Duration judgment and the segmentation of experience

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Two experiments tested an interval segmentation explanation of duration judgment. In Experiment 1, a 170-sec time interval was filled with 27 unrelated words and three high-priority events (HPEs). These HPEs were clustered at the beginning of the interval (unsegmented condition) or distributed throughout the interval (segmented condition). Both recognition and recall of list information were measured, in addition to duration estimates. While no differences in memory performance were found, duration estimates were greater in the segmented condition. Experiment 2 also tested the effects of interval segmentation but used 35 words and eight HPEs, a longer clock duration, and also measured the remembered number of events (RNE) in the interval. As in Experiment 1, the segmented condition produced longer duration estimates in the absence of memory performance and RNE differences. A segmentation hypothesis seems a better explanation of these results than previously proposed storage size or amount-of-processing models of duration judgment.

Researchers who examine factors affecting psychological duration frequently demonstrate that periods that are "filled" with stimuli are judged to be longer than intervals that are relatively "empty." The "storage size" hypothesis (Ornstein, 1969) is one possible explanation for this phenomenon. According to this metaphor, retrospective duration estimates are based on the quantity of information stored during the period and accessible when the duration judgment is made. Other investigators have emphasized the amount of processing or the level of attention required by interval events (Underwood, 1975; Vroon, 1970). The relationship between these variables and time estimates is not always consistent, however. Vroon (1970) has demonstrated that the relationship between amount of processing and duration judgments can be negative or positive, depending upon whether overt responses are required. Regarding the storage size notion, Avant and Lyman (1975) and Block and Reed (1978) have demonstrated differences in judged duration that either are not related or are inversely related to measures of subjects' memory for interval events.

The effect of filler events on estimates of duration could also be explained by proposing that fillers are temporal markers that serve to segment experience; a filled interval might therefore seem longer than an empty one, not because of the amount of processing or storage space the intervening events require, but because processing these events generates temporal referents in memory with which to mentally reconstruct the duration of the time period. A very similar notion that focuses on the amount of change experienced during the judged interval has recently been proposed and studied by Block and Reed (1978). These experiments demonstrated that time periods during which subjects performed alternating types of processing were perceived as

longer than those during which a single type of processing was performed. These results were interpreted as supporting the hypothesis that subjective duration is based on the amount of change in cognitive context that is remembered from the judged duration. From the present theoretical perspective, these remembered changes segment experience, providing the subjective referents of time passage.

The present experiments were designed to test the hypothesis that judged duration is a positive function of the degree of interval segmentation.

EXPERIMENT 1

Experiment 1 was designed to test the hypothesis that retrospective duration estimates are positively related to the number of segments into which the time period is divided, independent of the number of stimulus representations retrieved from memory or the amount of information processing that occurs. To control these two concomitant variables, identical stimuli and instructions were transmitted to subjects; as a control check, both recognition and recall of stimulus items were measured.

Durations were segmented by embedding high-priority events (HPEs) (see Schultz, 1971) at strategic locations in a tape-recorded list of unrelated words. Subjects were requested to memorize the list, giving priority to words belonging to a particular category (in these experiments, presidents' last names). These so-called HPEs were clustered at the beginning of the interval (the unsegmented condition) or placed at approximately equal intervals throughout the list (the segmented condition). It was assumed that HPEs would serve as temporal markers delimiting the segments of the interval.

It is uncertain whether differences in the amount of

change in cognitive context exist between these two conditions. If memorizing HPEs involves a different cognitive context than memorizing lower priority words, then perhaps the segmented condition could be said to produce a greater number of changes than the unsegmented condition.

Method

Subjects. One hundred and eleven introductory psychology students participated in the experiment as partial fulfillment of class requirements. All subjects were randomly assigned to all conditions.

