AN INVESTIGATION OF THE INFLUENCE OF THREE MATCHING INSTRUCTIONS ON SUBFUSIONAL INTERMITTENT BRIGHTNESS

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

JONATHAN DAVID KAZSUK

1967

ABSTRACT

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by Jonathan David Kazsuk

In the past little attention has been paid to the question of instructions relating to the subjective brightness matching of subfusional intermittent photic targets to a steady photic target in a psychophysical situation. There are several qualitatively different sensory end-results over a range of photic intermittency conditions ranging from CFF to isolated flashes of light. This investigation was carried out in an attempt to gain some knowledge concerning the influence of three instructions for making brightness matches.

Two trained observers were instructed to attend to three aspects of subfusional photic intermittency. They were the on phase, the off phase, and a combination of the on and off phases. Pulse lengths were held constant while subfusional intermittency rates were manipulated from conditions very close to critical flicker frequency (high frequencies) to conditions of single flashes of light.

The influence of matching instructions on subjective brightness matches was shown to increase as the intermittency rates were decreased. Also, a sensory end-result shift was quantitatively deter-

mined within the range of intermittency rates used.

Approved: Sydney Bentley

Date: May 19, 1967.

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By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Psychology

1967

ACKNOWLEDGEMENTS

I am thankful to Dr. S. Howard Bartley for his personal interest in the conception and propagation of this thesis. For the use of his laboratory facilities and for suggestion and guidance during my program I am deeply indebted.

Drs. Bakan and Hanley, who served on my committee, were helpful with suggestions and critical inquiries.

Dr. R. J. Ball has through personal interest and technical assistance been an inspiration and a teacher.

Dr. C. W. Schneider contributed much to this student's exposure to psychology and gave many hours of his time and concern to make the collection of data possible.

My wife Kay deserves the deepest appreciation in return for her encouragement and support throughout the creation of this thesis.

A National Institute of Mental Health fellowship has provided funds and made it possible to concentrate on this thesis and a graduate program.

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INTRODUCTION

During the 1930's Bartley and Bishop (1933a, 1933b) became interested in investigating some of the temporal dimensions of visual activity. Using the rabbit as their preparation for gross neurophysiological recordings in the optic cortex, they removed the animal's eye and stimulated the stump of the optic nerve with direct intermittent electrical shocks. By manipulating the temporal aspects of the electrical shocks, they found that when the bursts of electrical stimulation were spaced 1/5 of a second apart that all small, all large, or all medium sized responses were elicitable in the cortex.

Bartley (1936) continued the neurophysiological work with the rabbit's eye intact and found that photic stimulation to the eye showed the same five per second cortical rhythmicity.

From these findings Bartley formulated the alternation of response interpretation of neurophysiological coding in the visual pathway (Bartley, 1961). The essential core meaning of this interpretation is based on the above findings of intrinsic periodicity within the visual modality of the rabbit which seems to provide the neural basis for handling photic and electrical stimulation in a prescribed way. If the photic stimulation is timed to the intrinsic periodicity of the sensory processes, then the maximum cortical response will result. It is further assumed that when the cortical response is at its maximum that the sensory end-result of brightness perception in human observers would be at its maximum.

Bartley (1938) then shifted his experimental endeavors, using temporal stimulation in the visual modality, to human observers in a psychophysical task and discovered what he called brightness enhancement. Brightness enhancement is a subjective phenomenon which occurs in certain psychophysical situations when the subjective brightness of an intermittent photic target exceeds the subjective brightness of a steady photic target of the same intensity.

In his original findings Bartley (1938) reported that brightness enhancement reached a peak at about 8-10 cycles per second (cps) when decreasing stimulus intermittency rates (SIR's) from critical flicker frequency (CFF). Bartley did not use low SIR's (below 3.6 cps) and used a target configuration with the steady and intermittent portions somewhat separated. However, since then brightness enhancement has been reported for SIR's from 2 to 20 cps, and it is not empirically known what aspects of the stimulus complex were most influential in producing these variations. Some of the stimulus dimensions which seem to influence the intermittency rates at which brightness enhancement has been found are listed below.

1. Pulse to cycle fraction (abbreviated PCF and also called light-dark ratio).
2. Photic intensity.
3. The spacial dimentions of the targets.
4. Binocular or monocular viewing.

Systematic studies are needed to investigate the influence played by each of these stimulus dimensions.

The conclusion that peak brightness enhancement does not seem to be locked onto any particular rate range should be noted at this point. While in rabbits the peak brightness enhancement may be locked onto 5 cps, experiments showing behavioral data to confirm it have not been reported. It has been shown that brightness enhancement in the human observer is a complex phenomenological phenomenon. This brings us to some questions on the nature of the sensory end-result itself.

Ranney (1964) has reported six levels of qualitative sensory end-results for human observers viewing a range of intermittency rates from CFF to discrete periods of light and dark flashes. The six levels of phenomenology were fusion, flutter, ripple, fine flicker, coarse flicker, and flash. Thus the same sensory end-results are not obtained at all frequencies below CFF. As the rate of intermittency is decreased from high to low, the appearance of light and dark phases becomes more pronounced. In accordance with Ranney's qualitative categories there is a certain rate range at which a sensory end-result is perceived as being a series of discrete light and dark periods.

While making brightness matches Valsi, Bartley, and Bourassa (1959) realized a sensory shift from fluctuations of lighter and darker phases of the intermittency with some brightness always present, to discrete light and dark phases. They considered this sensory shift to involve two very different brightness phenomena and recommended that the rates of intermittency corresponding to these two categories of sensory end-results should not be put on graph without designating their differences.

