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Prospective and Retrospective Time Estimation: A Dual Task Paradigm

Azizuddin Khan
Indian Institute of Technology, Mumbai

An experiment was conducted using 180 subjects to determine the effects of four factors on time estimation: cognitive load (low, medium, and high), actual duration (short vs. long), method of time judgment (verbal estimation vs. reproduction), and paradigm (prospective vs. retrospective). Analysis of variance was used to analyze the data. Time estimation data were analyzed using directional and absolute error. For directional error, all the main effects and few interactions were significant. For absolute error, main effects of paradigm and cognitive load as between subjects and main effect of actual duration as within subjects were significant; some interactions were also significant. In general, there was overestimation of short duration in all the conditions under prospective paradigm. Under retrospective paradigm, there was underestimation of time judgment. Time estimation under prospective paradigm was more accurate than under retrospective paradigm. Time judgment was more accurate under verbal estimation as compared to reproduction method.

Keywords: Absolute error, Directional error, Prospective paradigm, Reproduction of time, Retrospective paradigm, Verbal estimation.

Many of the human daily activities rely on our ability to perceive the flow of time (Husserl, 1964). Time estimation is the ability to judge the duration or apprehend the passage of time by the order of occurrence of experience or by physiological rhythm (Fraisse, 1984). There is resurgence of research in time estimation (Sévigny, Everett, & Grondin, 2003; Chaston, & Kingstone, 2004; Morillon, Kell, & Giraud, 2009). Researchers are trying to understand role and mechanism of time estimation in various pathological conditions such as anxiety depression, developmental dyslexia and schizophrenia (Lee,Dixon, Spence, & Woodruff, 2006; Mimura, Kinsbourne, & Connor, 2000; Nicolson, Fawcett & Dean, 1995; Tysk, 1984). Further, time estimation ability plays a crucial role in the realization of time-based prospective memory (Labelle, Graf, Grondin , & Gagné-Roy,2008; Khan, Sharma, & Dixit, 2008). Indeed, no single sensory organ or perceptual system is solely responsible for the encoding of psychological time. This has led most theorists to explain the experience of time as a function of cognitive processes alone or as a result of the interaction between cognitive and biological processes.

Biological models (Aschoff, 1984; Thatcher & John, 1977; Treisman, 1963; Treisman, Faulkner, Naish, & Brogan, 1990) propose that the time estimation is determined by biological rhythms and the internal clock. The biological approach to time estimation assumes that people have internal cycles that can be used to measure time (e.g., circadian rhythm) . . The concept of biological time assumes that there exists some kind of automatic rhythm that occurs continuously and is not directly and easily affected by changes in the environment.

Cognitive models (Block, 1974; Frankenhauser, 1959; Ornstein, 1969; Thomas & Weaver, 1975) suggest contextual, attentional, or influences related to capacity. According to cognitive theories, temporal experience of passage of time depends upon the nature and extent of the cognitive processing performed by a person during a given interval. There are several models that explain the effect of processing of information on time estimation.

Some important cognitive models include the storage size model (Ornstein, 1969), the change model (Block, 1985), the cognitive–attentional model (Thomas and Weaver, 1975), and the structural remembering model (Boltz, 1993, 1995).

The importance and ubiquitous nature of time has led psychologists to search for factors that affect time estimation in day-to-day life. The primary goal of research on time estimation is to determine factors that result in relative accuracy of these estimations and/or systematic distortion wherein the relevant time span is either under- or over- estimated. Within this scheme of categorization, four factors are of particular theoretical interest because they are assumed to directly influence the cognitive mechanisms responsible for duration judgments (Block, 1989; Hicks, Miller & Kinsbourne, 1976; Zakay, 1990).

The first of these involves the particular research paradigm, prospective or retrospective. Hicks, Miller and Kinsbourne (1976) reported that under the prospective time estimation paradigm, subjects are explicitly told in advance that they will be required to judge the duration of an interval. This procedure presumably motivates subjects to monitor the time passing by and to attend to any available temporal cues (Block & Zakay, 1996; Brown, 1997; Doob, 1971, Khan, 2005; Zakay & Block, 1996). In contrast, subjects tested under the retrospective paradigm are not given any warning about time estimation at the start of the interval. These subjects are unexpectedly asked to judge the duration of the interval after it has already passed by. Subjects tested under retrospective conditions are presumed to process temporal information in a more incidental and unreliable fashion. Since subjects do not pay much attention to time per se, they give more attention to processing of information itself (Tobin, Bisson, & Grondin. 2010, Block & Zakay, 1996). This could be the probable reason for inaccurate estimation of time under the retrospective paradigm. In the case of retrospective paradigm, the subject has to make judgment about time by relying on memory, whereas, in the case of prospective paradigm, the subject will deliberately pay attention to time.

