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The effects of spatial frequency and target type on perceived duration

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Two experiments are reported that attempt to demonstrate a critical role played by sensory persistence on a standard perceived-duration task employing brief visual stimuli. Experiment 1 examined the effect on perceived duration of varying the spatial frequency of a target. For both 40- and 70-msec flashes, increased spatial frequency resulted in reduced estimates of perceived duration. These results were contrasted with predictions derived from cognitive processing models of duration perception. In Experiment 2, three typical types of target employed in current research (an outlined circle, a "noise"-filled circle, and a completely filled circle) were shown to differ significantly in their perceived duration and in their sensitivity to increases in physical duration. The results were discussed in terms of variable degrees of retinal persistence produced by the three types of targets. The possible implications for specific discrepancies in the literature and across-study comparisons in general were enumerated.

Within the last 10 years, the number of research articles dealing with the perceived duration of brief stimulus events has increased markedly. In her recent review, Allan (1979) has noted explicitly the "dramatic change" in the character and extent of research in this area and has attempted both to integrate the myriad of findings and to examine the empirical support for specific models of time perception proposed by various researchers. However, a recurring problem faced by Allan (1979) as well as by others attempting to organize the duration literature (e.g., Eisler, 1976) is the frequently contradictory or, at best, inconsistent nature of that literature. Much of the early research in time perception was concerned with the apparent lack of consistency across the several methodologies that had been developed (cf. Bindra & Waksberg, 1956; Carlson & Feinberg, 1968, 1970; McConchie & Rutschmann, 1971). In her treatment of four specific areas of theory and research in the current time-perception literature (i.e., psychophysical function between physical and perceived durations, Weber's law, time-order error, and the role of nontemporal information), Allan (1979) also frequently attributes empirical discrepancies to important procedural differences across studies. Other inconsistencies in the literature have been hypothesized to result from such factors as practice effects (Eisler, 1976), additional task requirements (Erwin, 1976), the nature of the "stimulus set" established within the observer (Gomez & Robertson, 1979), attentional differences (Allan, 1979; Cantor & Thomas, 1977), range effects (Eisler, 1976), varying response measures (Eisler, 1976), and others.

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In a recent study, Beaton and Long (Note 1) proposed that a critically important variable in the perceived duration of a brief visual target is retinal persistence, which is sensitive to numerous characteristics of the target stimulus. Hundreds of studies examining so-called iconic memory, or short-term visual storage, have demonstrated that a brief visual stimulus phenomenally and behaviorally outlasts its physical offset (cf. Coltheart, Lea, & Thompson, 1974; Dick, 1974; Neisser, 1967; Sperling, 1960). Moreover, several studies within the last 5 years have indicated that, at the very least, a major portion of this "memory" is due to retinal persistence effects (Long, 1979a, 1979b, 1980; Long & Sakitt, 1980a, 1980b; Sakitt, 1975, 1976; Sakitt & Long, 1978, 1979a, 1979b). That is, retinal sluggishness appears to be the basis for the gradually fading image (or icon) of a brief visual target assessed by the various iconic memory tasks. Beaton and Long (Note 1) reasoned that, given the retinal basis for this persistence, the manipulation of certain stimulus variables might well influence the perceived duration of a brief stimulus by varying the degree of phenomenal persistence produced by the stimulus. In support of this proposal, they examined and compared the effects of target size, target luminance, and target duration on a standard perceived-duration task and on a probe-matching task borrowed from the persistence literature (e.g., Bowen, Pola, & Matin, 1974; Efron, 1970; Sakitt & Long, 1979a;

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Sperling, 1967). The striking comparability of results in all cases on the two tasks was interpreted as evidence for the same process(es) most likely underlying performance on both tasks. They argued that this process was very likely that of retinal persistence rather than varying information-processing requirements across stimuli, which previous investigators have favored (e.g., Avant & Lyman, 1975; Avant, Lyman, & Antes, 1975; Thomas & Cantor, 1975, 1976, 1978).