When the SIR is above CFF, the sensory end-result is one of uniform steady brightness. Slightly lower rates introduce what is called flicker. This flicker can be described as a slight brightness fluctuation, but since it is only slight the main characteristic of the field is a steady component of brightness which can be matched to any steady field adjacent or near it. As rates are lowered still further the appearance of brightness fluctuation increases until there is no steady component to be seen. This shift proceeds as rates are decreased until each light pulse is quite discretely separated from the pulse just preceeding and just following it. The separation between pulses may be made great enough so that there is no detectable influence of one pulse on another. When this is the case it can be said that a series of isolated pulses is involved.

The supposition which follows is that making brightness matches of a series of light and dark periods to a steady target is a different phenomenon than making brightness matches between a steady target and a fluctuating target containing a brightness component at all times.

With the exception of Colgan (1965) no researcher has reported giving specific instructions to the observers making intermittent brightness matches. Colgan varied the rate of photic intermittency using Sylvania glow modulator tubes and red filters (612-668mu). The intensity was about 2.2 c/ft.^{2}, and the results were reported as showing an increase in brightness enhancement from 20 cps until a rate of 2 cps was reached. A fairly large sample of naive subjects were given instructions for making brightness matches. One group was instructed to match to the on phase of the intermittency, another to the average of the on and the off phase, and a third group was told nothing. Colgan reports that the brightness enhancement was greatest for the group instructed to match to the on phase of the intermittency.

Schneider and Bartley (1966) manipulated the rate of intermittency from 20 to 1 cps and reported a gradual increase in brightness from 20 cps to 1 cps with the greatest rise in brightness being from 3 cps to 1 cps. The observer's instructions for making a match were implicit and were such that an observer (this author was one of two observers) was to match the steady photic source to an "average" of the intermittent target brightness.

The study by Schneider and Bartley was done because it was suspected that observers were shifting their brightness match criterian over the range of intermittency rates producing the various sensory end-results. To measure this, standard deviations were calculated for each of two observers for the 40 brightness matches during four sessions. Schneider and Bartley report an increase in standard deviations for the rates from 6 cps to 3 cps.

When the observer perceives the intermittent stimulus as a pronounced fluctuation of brightness and is required to match this to steady brightness, he has several alternatives to consider. He can match the light phase of the intermittency to the steady, the dark phase to the steady, or he can try to achieve a match to the "mean" of the fluctuating brightness. This is not a mean in the mathematical sense of the word for the observer is not making a direct observation but is using a criterian which seems to be appropriate. Hence, whatever the response is, it must not be treated strictly as an observation, i. e. as a sensation in and of itself but rather as a derivative. When the flicker is not pronounced, the alternatives are essentially reduced to making a match on the basis of a predominant steady component.

In order to learn more about the quantitative brightness effects related to the three alternatives listed above, two questions are asked. One, what effect does matching according to the three alternatives have on brightness matches over SIR's from CFF to discrete flashes? Two, at what intermittency condition does the sensory end- result shift from an experience with a brightness component present at all times to an experience of discrete flashes?

METHOD

<u>Apparatus</u>. The apparatus is shown diagrammatically in Figure 1. The photic sources S1 and S2 are Sylvania glow modulator tubes (R 1131 C). S1 is the steady photic source and is driven electronically by a Grasen-Stadler flicker-fusion apparatus. S2 is the intermittent source and is driven electronically by a modified Grass S-4. W1 is a calibrated neutral density wedge which controls the percentage of photic transmission passing to the observer's eye. W1 could be moved by a rack and pinion device by turning the dial D. W2 is a stationary balance wedge.

The scale numbers on W1 were used for recording a brightness match. These numbers were then converted to percentage of transmission and were accurate to within .1 per cent. RS is a reduction screen preventing any extraneous light from reaching the observer. LH is a light housing keeping the photic energy of S1 and S2 separate. FP is a piece of filter paper used to make the two photic sources S1 and S2 appear uniform. F is a permanent .4 neutral density filter over the S2 intermittent source. I and S represent the position of the intermittent and steady target images to the observer O.

The observer was located 80 cm. from the target which is drawn in Figure 2. The diameter of I and S is 1 cm. which subtends 43' of arc for the observer. The 3 cm. between the I and S targets subtends an arc of 2^{0} 9'. The overall target configuration is 5 cm. high and subtends an arc of 3^{0} 35'.

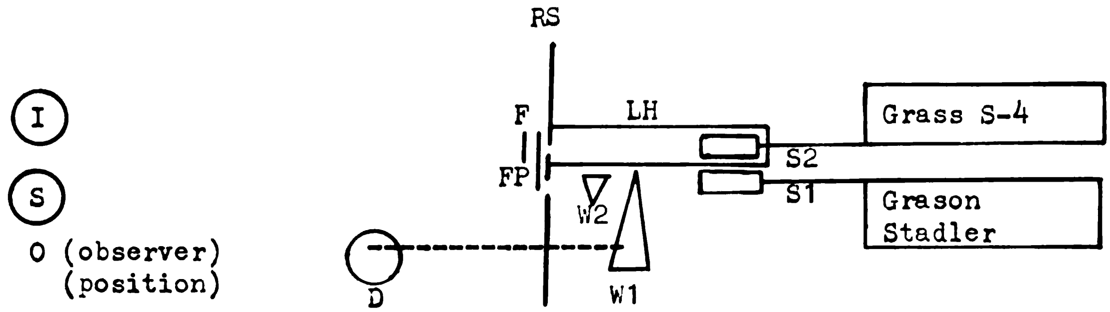
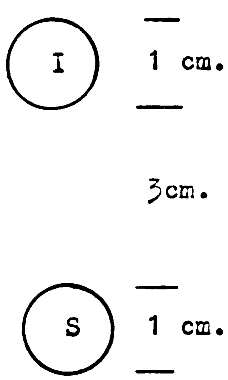