The second important factor that plays a crucial role in duration judgment is cognitive load. An individual has limited attentional resources to process information. When a subject is cognitively active, attention is split between the task's temporal and non-temporal information. Temporal information is encoded via the cognitive timer while non-temporal information is processed by its own independent mechanism (Ahmad, Keller, Robb, D.A. et al 2020, Boltz, 1998). Both compete for a limited pool of resources such that increased attention towards one dimension will decrease performance of the other. Miller, Hicks, and Willette (1978) manipulated task difficulty. They reasoned that the amount of processing capacity allocated to the memorization task would be inversely proportional to the chunk of information. When time judgment of intervals spent performing some effortful or difficult task are compared against judgment of intervals in which the only task was to keep track of time, involvement in a non-temporal task generally shortens the perceived duration (Block & Zakay, 1997; Hicks & Brundege, 1974; Macar, 1996). Further, increase in non-temporal processing demands lead to progressive shortening of perceived duration (Allan, 1979; Brown, 1997; Brown & Stubb, 1988; Smith, 1969).

In Ornstein's (1969) research, subjects retrospectively compared intervals involving perceptual motor tasks or complex categorization tasks against standard control intervals. The more difficult or complex the task, the longer was its perceived duration. Numerous studies indicate that retrieval requires more processing capacity. On the basis of these studies it has been suggested that task demands lengthen retrospective time estimation (Boltz, 1991, 1998; Lejeune, 2000; Trumbo & Milone, 1971). Both prospective and retrospective time estimation of the difficult condition were associated with more errors when compared to the judgments of the control and intermediate conditions. These results suggest that the expenditure of cognitive effort disrupts both prospective and retrospective timing. Thus differential cognitive load necessitates differential time estimation.

The third factor affecting time estimation is time judgment method (Brown, 1992). In the present experiment, we used verbal estimation and reproduction methods. In the verbal estimation method, a person is asked to use conventional time units to estimate an experienced duration subjectively.In the reproduction method, the person was asked to delimit a subjective duration to match it with the duration the just experienced. Although reproduction did not require a translation involving conventional duration units, the method had another drawback: if the rate of physiological and cognitive processes varies from one individual to another, the same rate sub served an individual's experiencing the target duration and reproducing the duration. Brown (1985) reported that more errors were associated with verbal estimation than with the reproduction method. He also suggested that both methods produced similar findings with regard to the effect of paradigm and task condition. However, research also showed (Zakay & Block, 2004) that the reproduction method produces more erroneous time estimation when compared to verbal estimation. In the case of verbal estimation, subjects had to estimate the time interval by remembering the passage of time, whereas, under the reproduction method which was an experienced duration, subjects had to reproduce the duration of time by performing an activity equal in length to the experienced duration. Different methods of time estimation will have differential time estimation under various levels of cognitive load and paradigm (Brown, 1985, Droit-Volet, Trahanias, & Maniadakis. 2017). Therefore, the goal of the present study was to investigate the role of method of time judgment on time estimation.

As Brown (1985) has suggested, time judgments can be transformed into measures representing a directional error and an absolute error. For determing the directional error, data were transformed into ratio scores by dividing each judgment by the corresponding actual elapsed time.

In the transformed data set, a value of directional error less than unity represents a judgment shorter than the actual duration (underestimation), whereas the value greater than unity represents a judgment longer than the actual duration (overestimation). A directional error with a value '1' represents perfect estimation.

Thus, absolute error scores were obtained by dividing the absolute difference between the value of each judgment and the corresponding actual duration, and converting it into percentage value of the corresponding actual duration.

The fourth factor which influences time estimation is actual duration of time. Short durations are generally overestimated while long durations tend to be underestimated (Poynter, 1983). But there is no consistent result whenever various other parameters were included such as paradigm and task demands. Further, still little is known time estimation of long durations, and how they compared with time estimations of short durations.

