© Journal of the Indian Academy of Applied Psychology,
January 2006, Vol. 32, No.1, 37-42.

Effect of Cognitive Load and Paradigm on Time Perception

Azizuddin Khan, Narendra K Sharma and **Shikha Dixit**
Indian Institute of Technology, Kanpur

An experiment was conducted to investigate the effect of cognitive load and paradigm on time perception. Data were collected using a balanced between subjects analysis of variance design in which 180 subjects participated under six treatment combinations involving three levels of cognitive load (low, medium and high) and two levels of paradigm (retrospective and prospective). Two dependent measures, namely directional errors and absolute errors, were derived from observed verbal estimations of time duration of 3 seconds. The analyses revealed significant main effects but nonsignificant interaction between cognitive load and paradigm. Actual duration was overestimated under all conditions except the treatment combination involving low cognitive load and retrospective paradigm. Time estimates were generally found to be negatively related to cognitive load under both the paradigms, though the strength of relationship was stronger under the prospective paradigm. The accuracy of time estimation deteriorated with cognitive load. Contrary to most existing findings, time perception was less accurate under the prospective paradigm than the retrospective paradigm at all levels of cognitive load. The results are discussed in the light of attentional-change and storage hypothesis models of time perception.

The study of time perception has long and diverse history in psychological literature. Time is a crucial dimension of our perceived world. Perceived time is not the same as the actual or chronological time (Fraisse, 1984). The same interval of actual time may be perceived as long or short, as fast or slow. Experienced time is affected by several factors such as motivation, interest, context, etc. Time perception is the ability to judge the duration or apprehend the passage of time by the order of occurrence of experience or by physiological rhythm.

People perceive time in two different ways - as background and as figure. Time serves as the dimension in terms of which events are organized together. Alternatively, it works as figure, when perceived against the background. In psychology, researchers are more concerned with subjective or experienced time, as compared to clock time. It is puzzling that no single sensory organ or perceptual system is solely responsible for the encoding of psychological time. This state of affair has led most theorists to explain experiences of time in terms of cognitive processes alone or as a result of the interaction between cognitive and biological processes.

The importance and ubiquitous nature of time has led psychologists to search for factors that affect time perception in day to day life. The primary goal of time perception research is to determine the factors that result in the relative accuracy of these estimations and/or systematic distortion wherein the relevant time span is either under- or overestimated. There are mainly two lines of thought that affect subjective experience of time: biological basis of time perception and cognitive basis of time perception.

According to the biological basis of time perception theory, biological time determines experienced time. Psychologists like Hoagland cited by Cohen, 1964, p (117-118) and Holbur (1969) propounded the idea of biological clock. The biological approach to time perception assumes that people have internal cycles that can be used to measure time. By attending to these cycles people know how much time has passed. This cyclic pattern that recurs on a daily basis in humans is termed as circadian rhythm. The concept of biological time assumes that there exists some kind of automatic rhythm that occurs continuously which is not directly and easily affected by environment.

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 (Rovee-Collier, 1995). There are several models that explain the effect of cognitive load or information on time estimation. Some important cognitive models include storage size model (Ornstein, 1969), change model (Block, 1978), cognitive–attentional model (Thomas and Weaver, 1975), and structural remembering model (Boltz, 1995, 1998). These models are neither mutually exclusive of each other nor exhaustive.

Several reviews of literature on time perception (Block, 1997; Hicks, Miller & Kinsbourne, 1976; Zakay, 1993) indicate that there are five general classes of variables that influence temporal judgment: (1) The method used to assess duration estimate such as production, verbal estimation, reproduction and comparative judgment; (2) Characteristics of the experience such as age, personality traits, degree of stress and arousal; (3) Use of the prospective versus retrospective research design; (4) Subject's activity during a time span (cognitive load of task) requiring active or passive participation; and (5) Characteristics of the events to be judged including their total duration, sensory modality and overall complexity. The present study proposed to experimentally investigate whether time perception under the prospective and retrospective paradigms is differentially influenced by cognitive load.

