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Some Properties of a New Temporal Illusion

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SOME PROPERTIES OF A NEW TEMPORAL ILLUSION

by

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VITA

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She has been second author on two publications: Bowen, R.W. & Markell, K.M. Temporal brightness studied with a large sample of observers: evidence for individual differences in brightness perception. *Perception & Psychophysics*, 1980, *27*, 465-476.

Bowen, R.W., Markell, K.M. & Schoon, C.M. Two-pulse discrimination and rapid light adaptation: complex effects on temporal resolution and a new visual temporal illusion. *Journal of the Optical Society of America*, 1980, in press.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Sometimes a single pulse of light can appear to flicker, or be perceived as two separate pulses (Dunlap, 1915). This "double flash" effect has been attributed to simultaneous activation of the rod and cone channels, which does not occur if small centrally fixated stimuli are employed (Bartley & Wilkinson, 1953; Springer, Deutsch & Stanley, 1975).

Recently, Bowen, Markell and Schoon (1980) have discovered a two-pulse "illusion" in the context of an experiment measuring two-pulse discrimination during rapid light adaptation. They found that if a single brief pulse of light (1 deg dia) is presented 80 to 240 msec after a 6 deg dia, 500 msec background field of the same luminance, the single pulse is seen as double. A follow-up study by Bowen, Markell, Pappageorge and Alfano (1979) found that, using the same paradigm, the illusion occurred under rapid dark adaptation (where the background was decremented, instead of incremented, for 500 msec) as well as for rapid light adaptation. Bowen et al. (1980) have observed informally that the illusion occurs with roughly the same strength when the test pulse is presented at intervals between 80 and 240 msec after the offset of the background field.

There is little in the present literature that would explain an illusion of this kind. Bowen et al. (1980) point out that it is unlikely that the illusion is the result of simultaneous activation of the rod and cone systems, since the illusion occurs with a small stimulus that is confined to the fovea. They also suggest that the illusion is probably not the result of afterimages or simple neural off-responses resulting from an interaction of the background field and test pulse. The illusion occurs when the test pulse is presented at all points between 80 and 240 msec after the offset of the background field, instead of at specific times between the background offset and the test pulse onset, as might be expected with afterimages or off-responses (Brown, 1965).

Crawford (1947), in his study of the increment threshold for a single flash presented during transient light adaptation, makes no mention of any two-pulse effect, even though he presented single flashes of light at intervals up to 500 msec after the offset of the background field. He was working in a range where the temporal illusion occurred in the Bowen et al. (1980) study, but with stimuli presented at a threshold detection level, instead of above threshold, as in the Bowen et al. study. Therefore, the paradigm used by Bowen et al. may be revealing a visual system response that is not noticed using measurements of sensitivity at threshold.

Since the test pulse and background field are separated by at least 80 msec when the illusion occurs, it is probable that a persisting response of the visual system to the background field interacts with the system's response to the test pulse. Bowen et al. (1980) present two possible explanations as to how the background field's persisting response could interact with the test pulse to produce the "flickering" illusion.

First, the persisting background field response could inhibit, or subtract from, the sensory response to the test pulse, producing a temporal gap in the single pulse, and thus giving it an appearance similar to that of two separate pulses of light. This first explanation would account for the illusion only if the interacting subtractive response was relatively brief and multiphasic or oscillating, since the illusion occurs when the test pulse is presented over a range of 80 to 240 msec after the offset of the background field. Also, Bowen et al (1980) have observed that the illusion is present even with pulses which are shorter than 5 msec in duration.

The other explanation for the occurrence of the illusion is that the background field's persisting response could add sensory activity to that already normally occurring to the test pulse. This could result if the presentation of the background field drives the visual system into some state where its response to the presentation of the test pulse is an oscillating one. This oscillating response may have the same effect on the visual system as two separate pulses of light, thus accounting for the flickering appearance of the single pulse. Some support for this view is presented by an informal observation that a single pulse appears brighter when presented with the background field in the range between 80 and 240 msec after the background field offset, than when presented alone without the background field (Bowen et al., 1980).

LITERATURE REVIEW

The illusion has an appearance very similar to that of two brief separate pulses of light. It may be of interest, therefore, to establish whether certain stimulus parameters that affect actual two-pulse discrimination tasks affect the flickering appearance of the illusion in a similar manner.

Two-pulse discrimination is usually measured by presenting an observer with two spatially-overlapping pulses of light, and varying the interval between the pulses until the observer can just discriminate two pulses.

Previous studies have examined the two-pulse task as a function of the luminance, duration and area of the pulses employed. Mahneke (1958) measured two-pulse resolution for light-adapted observers (at 30 cd/m^2) for variations in the duration of two pulses of light. He found that the two-pulse threshold decreased as the duration of the pulses increased. Mahneke concluded that increases in total light energy reduced the two-flash threshold. Kietzman (1967) conducted two experiments to examine the effects of both duration and luminance on two-pulse thresholds, and thereby test Mahneke's hypothesis. He found that two-pulse thresholds are lowered considerably when energy is increased by lengthening the stimulus duration of the two pulses (from pulses of 4 to 62 msec, a range of 1.4 log units), but they are reduced only slightly when energy is increased by increasing the luminance of the two pulses (from 40 to 612 ml, also a range of 1.4 log units). Therefore, Kietzman's experiments failed to confirm Mahneke's "quantity of light" hypothesis, since increasing stimulus energy by two different approaches failed to produce the same results. A later study by Purcell and Stewart (1971) confirmed Kietzman's duration findings.

In a similar experiment, Lewis (1967) examined the effect of luminance on the two-flash threshold over a greater range of luminances (ranging between .32 and 1000 ml) than Kietzman had used. He found that the greatest change in two-pulse thresholds for two dark-adapted subjects occurred at luminance levels lower than those investigated by Kietzman. He thus found that luminance changes do have an effect on two-pulse threshold, but that the effect is not linear. In a later study, Lewis (1968) found that two-flash thresholds decreased as pulse area increased, but that the effects of area decreased as luminance increased.

The general objective of the present study was to investigate whether stimulus parameters, specifically duration and area, which influence actual two-pulse discrimination have similar effects on the magnitude of the illusion. Does the illusory "double flash" event behave as if it were two physical light pulses? The following experiments may aid in the selection of the alternative models of the effect.