Unlike earlier studies, the present study employed time estimation of both short- and long-durations. There are very few studies that have employed long duration for prospective paradigm and short duration for retrospective paradigm. The issue is still unresolved as to whether similar or different mechanisms underlie the estimation of short- and long-durations. On the one hand, some researchers (Brown, 1985; Ornstein, 1969) suggest that judgments of short- and long-durations involve different mechanisms and are influenced by different factors. Short duration is assumed to be regulated by perceptual processes whereas long duration by cognitive processes. On the other hand, Block (1978, 1989, and 2003) argued that similar mechanisms are involved for both short- and long-durations. Consequently, the present study aimed at investigating the effect of short and long duration on time estimation. Specifically, the experiment attempted to answer the following questions:

Do factors such as cognitive load, duration of actual time, method of time judgment, and paradigm significantly contribute to the differential effect on time estimation? How does paradigm (retrospective/prospective) influence time estimation and in what ways? Does cognitive load affect time estimation in the same way under retrospective and prospective conditions? How do these factors (actual duration, cognitive load, and paradigm) collectively determine time estimation? How does the judgment method affect time estimation? Is overestimation or underestimation of short- or long-durations a valid conclusion under all circumstances (retrospective/prospective paradigm, and different cognitive loads)?

The present study is an attempt to compare prospective and retrospective time judgment under different cognitive loads. It also investigates the method of time judgment in short and long duration.

On the basis of above mentioned goals, the following hypotheses were formulated. Since the prospective paradigm is characterized by attention allocation and retrospective paradigm by memory model, the passage of time is more experience based and current in the former condition, and is likely to be judged more accurately. On the basis of above mentioned goals, the following hypotheses were formulated.

Since prospective paradigm is characterized by attention allocation and retrospective paradigm by memory model, the passage of time is more experience based and current in the former condition, and is likely to be judged more accurately. This leads to the following hypothesis.

H1: Time estimation would be more accurate under prospective paradigm than retrospective paradigm.

As cognitive load increases, the processing capacity allocated to the cognitive task increases. Consequently, lesser capacity is available for monitoring the passage of time with the result that accuracy in time estimation would decrease as cognitive load increases. Hence the following is proposed.

H2: There would be a negative relationship between cognitive load and accuracy in time estimation.

Literature has shown that time itself is one of the important determinants of perceived time. Therefore, duration (short vs long) will have an effect on time estimation. So, the following hypothesis is formulated:

H3: Duration of time (short versus long) would have significantly greater effect under prospective than under retrospective paradigm.

Previous literature (Brown, 1985) suggests that verbal estimation is more accurate than the reproduction method. However, there are also studies showing that time estimation is more accurate under the reproduction method. To resolve the issue, the following hypothesis is proposed.

H4: Time estimation would be more accurate in verbal time estimation than reproduction method

The purpose of present experiment was to extend previous research (Brown, 1984) by investigating whether variation in cognitive load, duration of actual time, paradigm and method of time judgment yield different time judgments for the same event. The experiment consisted of temporal information i.e. passage of time and non-temporal information i.e. short term memory task.

Method

The Task

The task for the subjects varied depending on the condition of the experiment. In the low cognitive load condition, subjects had to concentrate on items that appeared on the screen. In the medium cognitive load condition, subjects had to identify whether a stimulus is a fruit item or not by clicking the mouse at the appropriate place provided on the screen using the GO-NO-GO response paradigm; they had to do nothing when the item was not a fruit name (see Figure 1). In the high cognitive load condition, subjects had to memorize each item that appeared on the screen.

Independent Variables

The experiment employed four independent variables, namely, cognitive load, actual duration, paradigm, and method of time judgment with the levels as indicated.

Cognitive load: Three levels of cognitive load were employed: low, medium and high.

Cognitive load was employed as a between-subjects variable.

Actual duration: Two major categories of actual duration, namely, short- and long-duration were employed, with three levels for each long-duration (150s, 210s, and 270s) and short-duration (2s, 4s, and 6s). For each short and long duration verbal method was employed whereas reproduction method was utilized in only long actual duration. Therefore, actual duration was used as a between-subject as well as within subject variable.

Paradigm: Two paradigms employed in the experiment were prospective and retrospective paradigm. Paradigm was employed as a between-subjects variable.