The present study has two specific aims. First, it attempts to provide further support for the proposed role of a peripheral persistence effect on tasks of perceived duration. In this regard, Experiment 1 examines the effect of the spatial frequency of a stimulus on its perceived duration. The results are compared and contrasted both with the analogous findings in the persistence literature and with the predictions from current models of time perception that employ information-processing conceptualizations. Second, the present study also seeks to demonstrate the additional power of this peripheral interpretation of some perceived-duration findings by examining the ability of this alternate conceptualization to account for certain empirical discrepancies noted previously. Specifically, Experiment 2 attempts to show that the nature of the visual stimulus employed can have serious effects on the obtained functional relationship between variables on a perceived-duration task and, furthermore, that these effects are entirely consistent with predictions from a sensory persistence interpretation of task performance.

EXPERIMENT 1

In the current vision literature, a frequent stimulus manipulation involves varying the spatial frequency of a target. Specifically, grating stimuli are employed in which overall target area and space-average luminance are maintained constant, while spatial frequency is systematically varied. The rationale for the use of such stimuli rests in the extensive psychophysical and physiological research indicating that the human visual system may be specifically attuned to analyze the spatial frequency components of a target (cf. Campbell & Robson, 1968; Legge, 1978). Sine-wave gratings are then considered the "purest" and simplest type of target that may be used in the investigation of various properties or functions of the visual system. For example, in the area of visual persistence, which is of particular interest in the present context, several studies have attempted to examine the temporal response properties of the visual system through the use of grating targets (Bowling, Lovegrove, & Mapperson, 1979; Breitmeyer, 1975; Meyer & Maguire, 1977; Vassilev & Mitov, 1976; Williamson, Kaufman, & Brenner, 1978; Gildea & Long, Note 2). Recently, Sakitt and Long (Note 3) have demonstrated that the subjective persistence of a brief grating target is inversely related to the spatial frequency of that target. They employed a probe-matching task in which observers simply adjusted the onset of a brief probe flash to coincide with the end of any phenomenal persistence from a 50-msec target grating of a given spatial frequency. Sakitt and Long (Note 3) interpreted their findings as consistent with a peripheral locus to the persistence revealed by their procedures. As spatial frequency increases, the width of the individual bars in the grating pattern decreases, and other research has demonstrated that larger targets have phenomenally greater persistence than smaller targets (Sakitt & Long, 1978; Beaton & Long, Note 1). This explanation favoring peripheral factors contrasts directly with a previous hypothesis by Meyer and Maguire (1977) which equates iconic persistence with the poor temporal resolution of the "sustained" (vs. transient) cortical channels. Sakitt and Long (Note 3) attribute their findings to important precortical processes emphasizing retinal contrast effects.

The first experiment is concerned with examining the effect of spatial frequency on a standard perceived-duration task. If, indeed, there is a strong contribution to task performance from a retinal persistence component, it is predicted that perceived target duration will *decrease* with increasing spatial frequency of the target. This follows from the Sakitt and Long argument (1978, Note 3) that the individual bar width in the grating pattern is the critical target element rather than spatial frequency per se.

It is also informative to consider the predictions for the effect of this stimulus manipulation from current information-processing conceptualizations of perceived duration. The influential model proposed by Thomas and his colleagues (cf. Thomas & Brown, 1974; Thomas & Cantor, 1975, 1976, 1978; Thomas & Weaver, 1975) stresses the important role played by nontemporal variables in a brief stimulus. For example, in several studies, increasing target *area* has been found to produce increased estimates of target duration (Mo & Michalski, 1972; Thomas & Cantor, 1975, 1976). Similarly, Mo (1975) reported brief flashes of random dots to increase in perceived duration as the *number* of dots in the flash was increased. Avant and his co-workers (Avant & Lyman, 1975; Avant, Lyman, & Antes, 1975) reported a similar effect for dot patterns forming letters, nonsense syllables, and words. These researchers have generally interpreted their findings as reflecting the relative functioning of higher order mechanisms (e.g., information-processing stages, scanning processes) that are sensitive to the degree of nontemporal information in the target (cf. Allan, 1979). Given these previous findings and the cognitive models that have been proposed to account for them, it is nevertheless difficult to specify the predicted effect on perceived duration of varying the spatial frequency in the target. Although the size (i.e., area) of the individual bars in a grating target is greater for low spatial frequencies, overall target area and the relative amounts of light and dark areas are constant. Furthermore, the number of elements (i.e., bars) per target increases as spatial frequency is increased, and increasing number has been reported to result in greater estimates of duration (Mo, 1971, 1975). Cantor and Thomas (1977) also report that the perceived "compactness" of a stimulus (i.e., density of checkerboard squares in a constant area target) may be positively related to these same judgments. This latter finding would suggest a prediction of *increased* estimates of duration with increasing spatial frequency. But, finally, Thomas and Cantor (1975, 1976; Cantor & Thomas, 1976) have also argued that the degree of attention the observer allots to the nontemporal information is critical, so that little effect of spatial frequency might be expected if that dimension is not made salient to the observer by either instructional or task demands. To summarize, the cognitive models of duration discrimination would seem to predict either no effect or a *positive* relationship between perceived duration and spatial frequency of a brief target grating. As noted above, the sensory interpretation of Beaton and Long (Note 1), which emphasizes peripheral factors, would predict an *inverse* relationship between these same variables.