The experiment was designed with the following specific objectives. (1) The first objective was to compare prospective and retrospective time judgment in a task associated with different degrees of difficulty. Time perception research mainly employs two types of research paradigms - prospective paradigm and retrospective paradigm (Block, Hancock, & Zakay, 2000). In the prospective paradigm, subjects are explicitly told in advance that they would be required to judge the ensuing time interval. This presumably motivates the subject to monitor the time in passing by and attend to any available cues (Doob, 1971). In contrast, subjects tested under the retrospective paradigm are not given any warning about time judgment at the start of the interval; the subject would be unexpectedly asked the duration of the interval after it has elapsed. The subjects tested under retrospective condition are presumed to process temporal information in more incidental and unreliable fashion, because they do not pay much attention to time *per se*. Rather they give more attention to processing of information itself. (2) The second objective was to assess the effect of cognitive load on time perception. Individuals have limited attentional resources to process given information. As suggested by Hicks et al. (1976) and others (Thomas and Weaver, 1975), when a subject performs any activity, attention is split between the task's temporal and non-temporal information. Temporal information is encoded via cognitive timer while non-temporal information is processed by its own independent mechanism. Both compete for a limited pool of resources such that increased attention towards one dimension will decrease performance on the other (McClain, 1983; Smith, 1969; Underwood & Swain, 1973). Thus if a subject's attentional resources are more directed towards non-temporal information contents then there will be less attentional resources available to process temporal information. Consequently, there will be relatively poor performance on temporal processing.

The present study used verbal material as well as repeated presentation of the same stimulus several times to the subject. A similar study conducted by Brown (1985) employed nonverbal material and only once. Thus the present study may be seen as an extension of Brown's research. In the present study it was expected that prospective time judgment would be more accurate than retrospective time judgment. Further, a negative correlation between cognitive load and time judgment was expected.

Method

Experimental Design:

A 3 (Cognitive Load: low, medium, high) ´ 2 (paradigm: prospective, retrospective) balanced between subjects factorial design was used. The subjects were assigned randomly to the six treatment combinations.

The subjects were required to verbally estimate duration of 3s in an experiment which employed two independent variables, namely cognitive load (low, medium and high) and paradigm (prospective and retrospective) with the levels as indicated against each below.

Error in verbal time estimation was the dependent variable in the experiment. Judged durations were converted into absolute errors and directional errors as described in the section dealing with the results.

Subjects

One hundred and eighty subjects participated in the experiment. They were young adults with a mean age of 25.2 years ranging from 19 to 38 years drawn from the undergraduate and postgraduate classes of an engineering institute in Northern India. The subjects were told that the experiment was an investigation of attention or memory, depending on the cognitive load condition of the experiment.

Stimulus Material

The stimulus material consisted of a list of 30 items including 15 animals (taken from List 8, page 14 of Battig and Montague, 1969) and 15 fruit names (List 16, page 9 of Battig and Montague).

A computer program using visual basic was developed (1) to obtain personal information about the subject, (2) to present the items to the subject on a computer screen, one after the other, in a controlled manner, and (3) for recording subject's responses. Each animal or fruit name appeared on the screen for 2, 4, and 6 seconds with a blank interval of 3 seconds between two consecutive names. The subjects were required to estimate the blank interval of 3 seconds.

Procedure

Data were collected on individual subjects. The subject was seated in front of the color monitor of a computer. Appropriate instructions were given to the subjects to respond using the mouse attached to the computer. The subject first completed the personal details.

Depending on the experimental treatment in which a subject was participating, 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 participated 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 participated under the retrospective paradigm condition and were given no advance information about time monitoring and estimation task.

The subjects were urged to be as accurate as possible in making these judgments. Subjects provided time judgments through the method of verbal estimation.

Results and Discussion

Following standard practice, estimated times were transformed into measures representing Directional Error and Absolute Error which represent proportion of the respective duration being judged so that all scores are scaled down to the same denominator.

To obtain Directional Errors, each observation was divided by 3 (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 a value greater than unity represents a judgment longer than the actual duration (overestimation); a directional error with a value '1' represents perfect estimation.

The data were also converted into Absolute Errors by dividing absolute differences between the estimated times and actual time (3s) by actual time and multiplying the quotients by 100. Absolute error shows the proportional difference between objective clock time and judged time, and it is used to assess overall level of accuracy of time judgment (Brown, 1985); an absolute error of zero indicates perfect performance. Since directional error and absolute error are ratios of the same variable, these are unitless quantities.

The descriptive statistics related to the directional errors and absolute errors for the various experimental conditions are presented in Table 1. Directional errors as well as absolute errors were separately analyzed using analysis of variance designs. These analyses employed 3 (Cognitive load: low, medium, and high; between subjects) × 2 (Paradigm: retrospective and prospective; between subjects) designs. The analysis of directional error showed that prospective judgments (Mean = 1.38) were significantly longer than retrospective judgments (Mean = 1.04) {F (1,174) = 520.80, $p < 0.002$, ç^2 (partial) = 0.99}. The main effect of cognitive load was also significant {F (2, 74) = 158.48, $p < 0.006$, ç^2 (partial) = 0.99}. But the interaction between cognitive load and paradigm was nonsignificant.