Method of time judgment: Two methods of time judgment employed in the experiment were verbal time estimation and reproduction. Method of time judgment was employed as within subject variable.

Dependent Variables

Errors in verbal time estimation and time reproduction were the two dependent variables used in the experiment.

Subjects

One hundred and eighty subjects drawn from the undergraduate and postgraduate classes of an engineering institute participated in the experiment. The mean of age of the subjects was 24.73 years (SD = 2.72). The subjects were uninformed about the nature and purpose of the experiment. They were told that the experiment was an investigation of attention or memory. Informed consent of the subjects was obtained and they were debriefed toward the end of the experimental session.

Design

The design of the first part of the experiment was a 3 (Cognitive load: low, medium, and high; between subjects) × 2 (Paradigm: retrospective and prospective; between subjects) × 2 (Method of judgment: verbal time estimation and reproduction; within subjects) factor split-plot design. The design of the second part of the experiment was a 3 (Cognitive load: low, medium, and high; between subjects) × 2 (Paradigm: retrospective and prospective; between subjects) × 2 (Actual duration: short- and long-duration; within subjects) factor split-plot design. In the first part of experiment, there were two methods of time judgments (verbal estimation vs. reproduction) with one long duration. In the second part of the experiment, there were two durations (short vs. long) using the verbal estimation only.

Stimulus Material

The stimulus material consisted of a list of 30 items which consisted ot the names of 15 substances used for flavoring food (taken from List 25, page 20 of Battig and Montague, 1969) and 15 fruit names (List 16, page 14 of Battig and Montague, 1969).

Instrumentation and Presentation of Stimulus Material

A computer program using Visual Basic was developed (1) to record personal information about the subjects, (2) to present stimulus items to the subjects on a computer screen, one after the other, in a controlled manner, and (3) to record subjects' responses. A window appeared on the screen each time the subject completed the tasks required. The first window was designed to record personal details of the subject. The new window contained the identity number of the subject, identification category of the stimulus item shown as 'F' on the screen(subjects had to identify whether a stimulus is a fruit item or not by clicking the mouse at the appropriate place provided in the screen using GO-NO-GO response paradigm; they had to do nothing if an item was not a fruit name), a blank space for the appearance of items below the ID number, a 'Start' icon and "Click To Your Choice" icon on the right side of the 'blank space' icon. When the first item on the list appeared in the blank space on the screen, the subject clicked the 'Start' icon and a screen opened. The items appeared on the screen one after the other. Each item remained on the screen for the duration as required by the experimental condition (2s, 4s, or 6s). The inter-item interval was kept constant at 3s. After the disappearance of the last item on the screen, the screen was blank for 3s and then the instruction appeared on the screen for the subject to record (1) total estimated time from the appearance of the first item on the list to the disappearance of the last item including the following blank time, and (2) flashed duration of a word (appearance time) in the blank window provided for this purpose. After recording the estimated time, subject was required to click the 'Save' icon on the screen. Immediately following this, a new window automatically opened for the reproduction of the actual duration. Appropriate instructions appeared on the screen for the subject to record reproduced time. At this stage, the 'Back' icon was automatically disabled.

To summarize, an item appeared for 2s, 4s, or 6s (short interval) with an inter-item interval of 3s. A blank interval of 3s was included toward the end of the list. Thus, actual duration for presenting the entire list was 150s (appearance time of individual item: 2 s), 210s (appearance time of individual item: 4 s), or 270s (appearance time of individual item: 6s).Thus, the combination of short- and long-duration used in the experiment employed a pair-wise locking in short-long as 2s-150s, 4s-210s, and 6s-270s, respectively. Each subject had to estimate time interval for both short duration and long duration.

Procedure

Each subject was tested individually. The subject was seated in front of the color monitor of a computer. The subject first completed the personal details. The researcher then gave specific instructions regarding the task to be carried out depending on the treatment condition of the experiment in which the subject was participating. The subject was told to respond by clicking the mouse as described below. A trial consisted of following activities:

Each subject was presented 30 items one after the other. Each item remained on the screen for the duration as required by the experimental condition (Short duration: 2s, 4s, or 6s). The inter-item interval was kept constant at 3s. After the disappearance of the last item on the screen, the screen was blank for 3s and then the instruction appeared on the screen for the subject to verbally estimate (1) the total elapsed from the appearance of first word on the list to the disappearance of the last word (Long duration: 150s, 210, and 270s), and (2) flashed duration of a word (appearance time, Short duration: 2s, 4s, or 6s) in the blank window provided for this purpose. After completion of the verbal estimation of short and long duration, a new window appeared on the screen and subject was instructed to reproduce the total time estimation from the appearance of first word on the list to the disappearance of the last word. Since the present study employed verbal estimation to estimate short and long duration and reproduction method for long duration, two sets of analysis of variance were utilized in which actual duration was used as between and within subject design.