RATIONALE FOR THE PRESENT STUDY

The study investigated the effects of test stimulus duration, test pulse and background field size, and foveal versus peripheral fixation on the magnitude of the temporal illusion. The strength of the illusion was assessed with a rating scale procedure for the conditions studied. The observers were asked to rate the distinctness (depth of modulation) of the flicker they observed in the test pulse on a scale from zero (no flicker) to ten (maximally distinct flicker) for each trial presentation.

In order to make predictions about what the possible results of the three experiments might show, test pulse flicker ratings are compared, in a directional sense, with two-pulse threshold values. The underlying assumption in this comparison is that a single pulse judged to have a highly distinct flickering appearance, and thus given a high flicker rating, would have an appearance similar to that of two separate pulses of light having a low two-pulse threshold value, where a brief inter-pulse interval is all that is required for the observers to judge that two pulses of light are present. Therefore, both a single pulse given a high flicker rating, and two pulses with a low two-pulse threshold value would have a similar flickering appearance. Alternately, a low flicker rating given to a single pulse of light would correspond to a high two-pulse threshold value for a two-pulse stimulus where the two pulses were judged to be a single pulse unless a relatively long inter-pulse interval value separated them.

An increase in flicker rating caused by certain stimulus parameters of a single pulse would correspond to a decrease in the two-pulse threshold value for two pulses, since under both conditions, the pulse(s) appear to have a more distinct flickering appearance, or look more like two separate pulses of light. A decrease in flicker ratings for a single pulse would correspond to an increase in the two-pulse threshold value, since the pulse(s) would then have an appearance similar to that of a single pulse.

In Experiment I, observers were asked to rate the distinctness of the "flicker" they observed in the test stimulus, when presented following the background field, for seven test pulse durations at four different times between background field offset and test pulse onset. They also rated test pulse flicker present in three "control" conditions: two pulses of light presented in darkness (without the background field) where only the first pulse duration changed (using the same seven durations); a two-pulse threshold experiment, also varying the first pulse duration; and a single pulse presented in darkness condition under three different durations.

Comparison of these four conditions presented in Experiment I address several issues relevant to the temporal illusion:

1) These conditions may point to a more comprehensive explanation of the illusion by examining more closely the assumptions underlying the two hypotheses suggested by Bowen et al. (1980). If the illusion is the result of a "subtractive" effect of the background field's interaction

with the test pulse, causing a "gap" to appear within the single pulse, then it might be expected that as the test pulse duration increases, the magnitude of the flicker present in the test pulse should increase. This result would correspond to previous results (Mahneke, 1958; Kietzman, 1967; and Purcell and Stewart, 1971) showing that increasing the duration of the two-pulse stimuli, either by increasing the duration of both pulses, the first pulse, or the second pulse, decreases the two-pulse threshold. If the interval between two pulses becomes more distinguishable as pulse duration increases, then the "subtractive" effect of background-test pulse interaction may be more apparent as the test pulse duration increases.

If the illusion is the result of a background-test pulse interaction that adds a response component to the single pulse, then the strength of the illusion may appear to decrease as the pulse duration increases. This may result if the longer test pulses mask the "additional" pulse activity caused by an interaction with the background field, or if the visual system's oscillating reaction to the background field occurs maximally to brief test pulses.

2) What is the effect of background field offset-test pulse onset asynchrony on the illusion? Is the illusion of the same magnitude for different asynchrony conditions across different test pulse durations? There may be a specific range where the oscillating response of the visual system to the background field interacts with the test pulse to cause the illusion, and across this range there may be differences in what test pulse duration is judged to have maximal flicker.

3) If, as has been observed informally by Bowen et al. (1980), the illusion decreases in strength as the test pulse increases in duration, can a "forward visual masking" explanation account for this decrease? If a masking explanation is correct, then the two pulses presented in darkness condition, where a second 20 msec pulse is paired with longer and longer first test pulses, should be judged to flicker less as the first pulse becomes longer in duration. This result, however, would be contrary to past experiments which show that as the duration of the first pulse increases, the two-pulse threshold decreases (Mahneke, 1958; Kietzman, 1967).

4) The two-pulse threshold condition enables comparison of obtained threshold values and flicker ratings, so that a directional relationship between these two measures can be established. It would seem that an increase in a two-pulse threshold value would correspond to a decrease in flicker ratings for the same two-pulse pair. This condition will establish whether this assumption is valid.

5) The single test pulse presented in darkness condition examines the extent to which the test pulses used "flicker" when presented without the background field.

The second experiment employed the same flicker rating method to investigate the illusion using five different test pulse-background field size relationships for four test pulse durations. A control condition studied the rating of a single test pulse for four different sizes presented in darkness. This experiment examines three issues concerning the illusion:

1) In the Bowen et al. (1980) study, the test pulse was smaller than the background field. Does the illusion occur if the test pulse is the same in size or larger than the background field?

2) Lewis (1968) found that, in general, increasing the area of the pulsed stimuli decreased the two-pulse threshold. If a "subtractive" mechanism is responsible for the illusion, then it might be expected that, up to a certain point, the larger the test stimulus, the greater the effect of the illusion.

3) Does the stimulus size effect the flicker ratings of single pulses when they are presented without the background field?

Experiment III examined the effect of using foveal versus peripheral fixation on the strength of the illusion. Observers rated flicker for three test pulse durations under two background field size conditions, for each fixation position. They also rated flicker present in single pulses presented in darkness under either foveal or peripheral fixation. Bartley and Wilkinson (1953) and Springer, Deutsch and Stanley (1975) have attributed double flash effects seen in single pulses to simultaneous activation of the rod and cone systems. Bowen et al. (1980) point out that the flickering illusion occurs when using a stimulus that is confined to the fovea. Would the flicker ratings be different for more peripherally presented stimuli?

EXPERIMENT I TEST STIMULUS DURATION

Method

Observers The observers consisted of the investigator, and one college student paid for his participation. Both observers had normal visual acuity as tested by a Bausch & Lomb orthorater.

