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The Duration of a Brief Event in the Mind's Eye

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ABSTRACT. A new illusion of perceived duration associated with focused spatial attention is reported. Brief flashes in attended locations were perceived to last longer than the same flashes in unattended locations. That illusion was shown to be completely independent of another illusion concerning the perceived onset of a flash, ruling out the possibility that the effect on perceived duration is derivative of a comparison between perceived onset and offset. The illusion also occurred when the event duration was composed of a temporal gap rather than a brief flash, ruling out low-level visible persistence as a basis for the illusion. Taken together, the results point to cortical connections from higher brain centers' both speeding and prolonging the visual signals occuring in lower sensory regions. Those temporal consequences could easily subserve many of the perceptual benefits ascribed to attention for spatial and intensive properties.

DIRECTING THE MIND'S EYE to a spatial location can enhance visual perception in that location, even in the absence of eye movements (Mach, 1886/1959). Attended objects are seen more clearly (James, 1890/1950) and are detected and identified more readily (Bashinski & Bacharach, 1980; Cheal & Lyon, 1989; Downing, 1988; Posner, 1980; Tsal, Meiran, & Lamy, 1995). In addition, the perception of attended objects is less influenced by neighboring objects in space (Eriksen & St. James, 1986) and time (Spencer & Shuntich, 1970). To date, however, many more researchers have investigated the effects of spatial attention on spatial properties (e.g., acuity, perceived size) and intensive properties (e.g., contrast, brightness) than on the temporal properties of visual stimuli.

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In the present study, we explored the effects of spatial attention on the perceived duration of brief visual stimuli. We reasoned that there were three potentially separable temporal properties associated with a brief visual event: onset, duration, and offset. Recently, the authors of several studies reported that focused attention speeds the perception of stimulus onset (Stelmach & Herdman, 1991; Stelmach, Herdman, & McNeil, 1994). Downing and Treisman (1997) reported that attention also speeds the perception of offset, and Mattes and Ulrich (1998) found that attention prolongs perceived duration.

Despite the paucity of data on the question of perceived duration and attention, there are competing theoretical predictions in the literature. A *classic model of time perception* predicts that an attended event will be perceived as longer than an unattended event because timing is based on the attentional monitoring of an internal pacemaker (Thomas & Weaver, 1975). Withdrawing attention from an event will therefore attenuate the counting-like process that is normally responsible for time perception and will therefore lead to a shorter estimate of its duration. Previous evidence in support of the attentuation hypothesis has come primarily from studies using various dual-task methods and relatively long event durations, on the order of seconds and minutes (e.g., Katz, 1906; Macar, Grondin, & Casini, 1994; Zakay, 1993). It therefore remains to be seen whether that hypothesis generalizes to the perception of very brief events.

A recent model of the perception of very brief events is based on the *temporal response function* (Ikeda, 1986), which is a summary of the neural response associated with a flash of light. Stelmach and Herdman (1991) used that model in their study of attention in the perception of stimulus onset, arguing that the effect of focused spatial attention was to speed the rate of increase of the temporal profile associated with a stimulus. Their results indeed supported the temporal profile hypothesis by showing that flashes in attended locations were judged to onset before simultaneously presented flashes in unattended locations. They assumed further that a faster rising temporal profile would also be associated with an earlier decreasing portion of the profile; thus, they predicted (but did not test) that an attended stimulus would be preceived as shorter in duration than an unattended one.

Mattes and Ulrich (1998) recently addressed that question directly. In a series of experiments, using both a dual-modality (visual and audition) and a multiple visual location procedure, participants rated 70–120-ms flashes to be longer in duration when they occurred in the expected modality or location. Those results are therefore a strong refutation of the temporal profile hypothesis (Stelmach & Herdman, 1991) with regard to perceived duration. However, Mattes and Ulrich (1998) did not address the nature of the relation between perceived duration and onset.

Scope of the Present Study

Our primary aim in the present study was to collect data relevant to the competing hypotheses regarding the role of attention in perceived duration. Our second aim was to examine whether the effects of attention on perceived duration were related to, or separable from, the effects of attention on the perceived onset of an event. The question of the separability of those two effects is important for two reasons.

First, it is well known that there is a neural partitioning of information regarding stimulus onset and duration very early in the visual pathways (Breitmeyer, 1984; Schiller & Logothetis, 1990). That is, as early as the retinal ganglion layer, cells are specialized to signal either stimulus transients (onsets and offsets) or the sustained character of a stimulus. That division of labor is perpetuated through the system by the so-called magnocellular (transient) and parvocellular (sustained) systems, which maintain their distinctiveness well into the extrastriate regions of the cortex (Zeki, 1993). From that perspective, one would have no reason to expect a relation between the perceived duration and onset of a stimulus, because the relevant information would be carried in separate neural streams.