Depending on the experimental condition, the subject was instructed to pay attention to the presented items (low cognitive load), identify if an item was a fruit name (medium cognitive load), or memorize the items (high cognitive load).

Half of the subjects were tested under prospective paradigm condition and they were informed at the beginning of the experiment that they would be asked to judge the duration of the task interval after its completion and that they should monitor the time passed by. The remaining subjects were tested under the retrospective paradigm and were not given any advance information about time monitoring and estimation task.

The subjects were instructed to be as accurate as possible in making their judgments. At the end of the presentation of the entire list , subjects were asked to provide (a) verbal estimate of how long a particular item appeared on the screen during the presentation of items (Short duration: 2s, 4s, and 6s), and (b) total time taken for presentation of all the items (Long duration: 150s, 210, and 270s). In the present study, reproduction method was employed only once and the software was developed in such a way that it always came after the verbal estimation.

In the case of reproduction, subjects were asked to click the mouse twice to reproduce the duration that they judged to be equal to that of the total task duration: At the first click of the mouse, the computer started encoding passage of time and when the subject clicked the mouse again, time encoding was terminated.

Results

Following standard practice, the measures of judged time were expressed as proportions of the respective durations being judged so that all scores are scaled down to the same relative scale. As Brown (1985) has suggested, time judgments were transformed into measures representing directional error and absolute error, as explained in the introduction section.

Analysis of Directional Error Data

The means of directional errors for different treatment combinations are presented in the Table 1 and Table 2.

Method of Time Judgment

The main effects of all between subjects factors were significant--Cognitive load: $F(2,162) = 7.28$, $p < 0.01$, $\eta^2 = 0.08$; Paradigm: $F(1,62) = 8.10$, $p < 0.01$, $\eta^2 = 0.04$; and Method of time judgment: $F(1,162) = 1480.72$, $p < 0.01$, $\eta^2 = 0.46$. None of the interactions were significant. Therefore, the results confirm stated hypotheses that cognitive load, paradigm and method of time judgment influence subjective time estimation.

Table 1. Directional error (Method of Time Judgment) and varying cognitive load (low, medium, and high), actual long duration (150s, 210s, and 270s), and paradigm (retrospective and prospective).

Method of Time estimation	Cognitive Load	Paradigm	Mean	Std. Deviation	N
Verbal estimation method	Low	RP	0.95	0.38	30
		PP	1.06	0.26	30
		Total	1.00	0.33	60
	Medium	RP	0.75	0.29	30
		PP	0.95	0.32	30
		Total	0.85	0.32	60
	High	RP	0.81	0.36	30
		PP	0.86	0.26	30
		Total	0.84	0.31	60
	Total	RP	0.84	0.35	90
		PP	0.96	0.29	90
		Total	0.89	0.33	180
Reproduction method	Low	RP	0.60	0.26	30
		PP	0.69	0.41	30
		Total	0.65	0.35	60
	Medium	RP	0.49	0.22	30
		PP	0.62	0.32	30
		Total	0.56	0.28	60
	High	RP	0.47	0.25	30
		PP	0.50	0.26	30
		Total	0.48	0.25	60
	Total	RP	0.52	0.25	90
		PP	0.61	0.34	90
		Total	0.56	0.30	180

RP = Retrospective Paradigm, PP = Prospective Paradigm

Table 2. Directional error (Reproduction Method) under varying cognitive load (low, medium, and high), actual long duration (150s, 210s, and 270s), actual short duration (2s, 4s, and 6s), and paradigm (retrospective and prospective).