Method

Subjects. Five subjects (three male, two female) participated in the experiment. These subjects were undergraduates at Villanova University who participated in the research for partial fulfillment of a course requirement in general psychology. Each subject was run in a single session lasting about 1½ h.

Apparatus and Stimuli. A Scientific Prototype 3-channel tachistoscope (Model 320-GB) was used to present all stimuli and background fields. Square-wave gratings of three spatial frequencies (1, 3, and 10 cycles/deg) were used as the target stimuli. The average luminance of the grating was constant at 5 fL (i.e., white bars in grating were 10 fL); the luminance of the white pre- and postexposure field was also 5 fL (17.1 cd/m²). A small black fixation point was located in the center of these background fields. Both the target and background fields subtended 8.3 deg horizontally and 5.9 deg vertically. Target duration was either 40 or 70 msec.

Procedure. The perceived-duration task of Thomas and Cantor (1975, 1976) was employed. On each trial, the observer views the background field containing the fixation point. A warning signal ("click") was followed after 500 msec by the 40- or 70-msec presentation of the target grating. The target grating was immediately replaced by the background fixation field.

Before the experimental trials began, each observer received 5-10 min of practice in which he was shown all six possible combinations of spatial frequency and exposure duration. The purpose of the brief practice was to familiarize observers with the range of visual impressions they would experience in the actual experiment so that they could "anchor" their temporal judgments. Subjects were not told that stimulus duration would vary between 40 and 70 msec, nor were they trained to call any particular stimulus conditions "short," "medium," or "long."

Following practice, each subject received 120 total trials, which consisted of 20 presentations of the six spatial frequency and duration conditions. The order of the six stimulus conditions was randomized throughout the 120 total trials with the single constraint that each condition occur within every six trials. Following each presentation, the subject reported verbally whether the subjective impression of the target on that trial was "short," "medium," or "long" in perceived duration. The experimenter recorded these verbal responses and proceeded to the next trial without giving the subjects any feedback about their responses. After 60 trials, the subjects were allowed a brief 2-3-min rest period before the last 60 trials began.

Results and Discussion

Following the analysis employed by Gomez and Robertson (1979) and Thomas and Cantor (1975, 1976), the verbal responses of "short," "medium," and "long" on the perceived duration task were coded 0, 1, and 2, respectively. For each of the six stimulus conditions (three spatial frequencies and two durations), the mean responses for the five observers were then determined and subjected to a within-subjects analysis of variance. These data, averaged over subjects, are presented in Figure 1.