Stimulus Materials and Design. Using a Sony tape recorder, an audio tape consisting of four segments was prepared. A pair of segments was prepared for each of the two experimental conditions. The first segment of each pair was 170 sec in duration and contained (1) a list of 27 nouns taken from the Battig and Montague (1969) norms and (2) three American presidents' last names. The second segment was a 30-sec reference time interval of "empty" time. Twenty-seven additional nouns were selected from the same source as distractors for the recognition task; each distractor was chosen to match a stimulus item in approximate frequency and number of syllables whenever possible. The distractors for the presidents' names were selected from the total possible category members based on first-letter and syllable-number similarities (see Appendix A for a listing of stimuli used in Experiment 1).

The two experimental intervals prepared for this study (the first taped segment of each pair) were identical with respect to the stimulus items used, but they differed with respect to the placement of the HPEs (presidents' names). The interval with HPEs placed in Positions 1, 2, and 3 was considered to be relatively unsegmented and was labeled as such; the remaining interval was labeled as the segmented duration and had HPEs in Positions 10, 20 and 27.

The stimulus items for both experimental time periods were initially randomized and then were recorded at regular intervals by a female speaker. Care was taken to ensure that each item was articulated with approximately the same amplitude and duration. All intervals began and ended with the words "start" and "stop," respectively. The interstimulus interval was approximately 5 sec for all items. Instructions were prerecorded to ensure that all subjects experienced the same "clock" time during the experiment.

Three response sheets were prepared for the experiment: (1) a time estimation response sheet, (2) a recall memory response sheet, and (3) a recognition memory response sheet. The duration judgment response sheet was composed of two labeled lines. The top line was 30 mm in length and represented the duration of the reference recording. Above this line were written the words "duration of the reference recording." The bottom line was 300 mm long,¹ and written below it were the words "recording with words on it starts here," with an arrow pointing to the left end of the line. The recall test form was blank except for instructions typed at the top of the page. The recognition test form contained instructions and a list of 60 numbered "yes-no" pairs.

The design of the experiment included only one factor, the degree of interval segmentation. Two dependent variables, time estimation and memory performance (either recall or recognition), were measured. While all subjects performed the time estimation task, only one memory task was administered to each subject. The resulting design included four groups, segmented-recall, segmented-recognition, unsegmented-recall, unsegmented-recognition.

Procedure. At the beginning of the experimental session, each subject was seated in an individual isolation booth with headphones. When all subjects were correctly positioned with head-

phones in place, general prerecorded instructions were played over the sound system. The tone quality and amplitude of sound reaching all subjects were controlled by the experimenter from a master panel hidden from the subjects' view.

The following instructions were played to all subjects: "In a few moments you will be listening to a tape with words on it. Listen carefully to this tape as you will be tested on your memory for these words after the tape has finished. Pay special attention to any American presidents' names that you may hear. When you hear the word 'start' the tape has begun—When you hear the word 'stop' the tape has finished. After the tape has finished, await further instructions." After hearing the word "stop" on the first recording, the experimenter read the following instructions: "Now listen to this second tape—Pay attention to the time duration of this tape as it will be used as a standard reference time to estimate the length of the first tape. Again, when you hear the word 'start,' the tape has begun, and when you hear the word 'stop,' the tape has finished." These instructions were followed by a 30-sec segment of blank tape delimited by the words "start" and "stop." Immediately following the end of the reference recording, the experimenter distributed the time estimation instruction sheets and response sheets.

A comparative judgment technique was used to obtain duration estimates. Subjects were asked to delimit a line segment that represented the duration of the experimental interval relative to the reference interval duration, which was represented by a 30-mm line segment. Several minutes were allowed for completion of this task. After the duration judgment task, either a free recall or a recognition task was administered. For recall groups, the instructions requested subjects to list as many of the words presented on the first tape recording as they could remember. For recognition groups, subjects were to circle either "yes" or "no" in response to each of 60 words (30 stimulus words and 30 distractors) presented to them verbally over the sound system, depending upon whether they had or had not heard the word on the first recording.