Fig. 1. Schematic diagram of the apparatus showing the arrangement of light sources S1 and S2, neutral density wedges W1 and W2, the reduction screen, the dial for the wedge, and the appearance of the intermittent and steady targets.

Fig. 2. Schematic diagram of the steady and intermittent targets as they spacially appear in actual dimensions.



Observers. Two male graduate students including this author served as the observers. Each had many hours of experience serving in subfusional intermittent brightness matching experiments.

Procedure. Under all conditions, the observer using monocular vision matched the brightness of the steady target to the perceived brightness of the intermittent target (point of subjective equality). The intensity of the intermittent target was held constant at 1.8 c/ft.^{2} The current on both the steady and intermittent glow tubes was monitored and held constant at 25 ma. The intensity of the steady target ranged from 3.8 c/ft.^{2} to .1 c/ft.^{2} depending on the position of the neutral density wedge. The neutral density wedge controlled percentage of transmission of the steady photic energy to the observer so that the current to the glow tube could be held constant. The luminance of the glow tubes was nearly achromatic.

Before collecting data each observer practiced the instructions for several weeks in order to become familiar with the task.

The on-match instructional set meant that the observer attended to and attempted to match to the on phase of the intermittency. The mean-match instructional set meant that the observer attended to and attempted to match to a derivative of all brightness aspects of the intermittency. The off match instructional set meant that the observer attended to and attempted to match to the off phase of the intermittency.

A total of 3060 observations were recorded for each observer. (1) Three instructional sets were used. (2) Three pulse lengths were used. Using a pulse length of 20 ms the frequencies used were 45, 25, 20, 15, 12, 10, 8, 6, 4, 2, 1, .75, and .50 cps. Using a pulse length of 40 ms the frequencies used were 20, 15, 12, 10, 8, 6, 4, 2, 1, .75, and .50 cps. And, using a pulse length of 60 ms the frequencies used were 15, 12, 10, 8, 6, 4, 2, 1, .75, and .50 cps. (3) Thirty observations at each condition were collected over 3 sessions. In addition to the 3060 intermittent observations each observer made a total of 540 brightness matches with both targets at steady luminance. Ten steady observations were recorded at the beginning of each session and an additional 10 were recorded at the end of each session.

One pulse length with corresponding SIR's presented in random order was used over three sessions for the three instructional sets before the next pulse length was used. For each condition in each session, each observer made 5 ascending and 5 descending matches in alternate fashion.

Ten minutes for adapting to the target were given before each session.

All values obtained with the neutral density wedge were converted into the percentage of transmission (P of T) required for a match. The mean of 30 observations made under a particular condition was used as the percentage of transmission required to make the intermittent and steady targets look equally bright. The mean of the 540 steady matches was recorded as the P of T of the steady source necessary to make the two photic targets look equally bright when the intermittent photic target was made steady without changing its intensity.

RESULTS

The mean percentage of transmission over 3 sessions for each condition (3 pulse lengths with corresponding SIR's and 3 instructional sets) and for each subject to indicate a measurement of the point of subjective brightness equality are shown in Figures 3-8. The general observations from these figures pertinent to this investigation are listed below.

1. The instruction variable results in great brightness differences between the on-matches and the off-matches for the low SIR's. That brightness differences tend to decrease as SIR's are increased is shown in figures 9 and 10.

2. The off-match curve drops to zero brightness around 1 or 2 cps. As the pulse length increases the steepness of drop to the zero point increases for both observers.

3. The mean-match curves tend to fall closer to the on-match curves than to the off-match curves.

4. For the 40 and 60 ms pulses, the lower the SIR the higher the on and mean-match curves. These curves rise above the steady curve at about 10 cps and tend to increase in height as the SIR's decrease. This area above the steady line is the brightness enhancement area. For the 20 ms pulse the shape of the on and mean-match curves tend to resemble a shallow U. The highest and lowest SIR's show similar brightness levels. No substantial brightness enhancement was shown for this pulse length.

Fig. 3. Subjective brightness matches obtained by observer JK with the 20 ms. pulse.