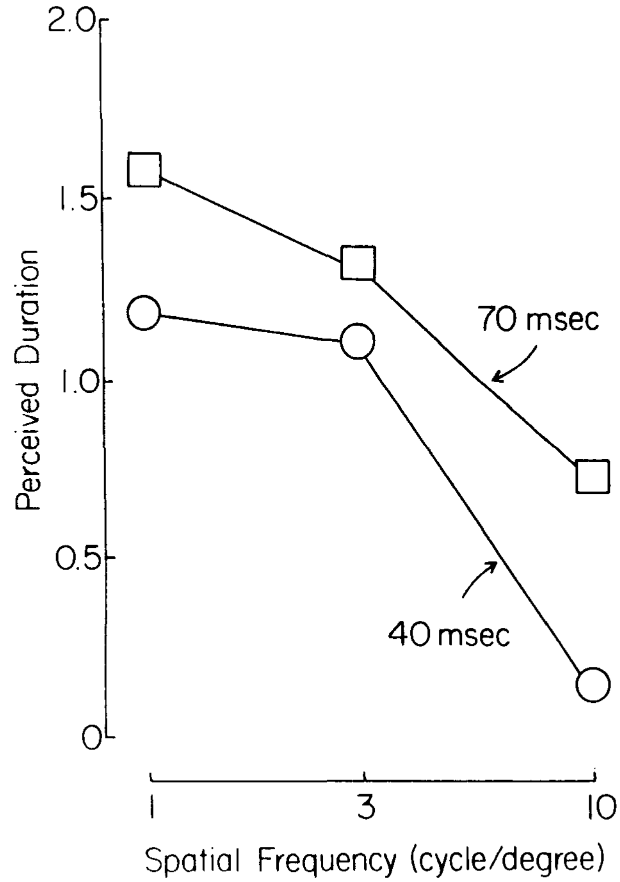

Figure 1. Temporal judgments on the perceived-duration task, averaged over observers, for the two target durations and three spatial frequencies examined (Experiment 1).

As predicted, the main effect of target duration is highly significant [$F(1,4) = 71.07$, $p < .001$], and the main effect of spatial frequency is also highly significant [$F(2,8) = 22.56$, $p < .001$]. Hence, perceived duration increases with increasing physical duration and decreasing spatial frequency. It can be seen in Figure 1 that the significant interaction [$F(2,8) = 8.97$, $p < .01$] results largely from a more pronounced reduction in perceived duration, with the highest spatial frequency at the 40-msec duration rather than at the 70-msec duration. Nevertheless, the inverse relationship between perceived duration and spatial frequency is true for both durations examined.

It is believed that the results shown in Figure 1 are directly comparable to those reported by Sakitt and Long (Note 3), who examined spatial frequency effects on persistence estimates. Because the fading retinal icon from a large target is discernible for a longer period than that from a small target (cf. Sakitt & Long, 1978, Note 3), lower spatial frequency targets were predicted and found to produce greater persistence on a common iconic memory task. In the present work, it was argued that if this sensory persistence is utilized by observers on tasks of perceived duration, a similar effect of varying spatial frequency would be predicted for the duration task employed in this experiment. Figure 1 would appear to support these predictions.

As noted above, it is unclear how the current cognitive processing models of perceived duration would treat the pattern of results shown in Figure 1. Overall area of the target as well as the total amount of light and dark areas within the target are equal across stimulus gratings. Rather, the changes are in number of target elements and in apparent "complexity" and would appear to require from extant models a prediction of increasing perceived duration as spatial frequency is increased. A post hoc hypothesis that the sizes of *subareas* within the overall target are dominant in duration judgments may be possible, but this would appear more consistent with the alternate proposal raised here of an underlying process that involves retinal contrast effects rather than one reflecting information-processing stages.

EXPERIMENT 2

The results of Experiment 1 as well as those previously reported by Beaton and Long (Note 1) provide strong support for the argument that sensory persistence effects play a significant role in at least some temporal judgments. Moreover, it is believed that these results may accomplish more than identifying an important variable in time perception research or providing a more parsimonious interpretation of various phenomena in that research. It is very likely that this particular variable of sensory persistence may well underlie apparent discrepancies in the duration literature. Specifically, in this general area of research, the "type" of stimulus whose perceived duration is assessed has varied greatly from study to study. Typical target stimuli have been checkerboard patterns (Cantor & Thomas, 1977), visual noise patterns (Cantor & Thomas, 1976), red dots (Thomas & Cantor, 1975, 1976), black letters (Erwin, 1976), white lights (Allan & Kristofferson, 1974), red lights (Buffardi, 1971), and outlined figures (Gomez & Robertson, 1979). Moreover, these stimuli have been of various sizes, and they have been used with both dark and light background fields. Such variant stimulus conditioners do not produce equivalent retinal stimulation and may, therefore, differ greatly in the amount of subjective persistence they produce. Hence, apparent differences across studies may reflect the differential degree of contribution to performance from a peripheral persistence effect. For example, Gomez and Robertson (1979; Robertson & Gomez, 1980) obtained a rather small effect of varying target size on duration judgments, which they also report can be found only in a within-subjects design. They interpret this finding in terms of a "stimulus set" that *must* be established within the observer for the effect of stimulus size reported by other investigators to be obtained. However, an alternate explanation may be possible. Gomez and Robertson (1979; Robertson & Gomez, 1980) employed *outlined* shapes of variable area for their stimuli. Most other investigators have employed filled or partially filled figures in their research (e.g., Thomas & Cantor, 1975, 1976). If these latter stimuli produce greater persistence effects (as would be predicted from increased retinal contrast), a size effect that has its basis in differential degrees of persistence produced by targets of various size may be much more pronounced with such stimuli. The low-contrast stimuli employed by Gomez and Robertson (1979) may have resulted in barely differing degrees of persistence for the large and small targets. The absence of any strong persistence difference may then have made any differences in perceived duration very slight. The present experiment attempts to examine this possibility by employing three different types of stimuli on the perceived-duration task described in Experiment 1. Outlined circles, partially filled circles, and totally filled circles (dots) will be used. It is predicted that the effect of a second variable (in this case, physical duration of the stimulus) will produce progressively stronger effects on perceived duration as the target is made more "distinct" via increased retinal contrast. That is, in addition to significant main effects of target duration and target type, a significant interaction is also predicted, with increasing target duration having a greater effect on perceived duration as the degree of filled (i.e., black) area in a constant size target is increased. To further support the argument that persistence differences are the bases for the predicted differences in perceived duration, the degree of persistence for these same stimuli will be assessed on a probe-matching task from the persistence literature (e.g., Sakitt & Long, 1979a). The identical pattern of results as described above for the duration task is predicted.