Results

Since the memory task was performed after the time estimation task, duration judgments for the two groups in each segmentation condition were collapsed into one group for purposes of analysis, resulting in a one-way analysis of variance with two groups. The effects of segmentation condition on the two types of memory performance measured were analyzed separately, resulting in two separate one-way analyses of variance, each with two groups. The mean scores for duration judgment and memory performance are listed in Table 1. Duration estimates were obtained by measuring the line segments marked off by subjects to the nearest millimeter. Mem-

Table 1
Mean Duration Estimates (in Millimeters), Recall Scores
(Number Correct), and Recognition Scores
(Number Correct)

	Unseg- mented	n	Seg- mented	n	Marginal
Duration Estimates	106.00	55	131.75	56	118.99
Recall Scores					
Overall	10.73	37	11.94	38	11.33
HPEs	2.89		2.89		2.89
Recognition Scores	26.40	18	24.80	18	25.60

Note—n = sample size.

Figure 1. Percent of subjects recalling individual words presented in Experiment 1.

ory performance was evaluated by totaling the number of items correctly recalled or recognized.

Time estimation. Results indicated that duration judgments were significantly affected by segmentation condition. Groups presented with the segmented list order estimated the duration of the interval to be longer than did the groups presented with the unsegmented list order [$F(1,109) = 7.03, p < .001$].

Memory performance. Recall scores were not significantly affected by the segmentation condition employed [$F(1,73) = 1.59$]. An additional one-way analysis of variance was performed to determine if there were differences between groups in regard to the number of HPEs recalled by subjects; the test revealed no differences [$F(1,73) = .004$]. Similarly, segmentation condition did not affect the overall recognition performance of subjects [$F(1,34) = 1.77$]. Figure 1 represents the recall performance for segmented and unsegmented conditions in Experiment 1 and serves to demonstrate the superior recall of HPEs relative to the other words presented during the experimental time periods.

Discussion

As demonstrated by the absence of significant differences in memory performance between the segmented word list and the unsegmented word list, the pattern of time estimation results is difficult to reconcile using a model that emphasizes the amount of information stored or retrieved. Although no direct measure of processing time or attention was employed in this experiment, the observation that subjects were required to memorize identical word lists does not support the conclusion that these processing variables could account for the difference in duration judgments found between experimental groups. As the only physical difference between word lists was the placement of HPEs, the hypothesis that duration judgments are based on the number of segments into which the time period is divided seems consistent with the pattern of results from Experiment 1.

EXPERIMENT 2

One alternative explanation for the difference in time estimates between segmented and unsegmented conditions in Experiment 1 is that the placement of HPEs affected subjects' estimation of the number of events that filled the interval. The second experiment was therefore designed to replicate the findings of the first experiment while adding a measure of the remembered number of events (RNE).

Method

Subjects. Twenty-nine introductory psychology students participated in the experiment as partial fulfillment of class requirements. All subjects were randomly assigned to conditions.

Stimulus Materials and Design. The method used in Experiment 2 was identical to the one employed in Experiment 1, with the following exceptions: (1) The number of stimulus items changed. Forty-three words were presented in Experiment 2, eight of which were HPEs (see Appendix B). In the unsegmented condition, HPEs were placed in Positions 1, 2, 3, 4, and 40, 41, 42, and 43. In the segmented condition, HPEs were in Positions 1, 7, 13, 19, 25, 31, 37, and 43. In every other respect, these two experimental conditions were identical. (2) The duration of each of the two experimental recordings was 225 sec. (3) The reference interval was 45 sec in duration. (4) A forced-choice recognition task was used in Experiment 2. The order of pairs on the test form and order of items within each pair were established by way of initial randomization, and then a common recognition response sheet was prepared for all subjects. (5) Subjects were asked to estimate the number of words presented in the experimental interval.

Procedure. The procedures for Experiment 2 were identical to those used in Experiment 1 with the exception of the instructions for the recognition task previously mentioned and the additional RNE task. Instructions for the recognition task requested subjects to choose the one item in each of the 43 stimulus-distractor pairs that they believed to have been present on the experimental tape recording. The RNE task was inserted after the time estimation task and required subjects to write down their estimate of the number of items present on the experimental recording.