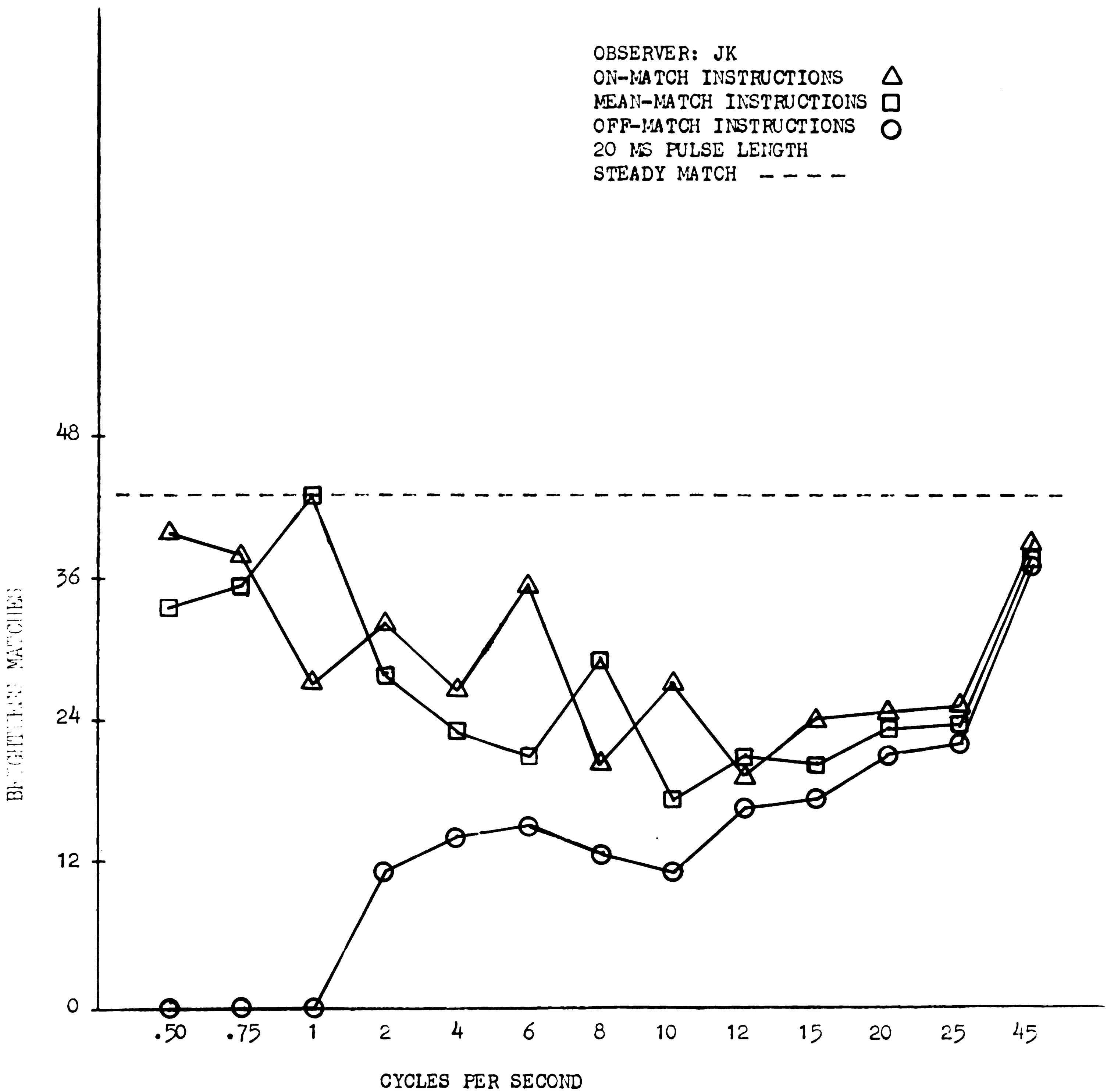


Fig. 4. Subjective brightness matches obtained by observer CS with the 20 ms. pulse.