A second reason to examine both the perceived duration and onset of an event was to determine whether the attentional influence on perceived duration was a direct effect or a by-product of an attentional influence on perceived onset. For example, a duration illusion could be derivative of an onset illusion, perhaps even along the lines of the temporal profile hypothesis (Stelmach & Herdman, 1991). That is, if attention selectively speeds the perception of onset, with no change in the perception of offset, then a temporal comparison of those two signals in the transient channel alone would result in an illusion of increased duration.

EXPERIMENT 1

Flashes in attended locations seem to last longer. To study the role of spatial attention in the perceived duration of a brief event, we combined methods from two psychophysical traditions. We used the method of constant stimuli to obtain objective measures of perceived duration (Coren, Ward, & Enns, 1999); we used spatial cuing to direct the mind's eye to a screen location other than the direction of gaze (Posner & Raichle, 1994). The participants were shown a standard flash at the center of the display, followed by arrows that correctly predicted the location of the test flash 80% of the time. The participant's task was to indicate whether the test flash was of shorter or longer duration than the standard. We gave feedback on each trial to optimize accuracy.

Method

The spatial and temporal characteristics of the events on a typical trial are illustrated in Figure 1. Three black square outlines (2.5° of arc, center-to-center separation of 3°) appeared at the center of a 13-in. Macintosh screen at the beginning of a trial, along with a standard black disc (.5°) in the center box that terminated after 90 ms. The central disc was replaced by two arrows (.75° horizontal) that remained on view for the remainder of the trial. After a period of 0–1,600

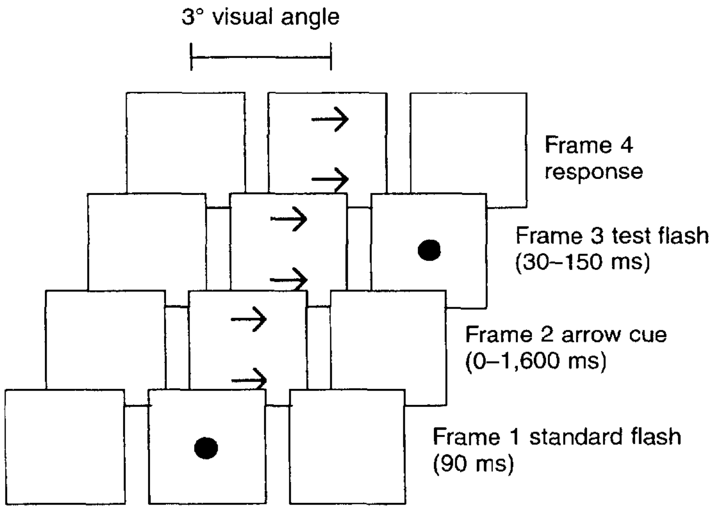

FIGURE 1. Illustration of the stimulus array on a typical trial in Experiment 1.

***Note.* The participant indicated whether the duration of the test flash was shorter or longer than the standard flash.**

ms, a test black disc identical in size to the standard disc was presented for a duration that was chosen randomly from the range of 30 to 150 ms, in 15-ms steps. In a control condition, no arrows were presented, but a 500-ms interval separated the standard from the test flash. The participant was then given up to 4 s to indicate with a key press whether the test flash was shorter or longer than the standard flash.

The participants were told that the arrows would be correctly predictive of the test disc location 80% of the time and that they should attend as quickly as possible to the indicated location without making any actual eye movements. To help ensure that eye movements did not play a role in this experiment, we monitored one of each participant's eyes with a video recorder throughout the testing session. (We did this only in Experiment 1.) The procedure is one we have detailed elsewhere (Brodeur & Enns, 1997; Enns & Richards, 1997). Briefly, it permits one to estimate eye movements using a time sampling procedure. All of the participants were very good at not moving their eyes during the trial. Omitting data from the participants who made the most movements had no impact on the results. However, the finding that gave us greatest confidence in the unimportance of eye movements was that all of the central results in this study were obtained with stimulus intervals of 200 ms or less, which is less time than is needed to execute an eye movement.

A total of 60 individuals participated in Experiment 1, with 10 assigned to each cue condition (no cue, 0, 100, 200, 500, or 1,600 ms). The participants were all students in psychology courses who gained extra-course credit for their participation. All were naive with respect to the hypotheses. The participants in the cue conditions were tested on a total of 480 trials, and those in the no cue condition were tested on 240 trials.

Results and Discussion

We first examined the data from each cue condition by plotting "longer than" responses as a function of the actual durations of the test flash. Figure 2 contains the resulting function from the no cue condition. The central dotted line, extending from the point where "longer than" and "shorter than" responses were equally likely (proportion = .5) to the interpolated data function, indicates that the participants were fairly accurate in judging the relative durations of the two flashes. The point of subjective equality (PSE), estimated in that way, was 87 ms, which indicates a very small overestimation in the duration of the standard disc.