Actual Duration	Cognitive Load	Paradigm	Mean	Std. Deviation	N
Long duration	Low	RP	0.95	0.38	30
		PP	1.06	0.26	30
		Total	1.00	0.33	60
	Medium	RP	0.75	0.30	30
		PP	0.95	0.32	30
		Total	0.85	0.32	60
	High	RP	0.81	0.36	30
		PP	0.86	0.26	30
		Total	0.84	0.31	60
	Total	RP	0.84	0.35	90
		PP	0.96	0.29	90
		Total	0.90	0.33	180
Short duration	Low	RP	0.69	0.36	30
		PP	1.02	0.46	30
		Total	0.85	0.44	60
	Medium	RP	0.78	0.42	30
		PP	1.10	0.39	30
		Total	0.94	0.43	60
	High	RP	0.70	0.42	30
		PP	1.41	0.70	30
		Total	1.05	0.68	60
	Total	RP	0.72	0.40	90
		PP	1.18	0.55	90
		Total	0.95	0.53	180

RP = Retrospective Paradigm; PP = Prospective Paradigm

In view of significant main effects, Scheffe's tests were conducted in order to determine the levels of the independent variables which contributed to the significant effect. Post-hoc comparison using Scheffe's test indicated that low cognitive load differed significantly from medium (M= 0.12) and high cognitive load (M= 0.16), but the difference between medium and high cognitive loads was not significant.

Actual Duration

The main effect of paradigm was significant: $F(1,162) = 44.31$, $p < 0.01$, $\eta^2 = 0.20$. The main effect of cognitive load was not significant. None of the interactions were significant.

The main effect of duration as within subject factor was not significant. However, all the interactions with duration were significant. The interactions pertaining to cognitive load × duration $\{F(2,162) = 6.64, p < 0.01, \eta^2 = 0.07\}$ were significant.

Paradigm × duration $\{F(1,162) = 15.96, p < 0.01, \eta^2 = 0.08\}$ was significant. The third order interactions were also significant – cognitive load × paradigm × duration: $F(2,162) = 3.96$, p

< 0.01, $\eta^2 = 0.05$; cognitive load × actual duration ×duration: $F (4,162) = 2.79$, $p < 0.02$, $\eta^2 = 0.06$; and paradigm × actual duration × duration: $F (2,162) = 3.78$, $p < 0.02$, $\eta^2 = 0.04$ were also significant. Since the effect of cognitive load was not significant, no post-hoc test was conducted. The aim of the study was to compare the effect of short and long duration on time estimation. The results revealed that when actual duration interacts with cognitive load and paradigm, it significantly affects time estimation.

Analysis of Absolute Error Data

Pictorial views of the absolute error data are presented in Figures 1. For directional error, the absolute data was analyzed using two analyses of variance designs.

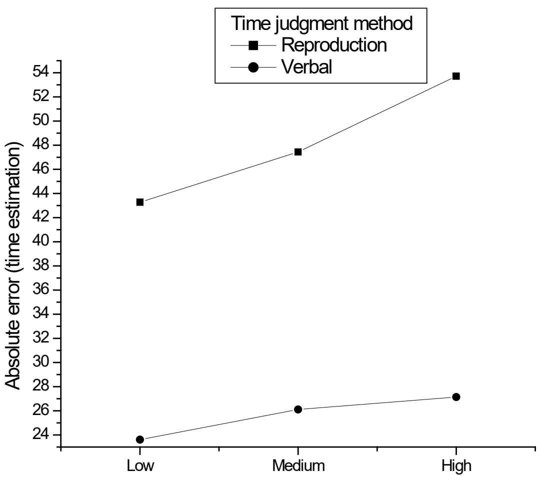

Figure 1. Absolute error as a function of cognitive load and time judgment method

Method of Time Judgment

The main effects of all between subject factors were significant except cognitive load – Cognitive load: $F (1, 162) = 2.49$, $p < 0.08$, $\eta^2 = 0.03$}; Paradigm: $F (1,162) = 3.82$, $p < 0.05$, $\eta^2 = 0.03$}. None of the interaction reached a significant level. Since interaction was not significant, simple effect and Scheffe's tests were not conducted.

The main effect of the method of time judgment was significant: $F (1,162) = 106.26$, $p < 0.01$, $\eta^2 = 0.38$. No interaction was significant.

Less error was associated with the prospective paradigm (M = 21.55%) than with the retrospective paradigm (M = 29.40%). The mean error scores in the main effect for cognitive load, $F (2,162) = 2.49$, $p < 0.08$ were as follows: low, 23.61%; medium, 26.11%; and high cognitive load, 27.14%. There was increase in time judgment error between low vs. high load. No other interaction was significant.