Method

Subjects. The subjects in this second experiment were 20 undergraduates (7 male, 13 female) at Villanova University who participated for partial fulfillment of a course requirement in general psychology. Each subject was run in a single experimental session lasting about 1½ h.

Apparatus and Stimuli. The same basic apparatus described in Experiment 1 was employed. However, in one of the procedures to be described below, a brief auditory tone was required. A Western Electric oscillator (19C) and a Bogen amplifier (CHB35A) provided a 2,000-Hz tone. Two Hunter timers (111-C) interfaced with the tachistoscope to present the tone for 150 msec at any variable delay after the offset of the target stimulus. Again, a constant 500-msec foreperiod followed the auditory warning signal and preceded the presentation of the target stimulus. Three circular targets .9 deg in diameter were employed. These three constant-area targets differed in the degree to which they were "filled." One target was just an outlined circle, the second target was partially filled with random black spots (Format material No. 7086), and the third target was a completely filled black dot. These target stimuli were centered in the white 8.3 × 5.9 deg target field. The luminance of the white backgrounds on which the targets were presented, as well as the luminance of the white pre- and postexposure fields containing the fixation point, was constant at 15 fL (51.4 cd/m^2). Target duration was either 40 or 70 msec.

Procedure. Two different procedures were used in Experiment 2: a measure of perceived duration and a measure of subjective persistence. Ten subjects were run on the perceived-duration task described previously. The observers were required to respond "short," "medium," or "long" following each presentation of the target. After a training period in which observers were familiarized with the six possible stimulus conditions (two duration, three stimulus types), a total of 120 experimental trials were administered. The order of the six stimulus conditions was randomized for each observer across the 120 total trials with the single constraint that each condition occurred every six trials. Twenty observations were obtained for each stimulus condition. After 60 trials, a brief 2-3 min rest period was allowed.

The second procedure employed in this experiment was a common probe-matching task frequently used in the visual persistence literature (e.g., Haber & Standing, 1970; Sakitt, 1976; Sakitt & Long, 1979a; Sperling, 1967). The observer was required to adjust the 150-msec tone so that it coincided in time with the end of the fading stimulus image. With this procedure, it is critical that observers are instructed to adjust the probe to the end of the fading stimulus trace rather than to target offset. It has been shown that observers can readily distinguish these two phenomenal events (Long, 1980; Sakitt & Long, 1979a; Gildea & Long, Note 2). In the present work we were interested in the total subjective impression of the stimulus; hence, observers were instructed to attend to the total fading image. The identical stimulus conditions were used as described for the perceived-duration task above. On each trial, the experimenter initially adjusted the probe so that the probe clearly preceded or clearly followed the end of the fading stimulus image. If the observer responded "early," the experimenter increased the interval by 50 msec (ascending series); if the observer responded "late," the experimenter decreased the interval by 50 msec (descending series). This procedure was continued until the observer responded "match," indicating that the tone and the end of the fading image coincided in time. The experimenter recorded this value, selected the next stimulus condition, and repeated the above procedure.