We measured the precision of the participants (variability around the PSE)

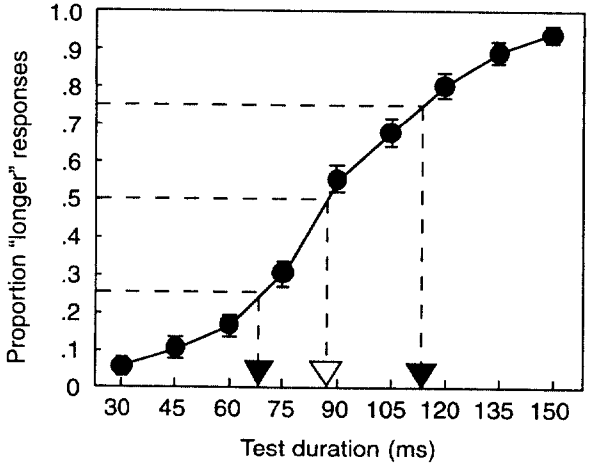

FIGURE 2. The psychophysical function obtained in a no cue control condition.

Note. Error bars indicate one standard error of the mean. The point of subjective equality (PSE) is given by the white arrow (estimated at 87 ms); the black arrows indicate the interval of uncertainty around the PSE. The just noticeable difference, defined as 1/2 the interval of uncertainty, was estimated at 22 ms.

with the traditional *just noticeable difference* (JND), defined as one half of the difference between the 0.25 and 0.75 cutoffs in the psychophysical function. Those are shown in Figure 2 as black arrows along the abscissa. For the no cue condition, the estimated JND was 22 ms, which is somewhat longer than the 15-ms step size we used in varying the duration of the test discs.

For each remaining cue condition, in which arrows were presented for varying durations before the test flash, there were two psychophysical functions of the kind illustrated in Figure 2: one for the validly cued and one for the invalidly cued trials. For each function, we used the estimated PSE to measure the magnitude of any duration illusion and we used the estimated JND to measure the variability (reliability) surrounding the PSE estimate.

The estimated PSEs for all conditions are shown in Figure 3. The dashed horizontal line at a PSE of 0 represents veridical perception of test flash duration. Negative PSE values represent an illusion of overestimation of time, whereas positive PSE values represent an illusion of underestimation. As those results show, PSEs for flashes in attended locations were reliably smaller than PSEs for flashes in unattended locations for every cue–test interval (all t tests, $p < .01$). The largest effects of attention were seen in the 100-, 200-, and 500-ms conditions, in

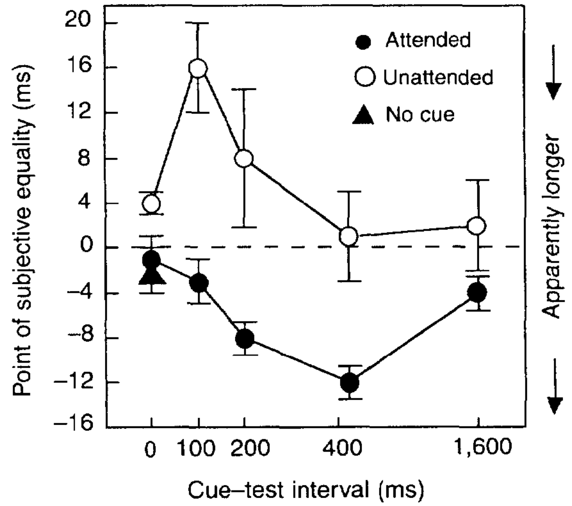

FIGURE 3. The mean points of subjective equality (with standard error bars) in Experiment 1.

Note. **Negative values correspond to an illusion of prolonged flash duration; positive values indicate an illusion of underestimation.**

which the difference between valid and invalid PSEs was as high as 18 ms. Finding effects of attention at those cue–stimulus intervals is quite typical of other attentional effects, such as stimulus detection and letter discrimination (Posner & Raichle, 1994). Finding the largest effects at 100–200 ms also helped to confirm that eye movements were not responsible for the illusion. Eye movements in response to an arrow take 200–250 ms to initiate and therefore could not contribute to the illusion at brief intervals. Furthermore, the greatest opportunity for eye movements occurred at 1,600 ms, where the illusion was small.

The deployment of spatial attention had no accompanying influence on the JND or response variability. Response variability rose and fell with the amount of time the participants were given to use the arrow cue ($p < .01$) but did not differ reliably for valid and invalid trials ($p > .10$; see Figure 4). The effect of cue–target interval is consistent with a division of attention at brief intervals between the arrow and the test flash (Duncan, 1980). Presumably, the participants were trying to both read the cue and perceive the test flash within a short time window in which some central cognitive resources must be shared. However, the absence of any systematic relation between spatial attention and JND is evidence that the illusion is concerned with the perception of duration, and not with decisional or response uncertainty (Bashinski & Bacharach, 1980; Busey & Loftus, 1994; Reinitz, 1990).