All instructions were prerecorded to fit the following "clock" time schedule: instructions, delay (approximately 10 sec), experimental tape recording (225 sec), delay (approximately 10 sec), reference recording (45 sec), time estimation task, RNE task, and memory task.

Results and Discussion

As in Experiment 1, a separate one-way analysis of variance was performed on each dependent variable; Table 2 presents the mean duration estimates, recall scores, recognition scores, and RNEs for each of the two levels of the segmentation factor.

Duration estimates were significantly longer in the segmented interval condition [$F(1,27) = 5.91, p < .05$]. Recall scores [$F(1,12) = 3.07$], recognition scores [$F(1,13) = .145$], and RNE [$F(1,27) = .13$] were unaffected by the level of interval segmentation, however. In addition, the number of HPEs recalled was not affected by this segmentation factor [$F(1,12) = .48$]. Figure 2 provides a graphical representation of the recall performance for all items used in Experiment 2.

The overall pattern of results in Experiment 2 supports the hypothesis that duration judgments are positively related to the number of segments into which the interval is divided, independent of the number of events recalled or recognized, or the amount of information processing required of subjects. The additional variable, RNE, also proved to be unrelated to estimates of duration. It is interesting to observe that even though the differences found between values of these memory measures were not statistically significant, mean values were actually higher in the unsegmented condition.

Because the 30-sec and 45-sec standard time periods used in Experiments 1 and 2 were represented by 30-mm line segments, duration estimates in millimeters can be transformed to seconds using multiplication factors of 1 and 1.5, respectively. These transformed time estimates are presented in Table 3. By comparing these values to the clock duration of experimental intervals, it is evident that all but the segmented condition in Experiment 2 produced underestimates of clock time. It is also interesting to note that the effect of segmentation on mean time estimates was substantially greater in Experiment 2 than in Experiment 1; comparison of the number of segments within experimental conditions provides an explanation of this finding. Although the number of segments credited to each time period depends

Table 3
Mean Duration Judgments (in Seconds) and Clock Duration (in Seconds) for Experiments 1 and 2

Experiment	Unsegmented	Segmented	Clock Duration	Segmented Minus Unsegmented	
				Duration Estimates	N
1	106	132	170	26	3
2	158	276	225	118	6

Note—N = number of segments.

upon the way in which "segment" is defined, HPEs were used in this study to delimit non-HPE time segments. Measuring the independent variable in this way, the unsegmented conditions in Experiments 1 and 2 contained one segment each, whereas the segmented conditions had four and seven segments, respectively. Table 3 presents the difference in duration judgments between conditions in each experiment compared to the difference in number of segments. This comparison indicates that the difference in magnitude of effect between experiments can be explained with the interval segmentation hypothesis.

GENERAL DISCUSSION

Past research has demonstrated that duration estimates of filled time periods can be related to the type of processing the filler stimuli require (Burnside, 1971; Vroon, 1970) and the number of interval events recalled or recognized (Block, 1974; Ornstein, 1969). Experiments 1 and 2 of the present study have demonstrated that even when two intervals of the same clock duration are filled with identical stimuli, processed and remembered to the same degree, they are not always remembered as being equal in duration.

Of the different models that have been proposed to describe time estimation data, most seem to emphasize the importance of one or more elements of information processing. Among those elements implicated as the mediating variable of duration estimation are selectivity of attention (Underwood, 1975), amount of information transmitted (Vroon, 1970), number and complexity of stimulus representations in memory (Ornstein, 1969), and familiarity of intervening events (Avant & Lyman, 1975). The present experiments demonstrate the effects of interval segmentation in the absence of differences in several of these variables. No differences in memory for interval events were found using a free recall task and two different recognition tasks. In addition, variables like familiarity of stimulus events, selectivity of attention, and amount of information transmitted were assumed to be controlled by presenting identical information to subjects in opposing experimental conditions. The present construct, degree of interval segmentation, does not emphasize any particular component of stimulus processing; instead, the focus is on the degree to