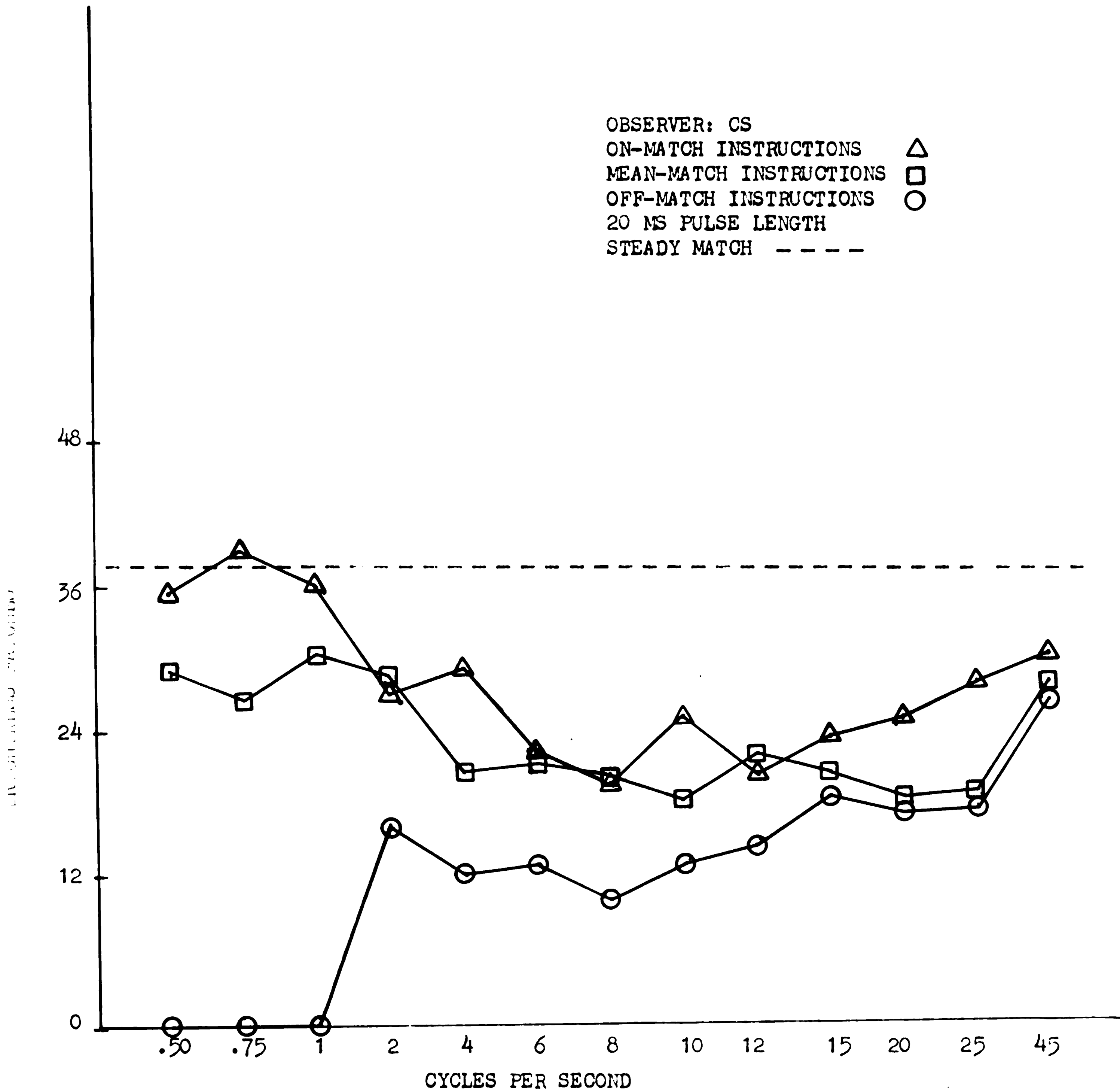


Fig. 5. Subjective brightness matches obtained by observer JK with the 40 ms. pulse.

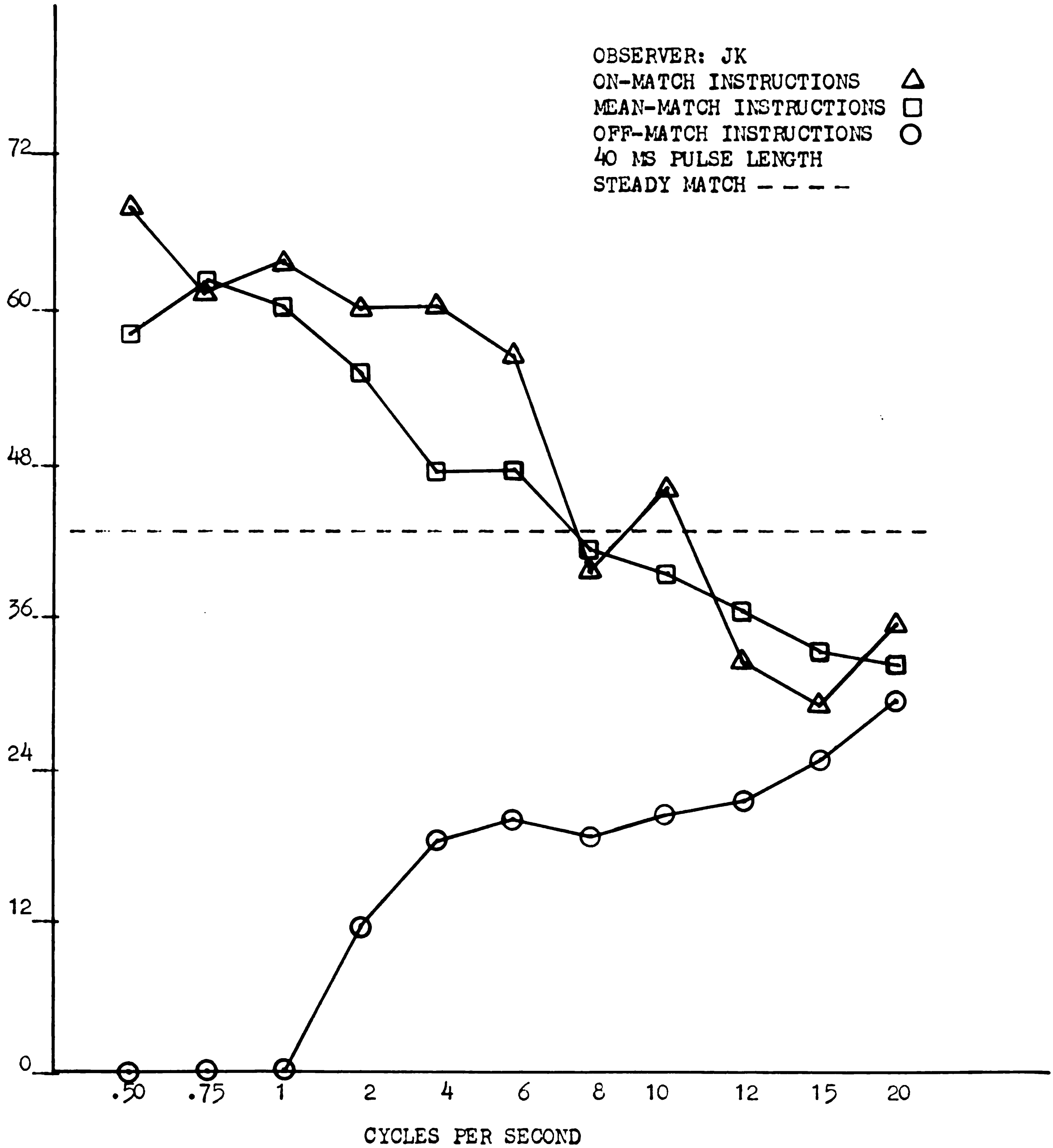


Fig. 6. Subjective brightness matches obtained by observer CS with the 40 ms. pulse.