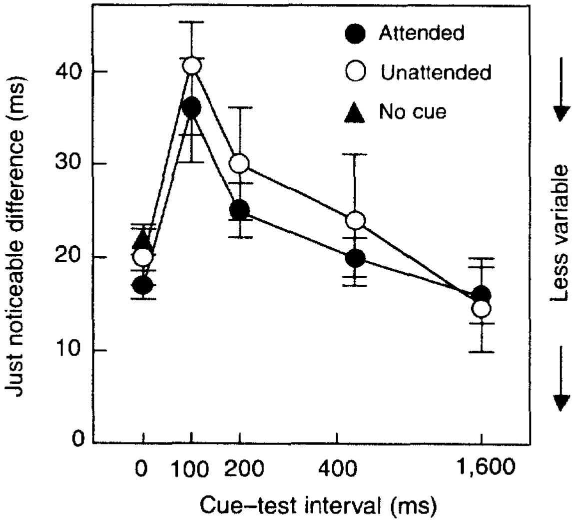

FIGURE 4. The mean just noticeable differences (with standard error bars) in Experiment 1.

***Note.* Smaller values correspond to less variability in the responses.**

In summary, the results of Experiment 1 suggest that the perceived duration of a flash in an attended location was as much as 18 ms longer than when the same flash occurred in an unattended location.

EXPERIMENT 2

We hypothesized that the influence of attention on perceived duration is separate from its influence on perceived onset. We examined the relation between the attention-based illusion of duration and an illusion of perceived onset; that is, directing attention to a location speeds the perceived onset of a flash (Stelmach & Herdman, 1991). As mentioned in the introduction, the duration illusion may be derivative of an onset illusion. However, the separate physiological substrates of transient and sustained visual signals also leave open the possibility that the illusions are unrelated because they occur in different visual pathways. In Experiment 2, we examined whether variation in the attributes relevant to one illusion (e.g., onset) would influence the illusion observed for the other attribute (e.g., duration).

Method

The design involved an orthogonal combination of nine different test flash durations and nine different stimulus onset asynchronies (SOA) between standard and test flashes. Figure 5 illustrates a typical trial, which followed the cueing method used in studies of perceived onset (Stelmach & Herdman, 1991). On each trial, a Tectronics oscilloscope equipped with fast P15 phosphor displayed three outline boxes (2.5°, white lines on a dark background), with the central box containing two arrows (.75° horizontal length). The participants were instructed to move their "mind's eye," but not their physical eyes, to the indicated location and to press the space bar as soon as they had done so. That initiated the presentation of a flash of a white disc (.5°), which was randomly selected from the standard (50 ms) or one of the nine different test flashes (10–90 ms in 10-ms steps). The first flash was followed by a second flash, after an interval that varied from 0 to 100 ms from the onset of the first flash. If the first flash consisted of the standard, then the second flash consisted of one of the nine test flashes; if the first flash consisted of a test flash, then the second flash consisted of the standard. Following the presentation of both flashes, the arrows remained on the screen for an additional 4 s, during which the participant could indicate with a button press whether the left- or the right-side flash appeared to last longer (for one group of participants) or appeared to begin first (for another group of participants).

A total of 20 participants were tested, with 10 assigned to each of the two instruction conditions (duration judgment, onset judgment). The participants were students in psychology courses participating for extra-course credit. All were naive with respect to the hypotheses. Each participant was tested on a total of 972 trials, with 12 trials in each of the 9 × 9 (Duration × Onset) combinations.

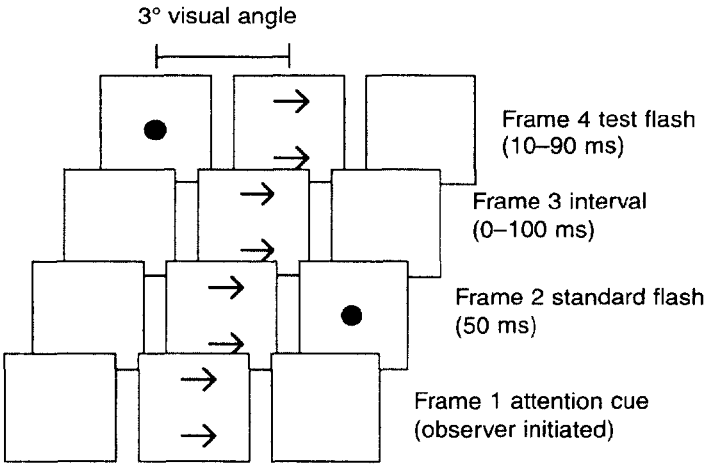

FIGURE 5. Illustration of the stimulus array on a typical trial in Experiment 2.