Apparatus The apparatus consisted of a three-channel Maxwellian-view optical system, utilizing glow modulator tubes (Sylvania R1131C) as individual sources for the test stimuli and fixation target, and a 150 W tungsten lamp (DZE-FDS) as the source for the background field. The system generated the stimulus array shown in Figure 1. One channel of the optical system produced the fixation target, a second channel produced the test pulse target, and the background field was produced in a third channel. Both the background field and test field had a retinal illuminance of 2400 trolands. The observers viewed the stimulus array monocularly through a 2mm. artificial pupil positioned a focal length's distance from the exit lens of the optical system.

The presentation of the background field was controlled by a high-speed shutter (Uniblitz). The sequencing and presentation of all stimulus events were controlled by laboratory constructed electronic timers. The glow modulator tubes were continuously irradiated with ultra-violet light to insure stable triggering. Luminance calibrations were made on a regular basis with an Ilford photometer (S.E.I.) using the method des-

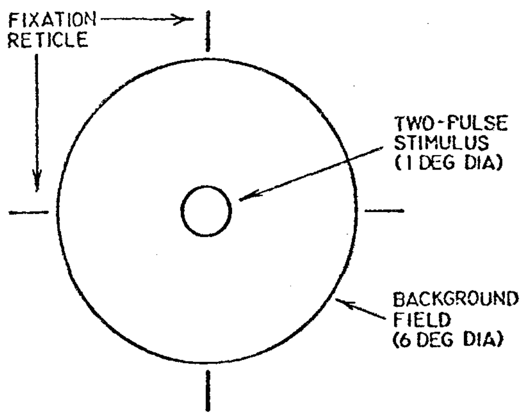

Figure 1. Stimulus configuration of fixation target, background field, and test pulse.

cribed by Westheimer (1969).

Observers were seated in a 3 by 6 ft. enclosure, with their head positioned on a chin-rest in front of the artificial pupil. The subject controlled the presentation of the stimuli by pressing a button located inside the box each time they were given a "go" signal by the experimenter.

Stimuli and Procedure The stimuli consisted of a 6 deg dia, 500 msec background field, and a 1 deg dia test target of varying duration.

The observers were presented with seven test pulse durations under four background offset-test pulse onset asynchrony conditions. In addition, the observers were presented with two no-background conditions; one where two test pulses were presented in darkness, and one in which a single test pulse was presented in darkness.

The seven test pulse durations used for the background offset-test pulse onset conditions were 10,20,30,50,70,90, and 110 msec, presented under four asynchrony conditions; 20,100,200 and 600 msec. For the no background two-pulse condition, the same seven first pulse durations were used (10,20,30,50,70,90,110 msec), followed 40 msec later by a 20 msec pulse. For the single pulses presented in darkness condition, three different durations were employed; 10,50 and 90 msec. Under each background and no background condition, each duration was randomly presented a total of 20 times over 5 forty minute sessions. The background present trials were randomized in blocks of seven under each asynchrony condition. The one and two pulse trials were presented randomly within these blocks of seven. At the beginning of each session, observers received the following instructions:

> Your task in this experiment is to rate the distinctness, or depth of modulation of the flicker present in the test pulse on a scale from zero (no flicker) to ten (maximally distinct flicker)for each trial presentation. Sometimes the test pulse will be presented after the background field, and sometimes the test pulse will be presented alone, but under any condition, always rate the distinctness of the flicker present in the test pulse using the same rating scale.

A two-pulse threshold experiment was also run using the same seven first pulse durations as in the two pulse no-background condition, followed by a second pulse always 20 msec in duration. The interval between the two pulses was varied in 5 msec steps, using a method of limits design, with 6 ascending and 6 descending thresholds collected on each first pulse duration over the course of two one hour sessions.

Results and Discussion

Mean ratings by asynchrony and duration for each subject are shown in Figure 2. The "illusion" was seen only under the 100 and 200 msec asynchrony conditions, with ratings for all durations under the 20 and 600 msec conditions consistently staying between 0 and 2 on the eleven-point scale employed. For the 100 and 200 msec asynchrony conditions, both subjects gave steadily decreasing ratings as the duration of the test pulse increased, with the highest average ratings given to the 10 msec pulse, and the lowest ratings given to the 110 msec pulse. The error bars indicate that the ratings for the 100 and 200 msec asynchrony conditions were stable, and decreased consistently and significantly as the test pulse duration increased. These results do not agree