Each target was presented in pairs of trials: one ascending adjustment and one descending adjustment. Therefore, each stimulus condition was presented to each observer on 12 total trials, half of which required an ascending adjustment series and half of which required a descending adjustment series. For each trial, the experimenter varied the initial ISI value from that used in the previous series of the same type. Seventy-two trials per subject per session were run, with the order of the six stimulus conditions randomized with the single constraint that each condition be presented every 12 trials (6 pairs). After 36 total trials, the observer was allowed a brief 2-3-min rest period. Ten observers were run with this probe-matching task.

Results and Discussion

As in Experiment 1, the verbal responses of "short," "medium," and "long" on the perceived duration task were encoded 0, 1, and 2, respectively, for data analysis. These data, averaged over the 10 observers, are shown in Figure 2 for the six stimulus conditions (three types of target and two durations). The main effect of target duration is again significant

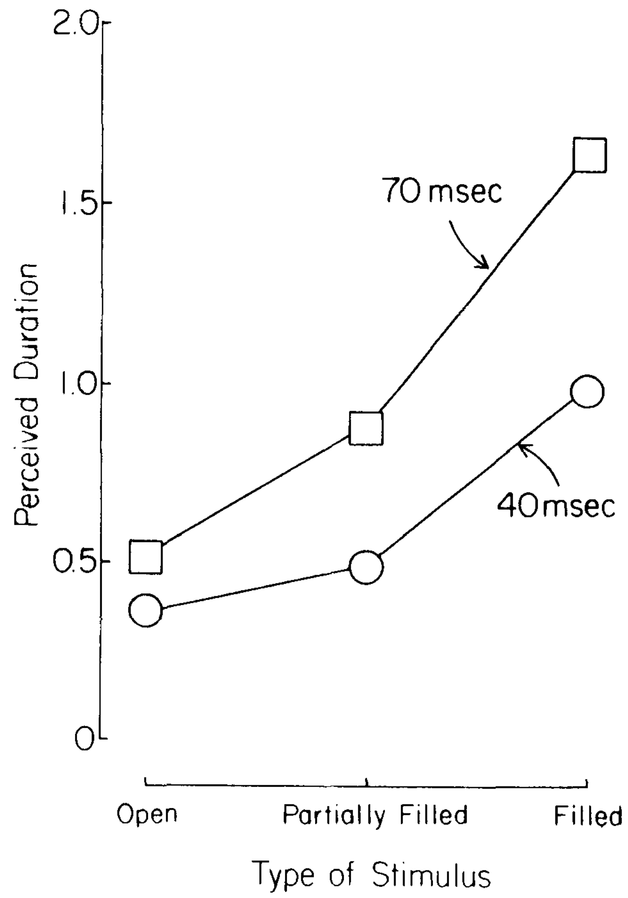

Figure 2. Temporal judgments on the perceived-duration task, averaged over observers, for the two target durations and three types of target stimulus (Experiment 2).

[F(1,9) = 28.09, p < .0001]. The critical main effect in the experiment, the "type" of target, is also highly significant [F(2,18) = 49.89, p < .0001]. As predicted, the more filled the target circles, the greater their perceived duration. This is true for both the 40- and 70-msec duration levels. And, very importantly, the predicted interaction between target duration and target type is also significant [F(2,18) = 18.23, p < .0001]. As seen in Figure 2, this interaction results from the fact that the higher the target contrast (i.e., degree of filling), the greater the effect of increasing target duration from 40 to 70 msec. This is believed to reflect the relatively greater persistence produced by the more filled targets. Outlined targets (open circles) would produce little retinal persistence in the conditions employed in this experiment (i.e., bright pre- and postexposure fields). Then as target duration is increased from 40 to 70 msec for these outlined targets, little additional persistence would result. And, in fact, Beaton and Long (Note 1) have previously found that subjects report no significant change in the persistence of a blank target (i.e., empty field) when it is increased from 40 to 70 msec under the identical instructional and background conditions employed here. If observers are using persistence effects in their duration judgments, reports of perceived duration should change very little as the duration of the open target is increased. In support of this prediction, only a nonsignificant increase (planned comparison, F = 1.45, p > .20) in duration judgments was found in the present study *for the outlined circles* when duration was increased (see Figure 2). This is definitely not the case for the partially and completely filled targets for which the fading icon is more noticeable. Both show a significant effect of increasing target duration (planned comparison for the partially filled targets, F = 9.55, p < .002; for the totally filled targets, F = 26.80, p < .0001). It is proposed that increases in the physical duration of a high-contrast target produce marked changes in poststimulus iconic duration and, thereby, appreciable changes in perceived target duration as well.[1]