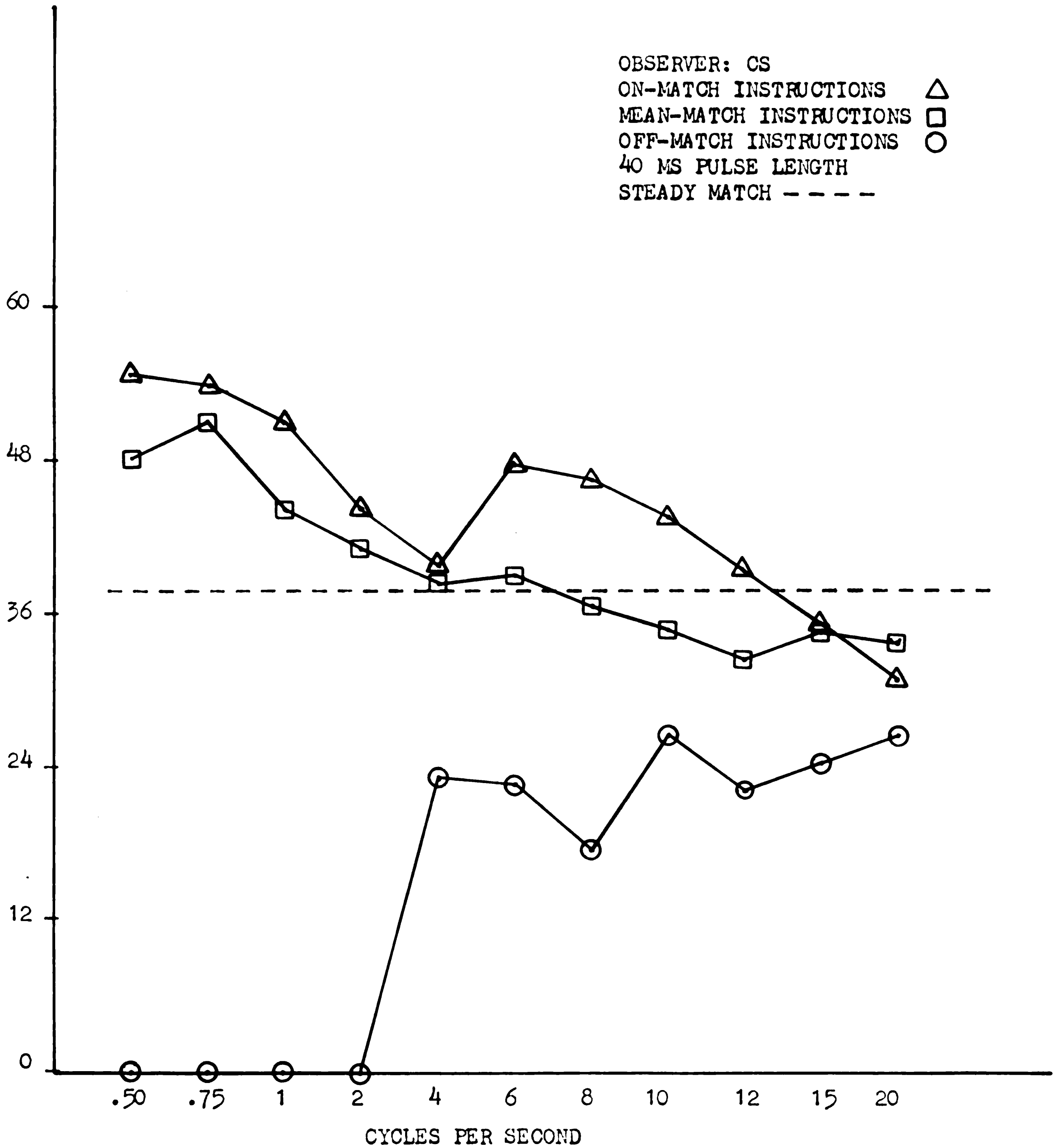


Fig. 7. Subjective brightness matches obtained by observer JK with the 60 ms. pulse.