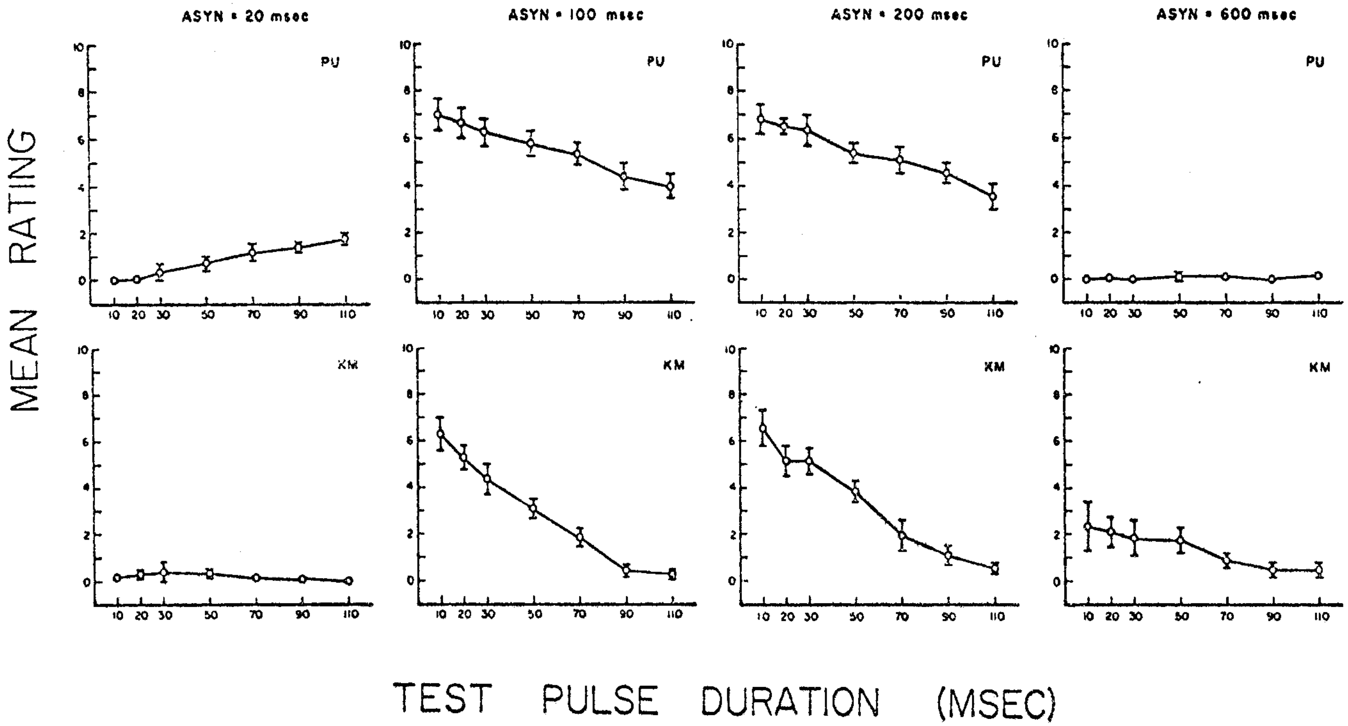

Figure 2. Mean rating as a function of test pulse duration and asynchrony condition.

with two-pulse threshold studies which show that increasing pulse duration decreases two-pulse threshold. Therefore, they do not support a subtractive model for the illusion, since the "gap" proposed by this model would hypothetically become more apparent as pulse duration increases.

In Figure 3, the single pulse presented in darkness results are on the left. The ratings were under three across duration for both observers. This indicates that very little flicker was judged to be present in the test pulses when the background field was not presented. On the right, under the two pulses presented in darkness condition, flicker ratings increased as the duration of the first pulse increased, for both observers. If the illusion is the result of the persistence of the background field somehow adding "activity" after the offset of the test pulse, flicker ratings should have increased for the background present condition as test pulse duration increased. This was not the case. Also, the hypothesis that if additional activity did come after the offset of the test pulse it may be masked is unlikely, since the additional brief pulse became more apparent as the first pulse duration in darkness increased. This is in line with two-pulse threshold studies showing that as the duration of a first pulse increases, threshold values decrease.

In Figure 4, although direct comparison between two-pulse threshold values(right) and two-pulse in darkness flicker ratings (left) is difficult, the two-pulse threshold results indicate that a high two-pulse threshold value corresponds to a low flicker rating, and vice-

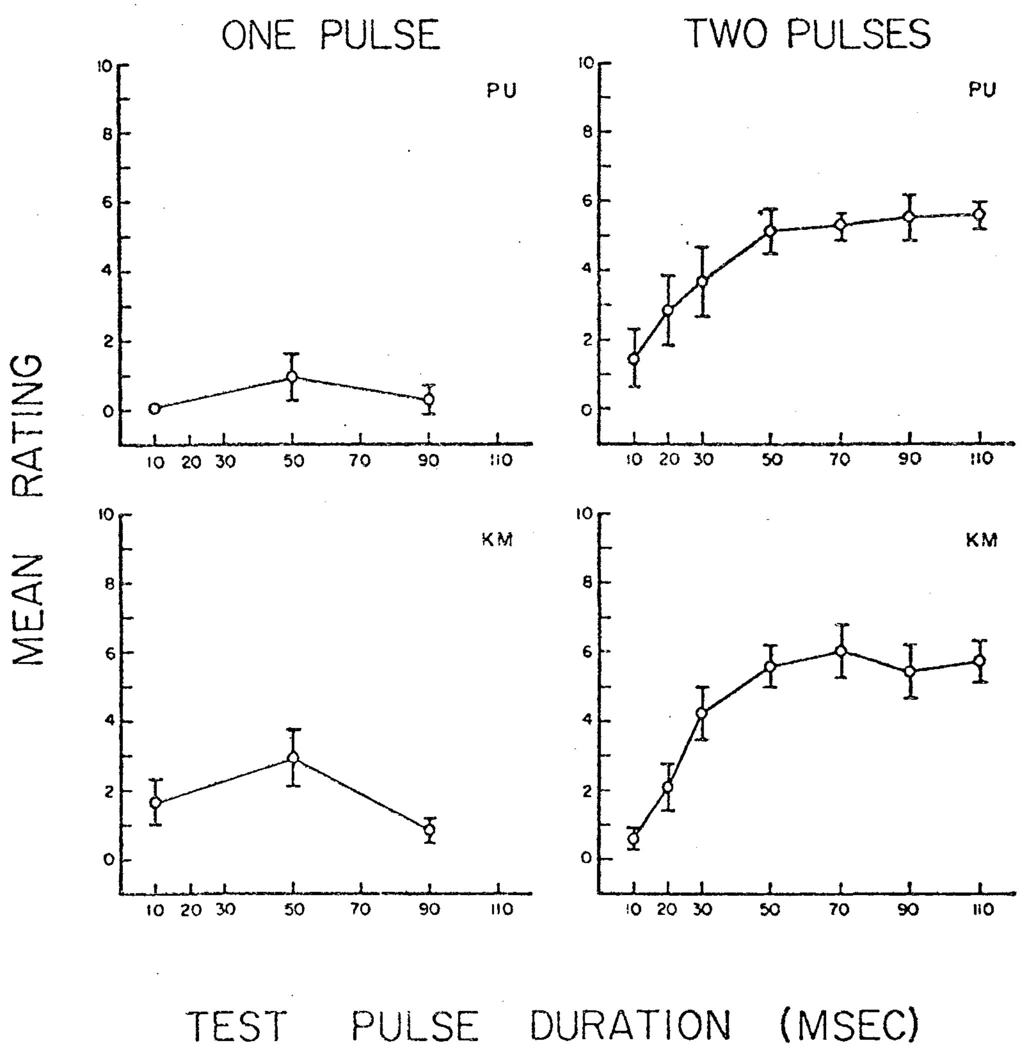

Figure 3. Mean rating as a function of test pulse duration for single pulses (left) and first pulse duration for two pulses (right) when presented without the background field.