This proposal is further supported by the results from the probe-matching task. For each observer, the mean adjusted latency for the auditory probe in each of the same six stimulus conditions employed in the perceived duration task was computed. The group means for the 10 observers are plotted in Figure 3, where it can be seen that the same overall pattern of results as shown in Figure 2 for the perceived duration task were obtained. The main effect of target duration is significant [F(1,9) = 29.12, p < .001], as is the main effect of target type [F(2,18) = 51.56, p < .0001]. And, again, the interaction is highly significant [F(2,18) = 28.52, p < .0001]. It is believed that these results on a task in which observers are explicitly instructed to attend to the

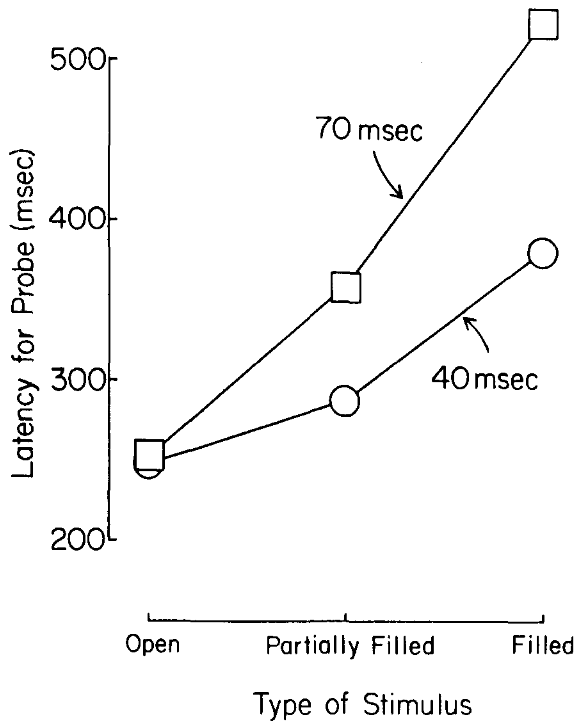

Figure 3. Adjusted latencies for the auditory probe on the probe-matching task, averaged over observers, for the two target durations and three types of target stimulus (Experiment 2).

fading trace of stimulus reflect peripheral persistence effects (cf. Sakitt & Long, 1979a). Hence, the varying degrees of persistence reflected by the results shown in Figure 3 are hypothesized to be the basis for the duration data represented in Figure 2. Lastly, it should be emphasized that we are not arguing that each of the peripheral icons lasts, on the average, for the durations shown in Figure 3. These values are to some extent task dependent and are surely influenced by decision and response times (even if these are relatively constant) as well as by individual criterion levels among observers (cf. Long, 1980). We believe that the values shown in the figure should best be treated as demonstrating relative effects on the phenomenal persistence rather than as absolute levels of retinal persistence.

The major aim of this experiment has been to demonstrate that, given an important role played by sensory persistence in at least some temporal judgment studies, one must be cautious in comparing (or contrasting) results obtained in various studies in which the degree of sensory persistence may have differed greatly (e.g., Gomez & Robertson, 1979; Thomas & Cantor, 1975). Apparent failures to replicate may be attributable to differences in subject or task variables that alter sensory persistence. Furthermore, the data presented in Figures 2 and 3 would also suggest that attempts to determine *the* relationship between variables in this area may be overly ambitious.

Empirical questions dealing with the exact nature of the psychophysical function between real and subjective duration or whether Weber's Law holds in time perception (cf. Allan, 1979) may have more than one answer, depending upon the stimulus conditions employed in their investigation. Low-persistence targets (i.e., outlined figures, bright pre- and postexposure fields, low target luminances, foveal presentation, and red in color) may result in "answers" to these question quite different from those for high-persistence targets. In support of this argument, we ran one additional (naive) observer on the probe matching task with several values of target duration and with two different types of target: the outlined circle that produces minimal persistence and the filled circle (dot) that produces appreciable persistence. The results are shown in Figure 4. It would appear that the nature of the psychophysical function relating physical duration to phenomenal persistence is rather different for the two types of target.