Actual Duration

The main effect of paradigm as a between subject factor was significant: $F (1,162) = 6.44$, $p < 0.01$, $\eta^2 = 0.05$, whereas the main effect for cognitive load was not significant. The two-way interaction cognitive load × paradigm was also significant {$F (2,162) = 3.37$, $p < 0.03$, $\eta^2 = 0.04$}. No other interaction was significant.

The main effect of duration was significant {$F (1,162) = 59.29$, $p < 0.01$, $\eta^2 = 0.25$}. The interaction duration × paradigm {$F (2,162) = 2.43$, $p < 0.09$, $\eta^2 = 0.03$} was significant. The three-way interaction of cognitive load × paradigm × duration (within) was significant: $F (2,162) = 3.71$, $p < 0.02$, $\eta^2 = 0.04$. No other interaction reached significance level. Since main effect of cognitive load was not significant, Scheffe test was not employed.

Discussion

The present study was designed to assess the role of cognitive load, actual duration, and method of time-judgment under retrospective and prospective paradigms in time estimation. The directional and absolute errors reveal different processes for time estimation. The directional error may be used to assess differences in terms of relative underestimation and overestimation of actual time, whereas the absolute error indicates the proportional difference between real and subjective time. Absolute error is also used to assess overall level of accuracy of judged time.

On reconciling the results of directional errors and absolute errors, the following general results can be stated. (1) Overall, actual duration was underestimated. (2) Judged time increased with the increase in cognitive load, irrespective of methods of time judgment. (3) Time judgments under prospective paradigm were more accurate than under retrospective paradigm, irrespective of the methods of time judgment. (4) Different trends were obtained for short- and long-durations. For directional error, time judgment was more accurate for short durations than long duration. Fewer absolute errors were associated with long duration when compared to the short interval.

Results for directional error (DE)

The following results were obtained for directional errors. They are identified as DE followed by a numeral to facilitate reference to a particular result during the discussion.

DE1: Errors under prospective paradigm were fewer than under retrospective paradigm.

DE2: Time judgments under prospective paradigm were better than under retrospective paradigm irrespective of the method of time judgment.

DE3: Directional errors in judged time increased with the increase in cognitive load irrespective of method of time judgment. Overall, verbal time estimation was more accurate than reproduction time

DE4: Overall, there was an underestimation of time However, there were different trends under short- and long-duration. Long duration was underestimated, though short duration was underestimated under the retrospective paradigm and overestimated under the prospective paradigm

DE5: There was better time judgment under short interval even with an increase in cognitive load Further, errors increased with increasing cognitive load. As cognitive load increased from medium to high, there was a transition from underestimation to overestimation of the short intervals. There was no such trend for long durations.

Results for absolute error (AE)

The following results were obtained for absolute error. They are identified as AE followed by a numeral to facilitate reference to a particular result during the discussion.

AE1: Absolute errors in judged time increased with the increase in cognitive load irrespective of the method of time judgment. However, there were more errors for reproduction time than verbal time estimation.

AE2: The error was less under prospective paradigm as compared to retrospective paradigm.

AE3: In general, the errors increased with increasing cognitive load. But there were more errors for short interval as compared to long duration.

On reconciling the results of directional errors and absolute errors, the following general results can be stated.

Judged time increased with the increase in cognitive load irrespective of method of time judgment (DE3, AE1 and AE3).

Overall, actual duration was underestimated (DE4).

Time judgments under prospective paradigm were better than under retrospective paradigm irrespective of the method of time judgment (DE1, DE2, and AE2).

Different trends were obtained for short- and long-durations. For directional error, time judgment was more accurate for short interval than long duration (DE5). Less absolute error was associated with long duration than short interval (AE3).

As indicated by the above general findings, cognitive load affected time estimation. Directional errors increased with the increase in cognitive load from low (Mean = 0.82), medium (Mean = 0.70), and high (Mean = 0.66). Similarly, there was an increase in absolute time judgment errors from low (Mean = 33.44%), medium (Mean = 36.47%), to high (Mean = 40.42%) cognitive load. Similar trends were obtained for short- and long-durations. However, there was less absolute error for medium cognitive load as compared to low cognitive load under short duration as compared to long duration.