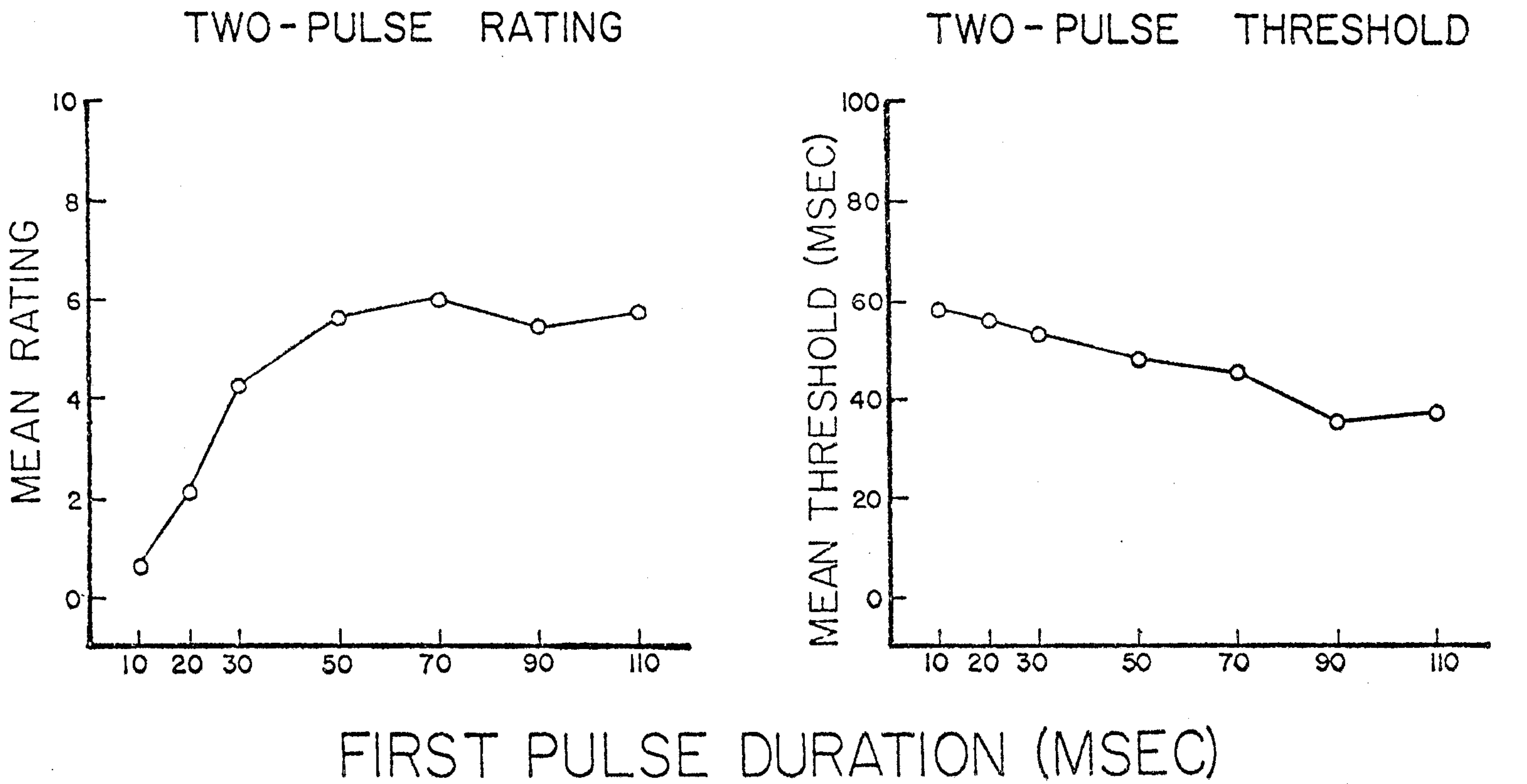

Figure 4. Two-pulse rating and two-pulse threshold as a function of first pulse duration.

versa (These results are from subject KM and were confirmed on a second subject).

EXPERIMENT II BACKGROUND AND TEST TARGET SIZE

Method

Observers and Apparatus used were the same as in Experiment I.

Stimuli and Procedure The observers were presented with five background field-test pulse pairs having different size relationships for four different test pulse durations (Figure 5). A no background single pulse condition was included for the four test pulse sizes under three test pulse durations.

For the five background present conditions, the background was 500 msec in duration, and the five size pairs consisted of: Background 6 deg, test .3 deg; Background 6 deg, test 1 deg; Background 6 deg, test 3 deg; Background 3 deg, test 3 deg; and Background 3 deg, test 6 deg. The background offset-test pulse onset asynchrony used was 100 msec. The four test pulse durations used were 10,30,50 and 90 msec.

The single pulse, no background condition was presented under four test pulse sizes (6 deg, 3 deg, 1 deg, .3 deg) for three durations (10,50,90 msec).

As in Experiment I, at the beginning of each session, the observers were instructed to rate the distinctness of the flicker present in the test pulse on a scale from 0 (no flicker) to 10 (maximally distinct flicker) for each background and no background trial. Under each condition, each duration was presented 20 times over 5 forty minute ses-