One final point related to these results concerns possible implications for another general area within the time-perception literature: duration discrimination (cf. Allan, 1979). Although duration discrimination has been depicted as independent of nontemporal variables, both Figures 2 and 4 indicate different empirical relationships for different types of targets. This, in turn, implies that the discriminability of two target durations may vary depending upon certain nontemporal conditions of the target. For example, Figure 2 indicates that observers may have considerable difficulty discriminating 40- and 70-msec open-circle targets, whereas 40- and 70-msec filled targets would appear relatively easier to discriminate. It would seem that models of duration discrimination, as well as the perceived-duration models noted earlier, may have to incorporate the important role played by a persistence that has its basis at a very peripheral level in the visual system.

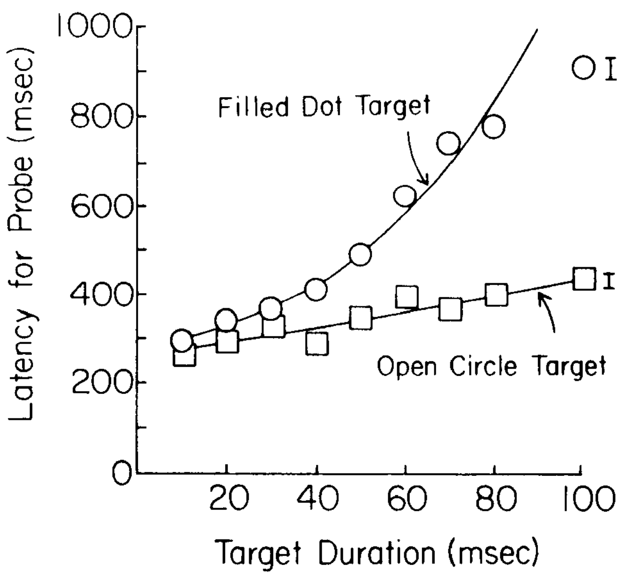

Figure 4. Adjusted latencies for the auditory probe on the probe-matching task for a single observer over several values of target duration and with two different types of target. Each data point is based on 16 trials; the brackets on the right of the figure represent the mean standard errors for the nine points in each curve. (The two curves were drawn by eye.)

SUMMARY

The present study has sought to provide further empirical support for the claim that sensory (i.e., retinal) persistence effects may play an important—yet generally overlooked—role in tasks involving the perceived duration of brief visual stimuli. Two rather distant approaches were undertaken in this regard. First, the effect of varying the spatial frequency of a brief stimulus was examined on a standard perceived-duration task that has been employed in numerous duration studies. It was argued that, whereas current information-processing models make no clear prediction about the relationship between spatial frequency of a target and its perceived duration, a sensory persistence interpretation predicts a simple *inverse* relationship. The results of Experiment 1 clearly supported the latter prediction. Second, the utility of the persistence interpretation for handling apparently discrepant results in the extant duration literature was noted. Specifically, Experiment 2 demonstrated that the type of stimulus employed on a task of perceived duration can significantly affect the nature of the relationship between variables even so basic as physical duration and perceived duration. Outline figures, which produce minimal persistence, were shown to exhibit a less pronounced effect on duration judgments than did more filled figures, which produce appreciable persistence following target offset. Two related conclusions were drawn from these results of the second experiment: (1) At least some empirical disagreements in the literature may have their basis in the type of target stimuli employed by various investigators, and (2) there may be no absolute relationship between certain stimulus variables and the perceived duration of very brief visual stimuli because of the multitude of stimulus and subject conditions that can influence the sensory contribution to the experience of duration. Different conditions might indicate very different relationships between the same two variables.

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NOTE

1. As one of the reviewers suggested, it would be possible to determine the spatial frequency components of the three targets employed in this experiment and then attempt to relate the results of Experiment 2 directly to those of Experiment 1 (Figure 1). However, the focus of the argument in the first experiment is that for the perceived-duration task, the size of the individual components (bars) in a grating pattern is the critical manipulation when varying spatial frequency. This follows from the proposed retinal locus of the persistence involved. Such an early level in the human visual system is peripheral to those stages that may perform a genuine spatial frequency analysis of the target (cf. Legge, 1978).

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