In general, these results are consistent with the various earlier findings that time estimation error increases as cognitive load is increased (Boltz, 1991; Brown, 1985; Brown & Stubbs, 1988; Hicks et al., 1976; Khan, Sharma, &

DixitA., 2006; Miller et Al., 1978; Thomas & Cantor, 1978; Thomas & Weaver, 1975) and support attentional allocation model proposed by Thomas and Brown, (1974). However, there were contradictory findings for short- and long-durations. The probable reason for differential finding related to the effect of cognitive load under short and long durations can be explained on the basis of different mechanisms involved in short- and long-durations. So far research in time estimation have generally employed either short interval or long duration. This experiment employed both short– and long-durations in a single experiment. There is a need to explore the reason for differential effect of cognitive load on the judgment of short and long durations further.

According to attentional allocation model, information consists of temporal and non-temporal properties. Human beings have a limited attentional capacity. Therefore, when subjects pay attention to non-temporal information, their ability to pay attention to temporal information gets deteriorated. Consequently, errors increase for time estimation and vice-versa. Results of the present experiment demonstrated that inaccuracy in prospective time estimates increased along with the increase in the cognitive load. This finding is consistent with earlier findings (Martinez, 1994; Predebon, 1996; Zakay, 1993). With the increase in cognitive load (from low to high), there was larger inaccuracy in time-judgment in the case of prospective paradigm. However, there was no clear relationship between cognitive load and time-judgment under retrospective paradigm. The results pertaining to retrospective paradigm were consistent with the storage-size hypothesis proposed by Ornstein (1969). The results showed that, in general, time judgments under prospective paradigm were more accurate than under retrospective paradigm. This result is consistent with the findings of Hicks et al. (1976). Attention to time-in-passing can be cited as the reason for relatively accurate time estimation by the subject under prospective paradigm (Boltz, 1989, 1993; Brown, 1985; Zakay, 1989, 1990). According to their view, subjective duration increases with the subject's attention to time. As subject pays attention to time, it results in the storage of subjective temporal units. On the other hand, subjects under retrospective paradigm process temporal information in an incidental manner. Since subjects under retrospective paradigm had no prior knowledge about the time estimation task, they might have retrieved temporal information from their memory. This, therefore, could be the probable reason for retrospective time judgment being less precise.

Unlike earlier studies, the present study employed time judgment of both short and long durations. There were very few studies that had employed long duration for prospective paradigm and short duration for retrospective paradigm. The issue is still unresolved as to whether similar or different mechanisms underlie the estimate of short and long durations. Some psychologists (Brown, 1985; Ornstein, 1969) are of the view that judgments of short and long durations involve different mechanisms and are influenced by different factors described in introduction. However, Block (1978) argued that similar mechanisms are involved for both short-and long-durations. In this study, actual duration was found to significantly influence time estimation judgment. Overall, actual long duration was underestimated while actual short duration overestimated under retrospective paradigm. The opposite was true under prospective paradigm. The present finding for prospective paradigm is consistent with the existing literature (Boltz, 1998).

Both methods (verbal estimation and reproduction) produced similar findings with regard to paradigm and cognitive load. In the analyses, verbal estimations of time were found to be more accurate than time reproductions. This finding is inconsistent with most of the earlier findings e.g., Clausen, 1950; Brown, 1985. The finding that verbal estimation produces more accurate judgments as compared to reproduction method can be explained on the basis of the task involvement and the gap between the presentation and reproduction of temporal information. Reproduction method requires active involvement in the task. This might have resulted in more errors in time judgment. In addition to this, the waiting period during the gap could have distracted the subjects from paying attention to time. Earlier studies (McClain, 1983; Predebon, 1996, 1999, 2002) utilized only short duration for comparing verbal and reproduction methods. The present study also employed long duration (150s, 210s and 270s) to determine the effect of verbal and reproduction method on time estimation. It is quite possible that, for longer durations, factors such as task involvement might be important. There is a need for further research using both short- and long-duration to determine the exact role of duration in reproduction method.

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Azizuddin Khan, Professor, Psychophysiology Laboratory, Department of Humanities and Social Sciences, Indian Institute of Technology, Mumbai - 400 076, Mumbai, India. Email: khanaziz@iitb.ac.in