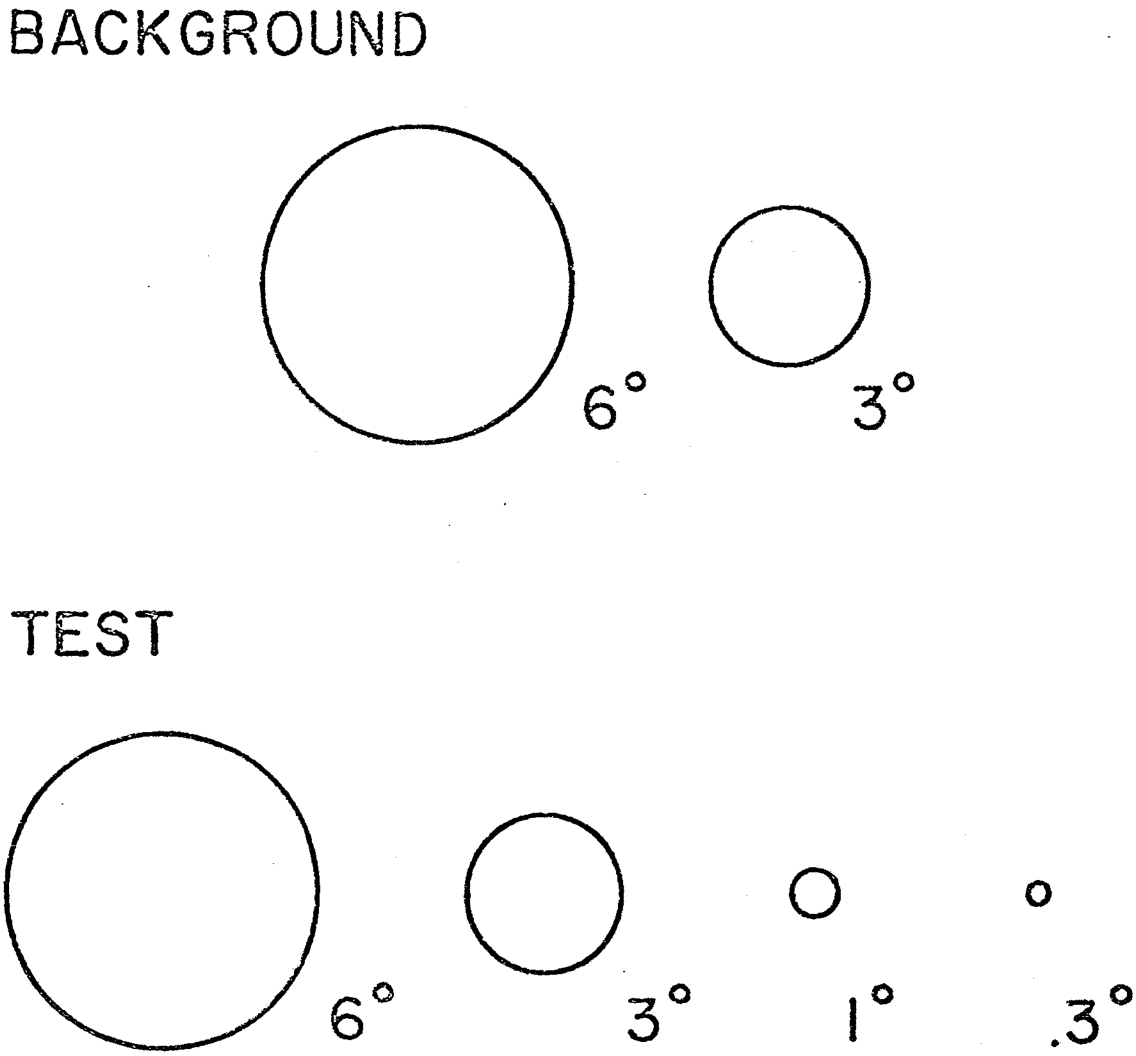

Figure 5. Background and test pulse size.

sions. The trials were presented randomly in blocks of ten under each size condition, with the no background condition trials randomly interspersed within these blocks.

Results and Discussion

The average ratings for each background field-test pulse pair are shown in Figure 6. For the 6 deg background field, with the exception of the 10 msec pulses for observer KM, flicker ratings increased as test pulse size increased. These data agree with two-pulse threshold results which show that threshold values decrease as pulse area increases. They could be explained in terms of a subtractive model of the illusion, since a "gap" or subtractive element produced in the test pulse by the persistence of the background field would be expected to become more apparent as the pulse size increased. The illusion occurred under the various test pulse size conditions as long as the background field was the same in size or larger than the test pulse (i.e. 3 deg background, 6 deg test pulse). Under all size conditions, the flicker ratings for the single pulses presented in darkness condition were between 0 and 2 for both subjects under all four test pulse size conditions. Increasing pulse size did not in itself increase flicker ratings for the single pulses.