***Note.* In this example, the standard 50-ms flash is shown on the attended side (right), and the test flash is presented in the unattended location (left). In the temporal order task, the participants indicated whether the flash on the left or the right appeared to onset first. In the duration task, a separate group of participants indicated whether the flash on the left or the right appeared to last longer.**

Results and Discussion

The mean PSE estimates for the temporal order task are shown in Figure 6. As can readily be seen, PSEs for the onsets of flashes in attended locations were consistently smaller than PSEs for the onsets of flashes in unattended locations (*M* onset illusion = 27 ms, $p < .05$, for all test durations), consistent with an illusion of earlier onsets for flashes in attended locations. However, there was no systematic relation between the size of that onset illusion and the duration of the test flash ($p > .10$). Focused spatial attention sped the apparent onset of all flashes, regardless of whether they were as short in duration as 10 ms or as long as 90 ms.

The mean PSE estimates for the duration judgment task are shown in Figure 7. As in Experiment 1, test flashes in attended locations were judged to last on average 30 ms longer than flashes in unattended locations. More important, there was no detectable relation between the size of that illusion and the relative onset asynchrony of the two flashes ($p > .10$). These results therefore provide clear evidence that the duration illusion associated with spatial attention is unrelated to the onset illusion, which is also influenced by attention.

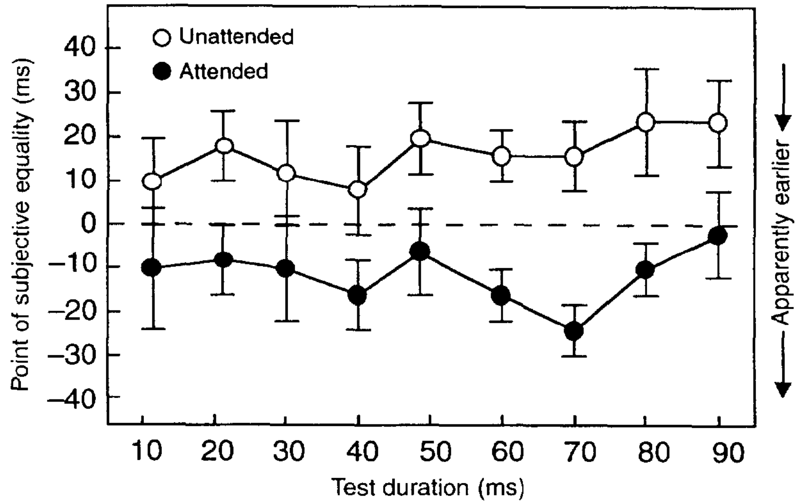

FIGURE 6. The mean points of subjective equality (with standard error bars) in Experiment 2 for the temporal order task, shown separately for each of the 9 different test flash durations.

***Note.* Negative values correspond to an illusion of speeded flash onset.**

A reviewer of an earlier draft of this article (Y. Tsal) pointed out that this duration illusion may not be a primary illusion, but rather may be derived from a more basic illusion involving perceived brightness. Bloch's law describes a linear trading relationship between apparent brightness and duration, at least for brief durations under photopic viewing conditions such as those used here. From that perspective, discs of shorter duration may have appeared to be dimmer than those of longer duration, allowing the participants to perform the task on the basis of brightness discrimination. Furthermore, focused attention may change the apparent brightness (or contrast) of the discs (Tsal et al., 1995).

To address that issue, we replied that we had previously replicated the design of Experiment 2 with *brightness-balanced discs*—a procedure designed to equate the brightness of two brief flashes that vary in duration (Di Lollo & Finley, 1986). A first group of participants ($n = 3$) were presented with pairs of dots, varying in duration and brightness. They were asked to discriminate the dots based on brightness alone. We used an adaptive staircase procedure to identify luminance values for discs of different duration that would appear to be equally bright under those conditions. The brightness-balanced discs were then used in the replication experiment ($n = 7$). The results we obtained did not differ significantly from those shown in Figures 6 and 7.