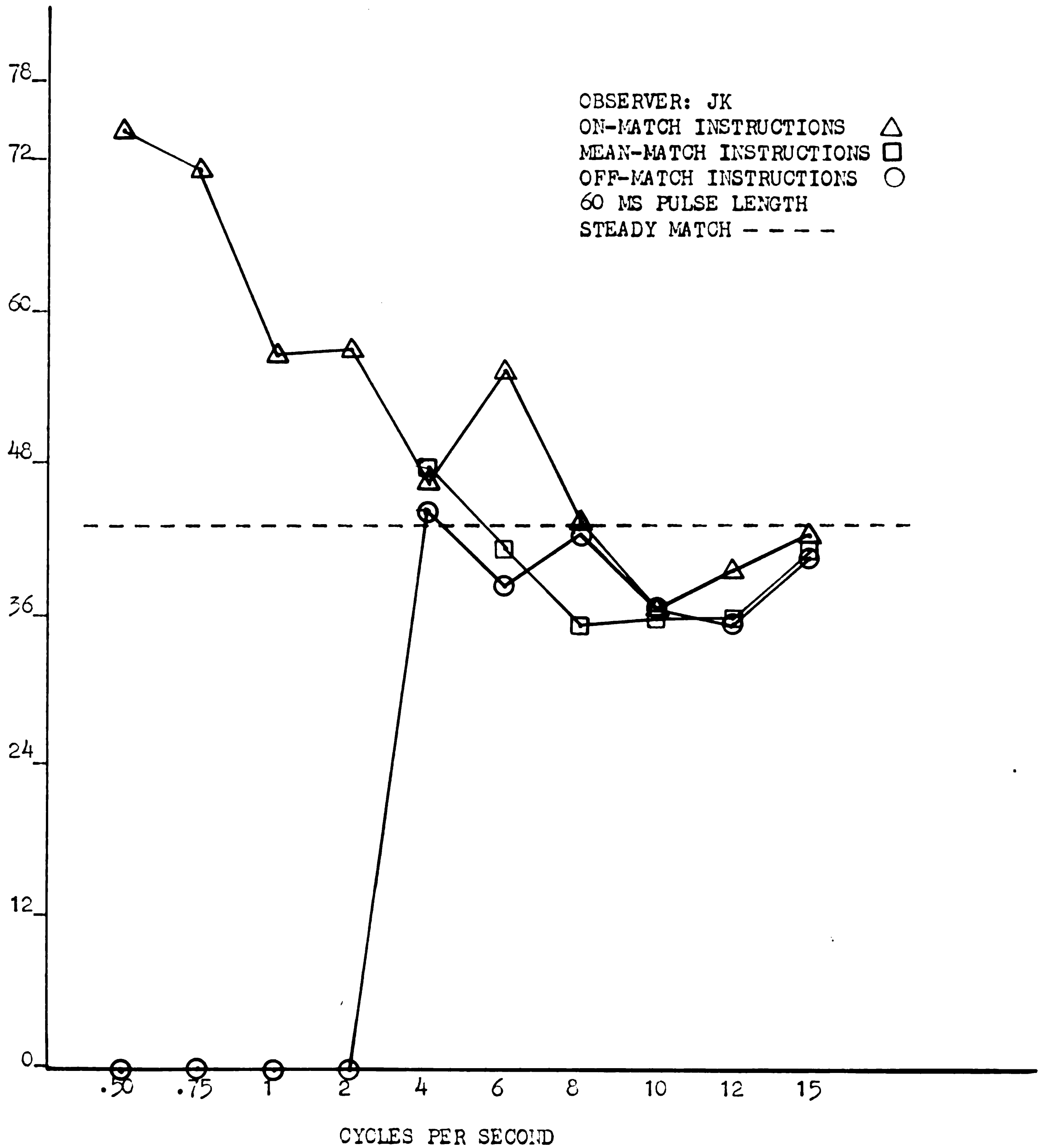


Fig. 8. Subjective brightness matches obtained by observer CS with the 60 ms. pulse.