For absolute errors, only the main effect of paradigm tended to be significant {F (1, 174) = 11.79, $p < 0.07$, ç^2 (partial) = 0.86}; none of the other effects were significant. However, less error was associated with the retrospective paradigm (Mean = 39.3%) than with the prospective paradigm (Mean = 53.7%) as shown in Table 1. Overall, there was increase in time judgment error between low (45.0%) to high cognitive load (53.3%).

Table1. Means (standard deviations) of Errors for Different Treatment Combinations of Cognitive Load and Paradigm.

(a) Directional Error				
Paradigm	Cognitive load			Total
	Low	Medium	High	
Retrospective	0.86 (0.48)	1.09 (0.45)	1.18 (0.59)	1.04 (0.52)
Prospective	1.21 (0.48)	1.39 (0.41)	1.53 (0.81)	1.38 (0.60)
Total	1.03 (0.51)	1.23 (0.46)	1.36 (0.73)	1.21 (0.59)
(b) Absolute Error				
Paradigm	Cognitive load			Total
	Low	Medium	High	
Retrospective	41.1 (27.2)	34.4 (29.7)	42.2 (39.1)	39.3 (32.2)
Prospective	48.9 (61.4)	47.8 (33.5)	42.2 (32.2)	53.7 (58.0)
Total	45.0 (47.5)	41.1 (32.1)	53.3 (58.6)	46.5 (47.3)

As indicated by the above general findings, cognitive load affected time estimation. Directional errors increased with the increase in cognitive load (mean values – low: 1.03; medium: 1.23; high 1.36). Similarly, there was an increase in mean percentage absolute time judgment errors with increasing cognitive load (low: 45.0%; high: 53.3%). However, the low absolute error (41.11%) was obtained for the medium cognitive load. In general, these results are consistent with the various earlier findings (Boltz, 1991; Brown, 1985; Eisler, Eisler & Mongomery, 1996; Fortin & Rousseau, 1987; Hicks et al., 1976; Thomas & Weaver, 1975).

Overall, there was an overestimation of time under both paradigms as revealed by values of directional errors which were greater than unity. The results showed that time interval was overestimated more under the prospective paradigm than under the retrospective paradigm. A possible reason for this is that the subjects might be motivated to pay attention to time-in passing under the prospective paradigm, as suggested by Doob (1971), which would not be the case under the retrospective paradigm. Further, subjective duration increases with the subject's attention to time (Brown, 1985). As the interval to be judged was repeatedly presented, the subject might have paid more attention to time leading to the storage of subjective temporal units, hence overestimation might result. This result is consistent with the findings of Hicks et al. (1976). On the other hand, subjects under retrospective paradigm processed temporal information in an incidental manner. Since subjects under retrospective paradigm had no prior knowledge about the time perception, they might have retrieved temporal information from their memory. The same time interval was presented repeatedly again and again, this might result into better memory and consequently more accurate time perception performance than under prospective paradigm. That might be the reason for retrospective time judgment, though an overestimation, to be more accurate compared to that under prospective paradigm.

The present experiment also revealed that cognitive load affected directional errors. Prospective time estimates decreased as cognitive load increased. These findings are consistent with earlier findings (Brown, 1985; Martinez, 1994; Predebon, 1996; Zakay, 1993) and support attentional allocation models (Boltz, 1991; Hicks et al; 1976; 1978; Thomas & Weaver, 1978). However, in the present study, there was larger inaccuracy in time perception under prospective paradigm as compared to the retrospective paradigm. According to the attentional allocation model, information consists of temporal and non temporal properties. Human being has 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. This result is not consistent with existing literature. However, there was no clear cut relation between cognitive load and time-judgment under retrospective paradigm. The probable reason for this finding could be that there might be the possibility that short- and-long duration affect time perception differently. Apart from that, in the present study the same stimulus was presented again and again several times. This could be the reason for the larger error in prospective paradigm as compared to retrospective paradigm. Subjects probably store temporal information continuously which consequently results into more overestimation and inaccurate time perception under prospective paradigm. The inconsistent findings can be also attributed to different mechanisms involved in short- and long-duration and stimulus material used in the study. Brown (1985) employed nonverbal material (mirror drawing) and longer duration (8 sec and 16 sec) in his study. However, the present study employed verbal material. The inconsistent finding can be attributed to differential stimulus material and repeated exposure of actual duration used in the study.