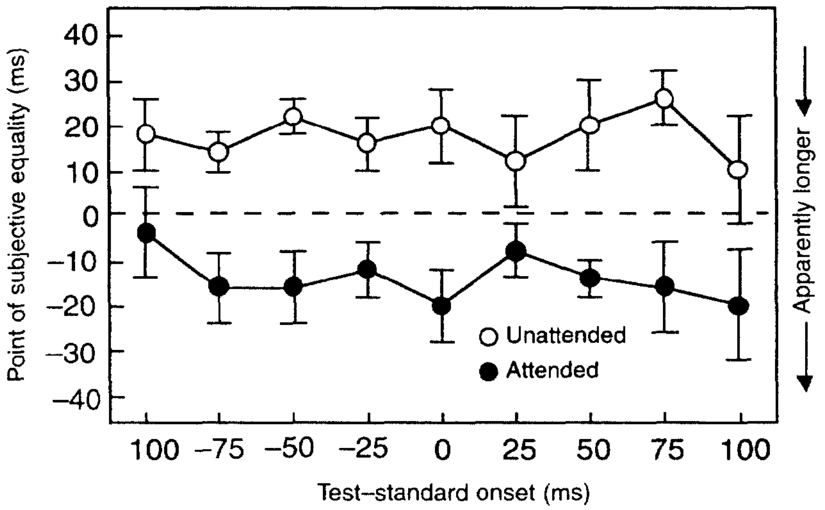

FIGURE 7. The mean points of subjective equality (with standard error bars) in Experiment 2 for the duration task, by temporal order condition.

Note. **Negative values correspond to an illusion of prolonged flash duration.**

The similar results obtained with discs of constant luminance and brightness-balanced discs suggest that differences in perceived brightness did not play a large role in the duration and onset discrimination tasks. Although that does not rule out entirely the possibility that focused attention influences the perceived brightness of a stimulus, it does indicate that substantial variations in luminance do not change the results we obtain in a duration discrimination task.

EXPERIMENT 3

In Experiment 3, we examined the hypothesis that attention also increases the perceived duration of a temporal gap. In Experiments 1 and 2, we demonstrated the existence of an illusion of perceived duration that is sensitive to the spatial focus of attention. In Experiment 1, we showed that focused spatial attention increased the perceived duration of a flash without influencing response variability or decisional criteria. In Experiment 2, we showed that this illusion of duration was functionally independent of another temporal illusion, that of perceived onset. In those experiments, however, we did not constrain the location of the illusion along the visual pathway from eye to brain.

In thinking about possible loci for the illusion, two possibilities spring readily to mind. One is at a relatively low level of visual processing, namely, that of visible persistence (Coltheart, 1980; Di Lollo, 1980). The other is at a higher level of processing, at which objects and events are registered independently of the specific stimulus features such as luminance values and contours that were used to signal the events.

Visible persistence refers to the continued neural response associated with a brief visual flash after the flash has been turned off. The main reason that researchers believe that visible persistence is a low-level visual phenomenon is that its duration is extremely sensitive to variations in the physical characteristics of the inducing stimulus. For example, (a) the duration of visible persistence is inversely related to stimulus duration, with the longest persistence being produced by the shortest flashes (Di Lollo, 1980); (b) it is inversely related to stimulus intensity, with the longest persistence being associated with the dimmest flashes (Di Lollo & Hogben, 1987); and (c) it is inversely related to element proximity, with the longest persistence being produced for stimulus elements that are distant from one another (Groner, Groner, Bishof, & Di Lollo, 1990).

If the present illusion of perceived duration is based on visible persistence, perhaps because focused spatial attention has the effect of prolonging its duration, then there is a straightforward way to test that hypothesis. Instead of having participants judge the duration of a brief flash of light against an unlit background, which serves to maximize visible persistence, we could have participants judge the duration of a temporal gap in a light that was otherwise continuously visible. Such a stimulus would not only produce very little visible persistence—because of the well-known inverse duration effect—but any visible persistence produced would decrease the apparent duration of the temporal gap. An account of the duration illusion based on visible persistence would therefore predict a reversal of the illusion in the temporal gap experiment.

Alternatively, observation of the same illusion for a brief flash and a temporal gap would suggest that the illusion was operating on a representation of the stimulus that was postpersistence. That is, the illusion would concern a representation of temporal duration that was free of at least one of the sensory characteristics that is known to be associated with brief visual stimuli.

Method

The experiment was conducted in exactly the same way as the duration judgment task in Experiment 2, with the exception that the stimulus array involved two discs that each offset for a brief duration at some point during the trial. Those displays are illustrated in Figure 8. The participants therefore indicated on each trial whether the left- or the right-side temporal gap appeared to last longer. A different set of 9 individuals participated in Experiment 3, drawn from the same population as in previous experiments.

Results and Discussion

The mean PSE estimates for the gap duration task are shown in Figure 9. Despite the fact that the participants were now judging the duration of a gap rather than a flash, gaps in attended locations were judged to be on average 48 ms longer than gaps in unattended locations. As in Experiment 2, there was no detectable relation between the size of that illusion and the relative onset asynchrony of the two gaps ($p > .10$). Those results are therefore clear evidence that the duration illusion is not dependent on visible persistence.