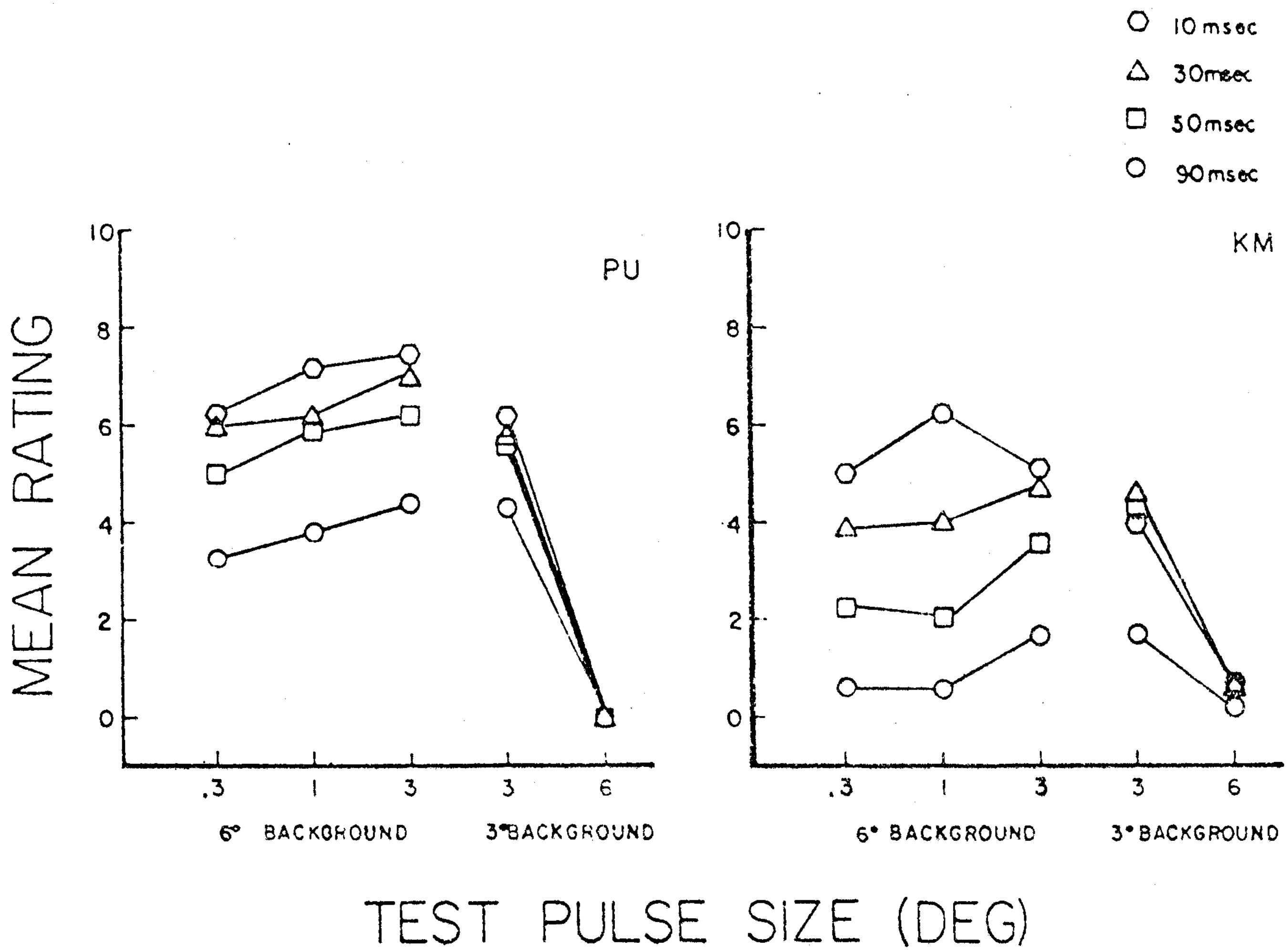

Figure 6. Mean rating as a function of background field-test pulse size for four test pulse durations.

EXPERIMENT III FOVEAL VERSUS PERIPHERAL FIXATION

Method

Observers and Apparatus were the same as those used in Experiment I and Experiment II.

Stimuli and Procedure The observers viewed test pulses under two background field sizes using either foveal or 3.3 deg peripheral fixation. The observers also viewed single pulses in darkness under each fixation condition. For the background present conditions, the background field was either 6 deg or 3 deg, and always 500 msec in duration. The test target was 1 deg, presented for either 10, 50 or 90 msec. For the single pulses presented in darkness condition, the pulse was either 10 or 90 msec, and always 1 deg. For both the background present and darkness conditions, the subjects were instructed to either fixate in the center area of the four fixation lines, or to fixate on the left fixation target line, an eccentricity of 3.3 deg. The trials were run randomly in blocks of 14 under a given fixation and size condition, with the one pulse trials randomly distributed within these blocks. Twenty trials were run under each fixation position for each background field size.

The observers task again was to rate the distinctness of the flicker present in the test pulse on a scale from 0 (no flicker) to 10 (maximally distinct flicker).

Results and Discussion

When the test pulse was presented with the 6 deg background field, there seemed to be no systematic change between the foveal and peripheral test pulse positions, with observer PU rating the 50 and 90 msec pulses slightly higher for the foveal over peripheral condition, and observer KM rating the 50 and 90 msec pulses slightly lower for the foveal position (Figure 7). For the 3 deg background field condition however, both observers gave the peripherally located test pulses higher flicker ratings than the foveally located pulses. The probable reason for the 6 deg background field results is that the background field infringes on both the peripheral and foveal fixation conditions, and so the effect of fixation condition is confounded with background field size. The 3 deg background field results indicate that the peripheral fixation position seems to enhance the distinctness of the flicker perceived to be present in the test pulse.

Under all conditions, observers gave the shorter test pulses higher flicker ratings than the longer pulses. Flicker ratings for the single test pulse under both foveal and peripheral fixation conditions were under one for both subjects, and no differences were seen in the flicker judgements between the two positions when the single pulses were presented in darkness.

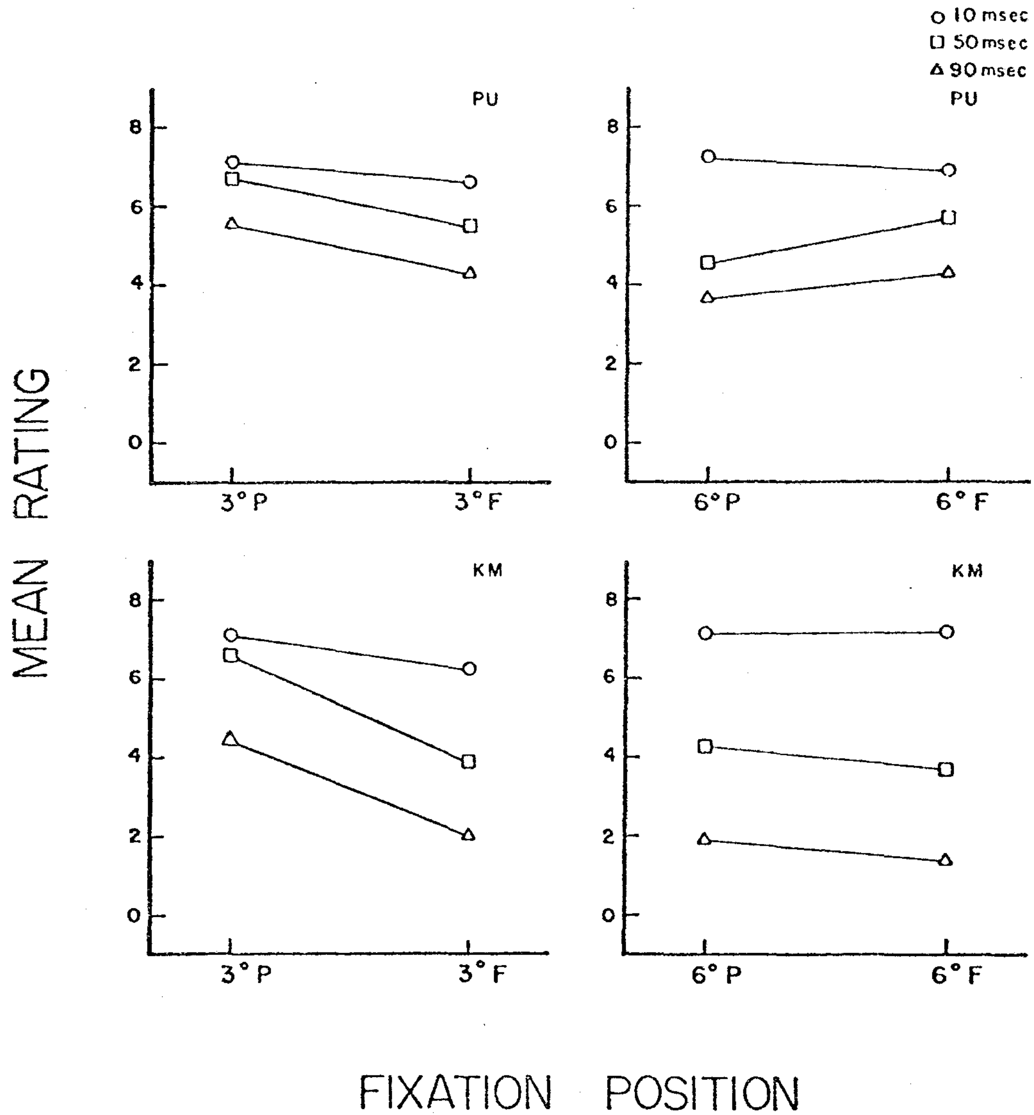

Figure 7. Mean rating as a function of fixation position and background field size for three test pulse durations.