Future studies may be conducted with a range of time duration (short and long) as well as different materials (verbal and nonverbal) to provide a direct comparison. If such an experiment is devised, it may also be possible to investigate if the errors in perception of short and long intervals are moderated by the nature of the material.

References

Battig, W.F., & Montague, W.E. (1969). Category norms for verbal items in 56 categories: replication and extension of Connecticut category norms. *Journal of Experimental Monograph*, *80*, 1- 46.

Block, R .A. (1978). Remembered duration: Effects of event and sequence complexity. *Memory & Cognition*, *6*, 320-326.

Block, R. A. (1997). Prospective and retrospective duration judgments: A meta-analytic review. *Psychonomic Bulletin & Review*, *4*, 184-197.

Block, R. A., Hancock, P.A. & Zakay, D. (2000). Sex differences in duration judgments: A meta-analytic review. *Memory & Cognition*, *28*, 1333-1346.

Boltz, M. (1991). Time perception and attentional perspective. *Perception & Psychophysics*, *49* (5), 422-433.

Boltz, M. (1995). Effects of event structure on retrospective duration judgments. *Perception & Psychophysics*, *57* , 1080-1096.

Boltz, M. (1998). Task predictability and remembered duration. *Perception & Psychophysics*, *60* , 768-784.

Brown, S. W (1985). Time perception and attention: The effects of prospective versus retrospective paradigms and task demands on perceived duration. *Perception & Psychophysics*, *38* , 115-124.

Cohen, J. (1964). Psychological time. *Scientific America*, November, 117-118

Doob, L.W. (1971). *Patterning of Time*. New Haven, CT: Yale University Press.

Eisler, A. D., Eisler, H., & Montgomery, H. (1996). Prospective and retrospective time perception: Cognitive and biological approaches. In S. C. Masin (Ed.), *Fechner Day, Proceedings of the Twelfth Annual Meeting of the International Society for Psychophysics*, University of Padova.

Fortin, C. & Rousseau, R. (1987). Time perception as an index of processing demand in memory search. *Perception & Psychophysics*, *42* , 377-382

Fraisse, P. (1984). Perception and estimation of time. *Annual Review of Psychology*, 35, 1-36.

Hicks, R. E., Miller, G.W., & Kinsbourne, M. (1976). Prospective and retrospective judgments of time as a function of amount of information processed. *American Journal of Psychology*, *89* , 719-730.

Holubar, J. (1969). *The Sense of Time*. Cambridge, Mass.: M.I.T. Press.

Macar, F., Grondin, S., & Casini, L. (1994). Controlled attention sharing influences time perception. *Memory & Cognition*, 22 , 673-686.

Martinez, B. B. (1994). The role of cognitive changes in immediate and remote prospective time estimation. *Acta Psychologica*, 85, 99 – 121.

McClain, L. (1983). Interval estimation: Effect of processing demands on prospective and retrospective reports. *Perception & Psychophysics*, *34*, 185-189.

Ornstein, R. E. (1969). *On the Experience of Time.* New York: Penguin Books.

Predebon, J. (1996). The effects of active and passive processing interval events on prospective and retrospective time estimates. *Acta Psychologica*, *94*, 41-58.

Rovee-Collier, C. (1995). Time window in cognitive development. *Developmental Psychology*, *31*, 147-169.

Smith, N. C. (1969). The effects on time perception of increasing the complexity of cognitive task. *Journal of General Psychology*, *81*, 231-235.

Thomas, E. A. C., & Weaver, W. B. (1975). Cognitive processing and time perception. *Perception and Psychophysics*, *17*, 363-367.

Underwood, G., & Swain, R. A. (1973). Selectivity of attention and the perception of duration. *Perception*, *2*, 101-105.

Zakay, D. (1993). Relative and absolute duration judgment under prospective and retrospective paradigms. *Perception & Psychophysics*, *54* , 656 - 664.

Azizuddin Khan, Research Scholar, Department of Humanities and Social Sciences, I.I.T., Kanpur

Narendra K Sharma, PhD, Professor, Department of Industrial and Management Engineering, I.I.T., Kanpur

Shikha Dixit, PhD, Associate Professor, Department of Humanities and Social Sciences, I.I.T., Kanpur