It is also worth considering the possibility that the duration illusion is mediated indirectly by the perception of enhanced stimulus clarity or resolution (Tsal et al., 1995). If a disc is seen with higher spatial and temporal fidelity when attended, it may be that quality that mediates the discrimination task, rather than disc duration. We think the similarity in the results of Experiments 2 and 3 are especially helpful here. In Experiment 2, the event to be judged was the brief flash of a disc. If attended discs appeared to be sharper in spatial–temporal contrast, then the participants may have indeed been judging disc clarity rather than dura-

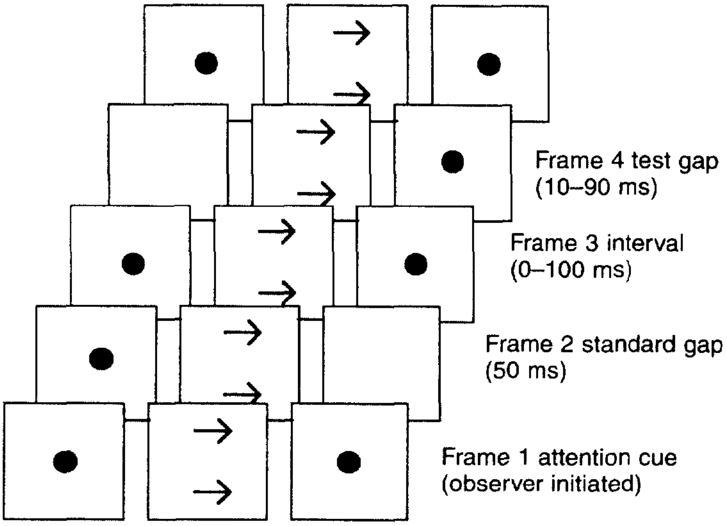

FIGURE 8. Illustration of the stimulus array on a typical trial in Experiment 3.

***Note.* In this example, the standard 50-ms temporal gap is shown on the attended side (right) and the test flash is presented in the unattended location (left). The participants performed the duration task, indicating whether the temporal gap on the left or the right appeared to last longer.**

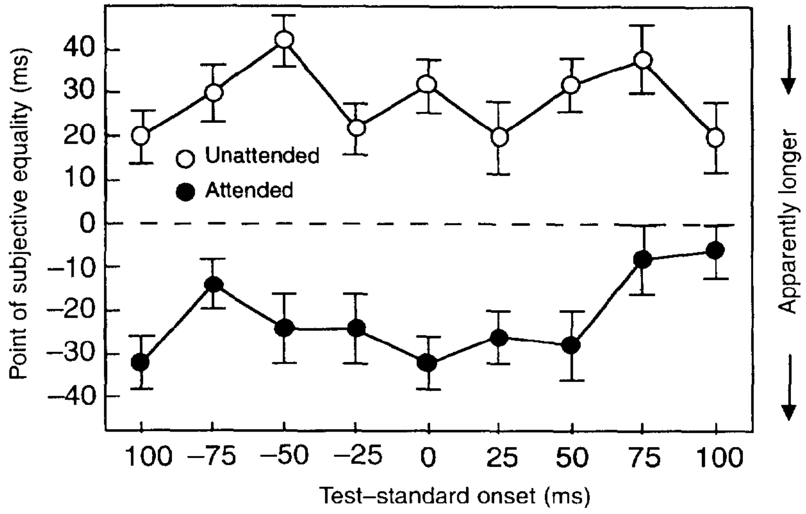

FIGURE 9. The mean points of subjective equality (with standard error bars) in Experiment 3 (duration task), by temporal order condition.

Note. **Negative values correspond to an illusion of prolonged gap duration.**

tion. However, consider the same logic applied to Experiment 3, in which the event to be judged was the duration of the temporal gap in the disc. The attended disc should be seen more clearly before and after the gap. If increased disc clarity led to an increase in "longer than" reports in Experiment 2, it should do the same in Experiment 3, in which a disc judged to be on view longer would actually work to produce a reversed illusion; in Experiment 3, the attended gap should be reported to be shorter than an unattended gap.

One way to rescue the attentional resolution account (judgments of duration are mediated by perceived clarity) might be to assert that the temporal gap between discs is the perceptual event of interest in Experiment 3. It is that gap that is seen more clearly when attended. However, that begs the question of what it means to see the absence of something "more clearly." Recall that the "stimulus quality" of the gap is identical to that of the entire screen (all pixels are turned off equally). When we discuss the perception of events, especially those involving unfilled space between two stimuli separated in time, it seems natural to us that the perception of duration should be considered primary, with the perception of stimulus quality being mediated or derived from the perception of duration. Of course, the last word should be given to the data. Future researchers could address those questions by having participants judge both the brightness and the duration of stimuli, perhaps using the orthogonal design described in Experiment 2.

GENERAL DISCUSSION

The novel finding of the present study is that directing attention to a spatial location before the occurrence of a brief event increased the perceived duration of that event. That result was shown to hold both for a brief flash of light (Experiments 1 and 2) and for a brief temporal gap in a light that was otherwise continuously present (Experiment 3).