CONCLUDING DISCUSSION

A review of the results outlines four basic properties of the illusion. First, the flicker ratings of the test pulses are very similar for asynchronies of either 100 or 200 msec. Next, across all background present conditions for all three experiments, the ratings decreased as the test pulse duration increased. Third, flicker ratings increased as test pulse area increased, and the illusion did not occur unless the background field was the same in size or greater than the test pulse. Finally, flicker ratings were greater for test pulses presented in a peripheral over a foveal fixation position for the 3 deg background field.

Neither the subtractive nor the additive explanations for the occurrence of the illusion suggested by Bowen et al. (1980) account for all the results in the present three experiments.

The first property of the illusion listed above is the similarity of the flicker ratings reported for the 100 and 200 msec asynchrony conditions. Bowen et al. (1980) pointed out that the illusion occurs at all points between 80 and 240 msec after the offset of the background field. The results from Experiment I show that not only does the illusion occur in this range, but the distinctness of the flicker seen in the "illusory" pulse decreases in a very similar manner for the two asynchrony conditions as pulse duration increases. This result does not support a subtractive explanation of the illusion, since as stated in the introduction, not only would the interacting response have to be brief and multiphasic, it would also always have to produce a "gap" at the same point within a test pulse under a specific duration, and produce this specific gap for a range of asynchrony positions.

The second property of the illusion, that the distinctness of the flicker present in the illusory pulse decreases as test pulse duration increases, is not in agreement with two-pulse threshold findings. These findings show that threshold values decrease as pulse duration increases. This second property also seems to point away from a subtractive explanation of the illusion, since the illusory "gap" postulated in this explanation would be expected to become more distinct as pulse duration increases. An additive oscillating activity model may be supported by these results due to the subjective judgement of the observers in the experiment that when a brief (10 to 20 msec) pulse is shown in the illusory range after the background field offset, the pulse often takes on a multiple pulse appearance, with a more distinct flickering appearance than an actual two-pulse stimulus. This multiple appearance does not seem to occur for longer pulses.

The results of the two-pulses presented in darkness condition of Experiment I were in agreement with two-pulse threshold results showing that increasing the duration of a first test pulse decreases threshold values. These results indicate that if an additive element explanation were responsible for the occurrence of the illusion, the second property of the illusion, that its magnitude decreases with increasing test pulse duration, cannot be explained as forward masking of the additional "element" for longer duration test pulses. Adding a brief test pulse at the end of an increasing first pulse causes flicker ratings to increase as first pulse duration increases, and the additional activity is therefore not masked, but becomes more and more distinct. (A pilot experiment showed that adding an increasing second pulse to the end of a brief first pulse seems to cause flicker ratings to decrease for long second pulse durations. These ratings were difficult to make, and stayed consistently low across all durations. This seems to indicate, however, that placing additional activity at the beginning of an increasing pulse does not cause flicker ratings similar to those obtained for the "illusory" pulse).

The effect of test pulse area on the illusion is that the magnitude of the distinctness of the flicker present in the test pulse increases as test pulse size increases. This result is in agreement with two-pulse threshold studies that show that increasing pulse size decreases the threshold value. Contrary to the first two properties of the illusion discussed, this third property of the illusion seems to support a subtractive explanation. Under this explanation, as the size of the test pulse increases, the "gap" within the pulse might be expected to become more distinct.

The illusion occurs only if the background field is the same in size or larger than the test pulse. When the background field is smaller than the test pulse, no flicker is apparent in the pulse, and a forward masking effect takes place. This causes the test pulse to take on an annulus-like appearance, with a dark circle present in the position where the background field has been flashed. Hence, in order for the background field to interact with the test pulse to cause its illusory flickering appearance the area of the background field must encompass that of the test pulse.

The single pulse in darkness condition showed that neither increasing pulse duration, pulse size, or changing fixation position caused the pulses to take on a "double pulse" appearance in the absence of the background field. This would seem to rule out any possibility that the illusion is caused simply by differential response latencies of the rod and cone channels, since under the present stimulus conditions, even presenting a 6 deg pulse to the observers, thus stimulating both the rod and cone systems, did not cause them to report any "double-flash" effects in darkness.

Experiment III results show that there was an increase in flicker ratings for peripheral over foveal fixation using a 3 deg background field. Even though simultaneous activation of the rod and cone systems does not seem to be related to the illusion, peripheral fixation does seem to enhance the strength of the illusion.

The illusion occurs only in the presence of the background field. Its flickering appearance is most distinct with brief pulses, large pulses and peripheral fixation. Neither an additive nor a subtractive explanation of the illusion is sufficient to explain its occurrence. However, the conditions under which the illusion's flickering appearance is strongest are very similar to stimulus conditions which are thought to be important in activating the hypothetical "transient" or "phasic" processing channel in the visual system. This channel has been shown to be highly responsive to brief, relatively large and peripheral stimulus presentations. It may be that the persistence of the background field interacts with certain parameters of the test pulse in such a way that the "transient" channel responds to the presentation of the test pulse with an oscillating response that results in the flickering appearance of the test pulse.

It is improbable that this explanation is the only one that would account for the results of these three experiments. It is tempting, however, to conclude that some type of "transient" mechanism plays a role in the occurrence of this flickering "illusion".

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APPROVAL SHEET

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The thesis is therefore accepted in partial fulfillment of the requirement for the degree of Master of Arts.

December 4, 1980 — R. W. Bowen

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