 3 and 4 (combined data)

Description task	Imagery task order		
	Environmental-internal	Internal-environmental	Average
Table of means			
Environmental-imagery	0.94	1.18	1.06
Internal-imagery	1.05	1.05	1.05
Average	1.00	1.11	1.05
Table of effects			
Environmental-imagery	- 0.06*	+ 0.06*	+ 0.00
Internal-imagery	+ 0.06*	- 0.06*	+ 0.00
Average	- 0.06*	+ 0.06*	+ 0.05

Note. Significant effects are indicated by an asterisk (\*). The grand average (1.05, or an effect of + 0.05) reveals the time-order effect. Data are from Block (Note 1).

A subsequent free recall test revealed that the task requiring environmental imagery produced a higher level of recall of words than did the task requiring internal imagery. This is additional evidence rejecting a storage-size hypothesis.

### Time-Order Effects

The results of some of these recent experiments (Block, 1982, Note 1) also reveal the likely origin of time-order effects in retrospective duration judgments of relatively long time periods. Contrary to what is implied by Ornstein (1969), a positive time-order effect was found in all of the experiments discussed here. With all other factors equal or controlled by counterbalancing, the first of two equal time periods is remembered as being 12 percent to 21 percent longer in duration than the second time period. This reliable finding of a positive time-order effect has played an important role in the present contextualist account, as well as in exploring effects of various contextual factors. The positive time-order effect is eliminated if the environmental context prevailing during the second of two durations is changed (Block, 1982; see Table 1) or if the changes in emotional context that might ordinarily occur during the first duration do, instead, occur during an experimental task that precedes it (Block, Note 1; see Table 3). Thus, the finding of a positive time-order effect in previous experiments is explained in terms of the greater contextual changes that ordinarily occur during the first duration.

## A Contextualist Model of Temporal Experience

The findings of the studies reviewed here, especially the interaction effects in the later studies (Block, 1982, Experiment 3; Block, Note 1), suggest that the remembered duration of a time period is a product of the combined influence of many factors. Jenkins (1979) proposed a general contextualistic model of memory, which he applied specifically to research on levels of processing. Bransford (1979, pp. 6-9) presented a similar model of »learning, understanding, and remembering«. Figure 1 shows an adaptation of this general model to the understanding and explanation of interacting factors that affect temporal experience. Each of the four vertices of the tetrahedron represents a cluster of factors that are commonly found to affect temporal experiences. (The studies reviewed here involved manipulations of variables on all four vertices). Each of the six edges of the tetrahedron represents a two-way interaction of different kinds of factors, and each of the four planes represents a three-way interaction. (In the research described here, two- and three-way interactions were routinely found.) Finally, the whole, solid tetrahedron represents the complex four-way interaction of the different kinds of variables. Just

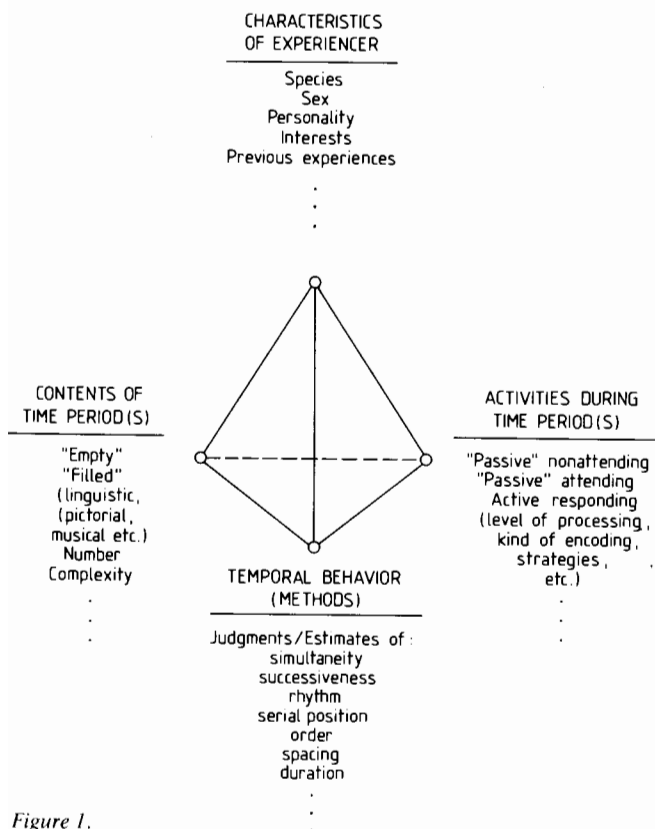


Figure 1.

as such a contextualistic model seems to be necessary to capture the complex interactions of different factors in the research reported here, it also seems to be helpful in understanding the research reported elsewhere in this volume.

## Summary and Conclusions

All of the findings discussed here are consistent with a context-based approach, but strongly reject a stimulus-based approach like that advocated by Ornstein (1969) and Fraisse (1984). Other investigators (e.g. Poynter, 1983) using somewhat different methods have arrived at a similar conclusion. In addition to being able to explain diverse findings, a contextual hypothesis can also parsimoniously subsume other kinds of explanations, such as Vroom's (1970) informational hypothesis and G. Underwood's (1975) attentional hypothesis (see Block, 1979). In experiments directly comparing predictions of these rival hypotheses and those of a contextual hypothesis, the results have supported the latter. In contrast to other hypotheses, a contextual hypothesis may also be able to explain effects on the experience of duration in passing, or prospective duration experience (Block, 1979; Block et al., 1980). Finally, a contextualistic approach to remembered duration is consistent with current theories of memory dynamics.

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#### Reference Note

1. Block, R.A. *Remembered duration: Imagery processes and contextual encoding*. Manuscript in preparation, 1984.