The finding that the duration illusion was functionally independent of an attention-based illusion concerning the perceived onset of a brief flash (Experiment 2) has important implications for the neural substrates underlying the illusion. We note that it is completely consistent with separate attentional influences on the so-called sustained and transient visual channels (Breitmeyer, 1984; Schiller & Logothetis, 1990). Those visual pathways are already distinct in retinal ganglion cells, with the smaller, slower conducting parvo cells forming the basis of the sustained channel and the larger, faster conducting magno cells forming the basis of the transient channel. Consistent attributes of those channels can be traced into primary visual cortex and beyond to the temporal lobe (described as parvo-like) and the parietal lobe (magno-like). From that perspective, the existence of separate onset and duration illusions indicates that connections from the cortical centers for attention (Posner & Raichle, 1994; Zeki, 1993) have at least two functions: They speed conscious access to signals in the transient channel, and they prolong access to signals from the sustained channel.

Interestingly, no current theories of spatial attention predict an illusion of increased duration. Some theories, such as Posner's (1980) theory of pathway priming (by an exogenous cue or an endogenous intent), can be taken to imply that focused spatial attention speeds the perception of stimulus onset. However, the same theory implies nothing with regard to the perceived duration of an event. Other theories make explicit exactly the opposite prediction from what was found in the present experiments. For example, attentional resolution theory (Tsal et al., 1995) claims that focused attention increases the spatial and temporal resolution of vision. Therefore, focusing attention in the present experiments should have sharpened (i.e., shortened) the perceived temporal profile of a brief flash and not attending should have blurred (i.e., extended) the same temporal profile. The temporal profile hypothesis (Stelmach & Herdman, 1991) makes a similar prediction. Attention is said to sharpen the neural response profile by both reducing the latency of the response and speeding its decay.

Several theories propose that focused spatial attention increases the rate of information extraction and processing (Bundesen, 1990; Busey & Loftus, 1994; Reinitz, 1990). As is the case for the theories reviewed earlier, that hypothesis predicts that an attended event will be perceived earlier than an unattended event and, if anything, implies that the perceived duration of the attended event should be shorter, because less time would be needed to extract and process the information it contained. Clearly, the present findings with regard to perceived duration rule out all of those theories.

The illusion of increased duration is, on the other hand, consistent with an emerging theory in which focused spatial attention is considered to involve the establishment of an iterative processing loop between higher brain centers involved in object perception and lower brain regions involved in sensory registration (Di Lollo, Enns, & Rensink, 1999; Harth, 1993). In that view, focused attention magnifies and prolongs the sensory signals associated with the object of attention because of the high level of agreement between the expectations generated by higher brain centers and the incoming sensory data. However, one apparent limitation of the brain is that only a very small number (perhaps even only one) of these iterative loops can bring their products to consciousness at a time. Therefore, one consequence of focused spatial attention is that locations and objects that are outside the focus of attention are vulnerable to being replaced by the ongoing temporal stream of visual information (Brehaut, Enns, & Di Lollo, in press; Enns & Di Lollo, 1997; Giesbrecht & Di Lollo, 1998). For the present experiments, we can only speculate whether the illusion of increased duration was the product of an iterative loop established at the expected location, thereby prolonging the signal of the attended event, or reflects the rapid substitution of the unattended event with the blank screen in the sensory registers, thereby shortening the available signal from the unattended event. Future experiments should be designed to address that issue.

As with all perceptual illusions, we believe the present one should be studied, not as a curiosity or as a sign of a flawed design for a visual system but for what it may reveal about the hidden workings of the visual system (Coren & Girgus, 1978; Gregory, 1997). From that perspective, the illusion of increased duration may point to an important mechanism that may underlie many of the perceptual benefits previously ascribed to attention. If, as those results indicate, focused attention effectively increases the exposure duration of a brief event by prolonging the associated neural activity in a sensory register, then there are a number of attentional effects that may be directly derivative of this increased "exposure." For example, the benefits of focused spatial attention on metacontrast masking (Averbach & Coriel, 1961; Enns & Di Lollo, 1997; Ramachandran & Cobb, 1995) and on pattern masking (Breitmeyer, 1984; Liss & Haith, 1970; Reinitz, 1990; Spencer & Shuntich, 1970) would both be readily explained by an increase in the effective exposure duration of the target. Similarly, the benefits of focused spatial attention on spatial resolution (James,1890/1950; Mach, 1886/1959) would also be predicted by an increase in exposure duration, especially if the targets to be identified are presented briefly (Bashinski & Bacharach, 1980; Downing, 1988). The most general prediction would be that one should observe an attention-related advantage in any task that would otherwise benefit from an increase in stimulus duration.

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