Table 2
Mean Duration Estimates (in Millimeters), Recall Scores (Number Correct), Recognition Scores (Number Correct), and RNEs: Experiment 2

	Unsegmented	n	Segmented	n	Marginal
Duration Estimates	105.00	14	184.00	15	143.00
Recall Scores					
Overall	13.13	7	11.75	7	12.44
HPEs	5.70		5.40		5.57
Recognition Scores	39.75	7	36.43	8	38.20
RNEs	33.13		31.30		32.26

Note—n = sample size.

Figure 2. Percent of subjects recalling individual words presented in Experiment 2.

which memorial representations of processed events segment experience. Such a hypothesis is similar to Fraisse's (1963) emphasis on memory for change and recently, Block and Reed's (1978) "contextual change" hypothesis. It should be mentioned that degree of interval segmentation may not accurately predict duration judgments of very brief time periods (less than 1 sec). Temporal discrimination between empty durations on the order of 100 msec, for example, could not be accomplished by detecting a difference in the number of overt interval segmenters. One speculation is that this type of duration judgment relies on monitoring of organismic changes or segmenters (e.g., eye movements, visceral or somatic changes, etc.).

Limiting the discussion to time periods on the order of seconds or minutes, however, an emphasis on segmentation may provide a construct for integrating previous findings. It seems consistent with studies that demonstrate a positive relationship between amount of information retrieved and remembered duration, since it might be expected that the greater the number of distinct memories associated with a time interval, the greater would be the number of "segmenters" of experience. It is also consistent with findings that demonstrate a positive relationship between stimulus complexity and remembered duration, since complex information is presumably more difficult to chunk or reduce for maximally efficient storage. The same logic can be used to explain the negative relationship found between stimulus familiarity and duration estimates.

Additional research is needed to evaluate the importance of order information in time estimation. Such research would help answer the question of whether

judging duration is a process of simply evaluating the number of segments or changes, or if it is dependent upon the way in which these segments are linked together in memory.

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NOTE

1. An additional 300-mm extension of this line was drawn directly below it.

Appendix

(A) Word Lists Used in Experiment 1		(B) Stimulus Words Used in Experiment 2	
Unsegmented	Segmented	Unsegmented	Segmented
start	start	start	start
Johnson	knife	Garfield	Garfield
Washington	noun	Washington	lily
Lincoln	chair	Lincoln	captain
knife	legs	Kennedy	wool
noun	pear	lily	cat
chair	beer	captain	sister
legs	saw	wool	Washington
pear	oil	cat	minute
beer	doctor	sister	blue
saw	Johnson	minute	oil
oil	river	blue	diamond
doctor	baseball	oil	spider
river	rain	diamond	Lincoln
baseball	shirt	spider	chair
rain	oxygen	chair	foot
shirt	diamond	foot	noun
oxygen	minute	noun	plum
diamond	day	plum	rain
minute	sister	rain	Kennedy
day	Washington	doctor	doctor
sister	mile	magazine	magazine

(A) Word Lists Used in Experiment 1		(B) Stimulus Words Used in Experiment 2	
Unsegmented	Segmented	Unsegmented	Segmented
mile	brass	floor	floor
brass	inch	brass	brass
inch	magazine	knife	knife
magazine	iron	mile	Hoover
iron	captain	tent	mile
captain	Lincoln	day	tent
cat	cat	shirt	day
wool	wool	pliers	shirt
blue	blue	river	pliers
stop	stop	baseball	Johnson
		oxygen	river
		wood	baseball
		beer	oxygen
		crow	wood
		truck	beer
		saw	Truman
		botany	crow
		inch	truck
		Hoover	saw
		Johnson	botany
		Truman	inch
		Madison	Madison
		stop	stop

(Received for publication May 26, 1982;
revision accepted September 17, 1982.)