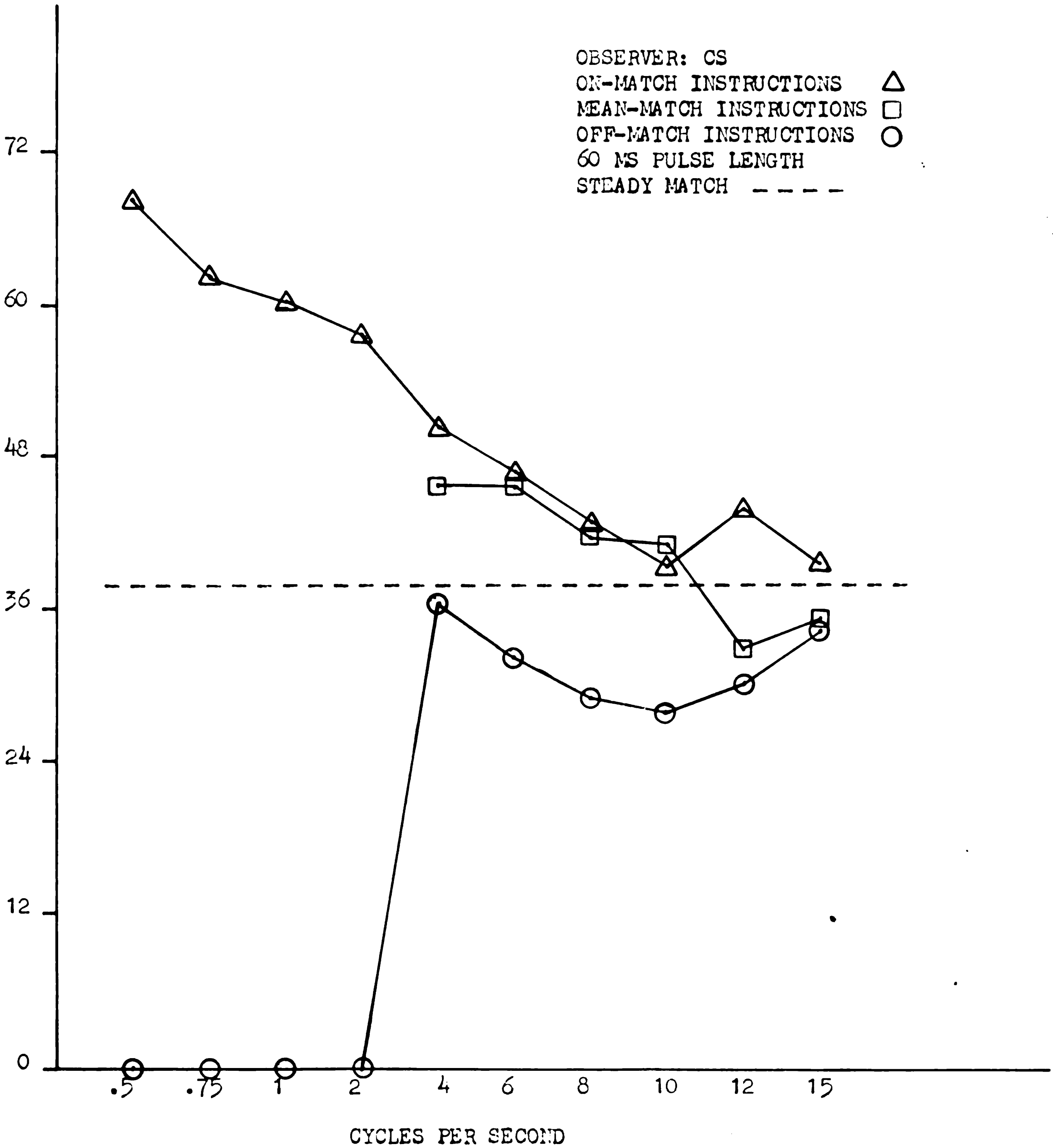


Fig. 9. Brightness differences between on-matches and off-matches for observer JK with each pulse length.

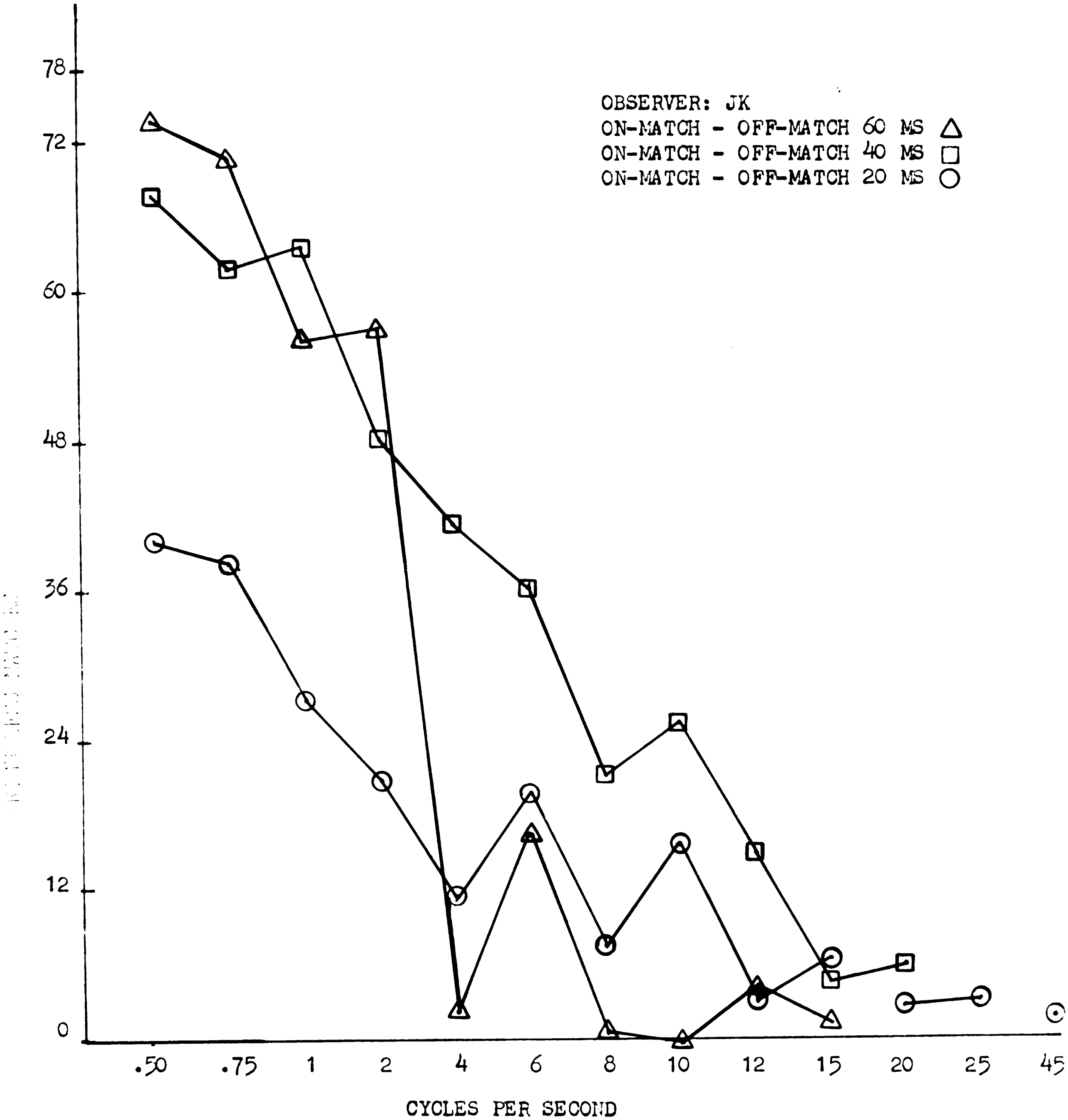
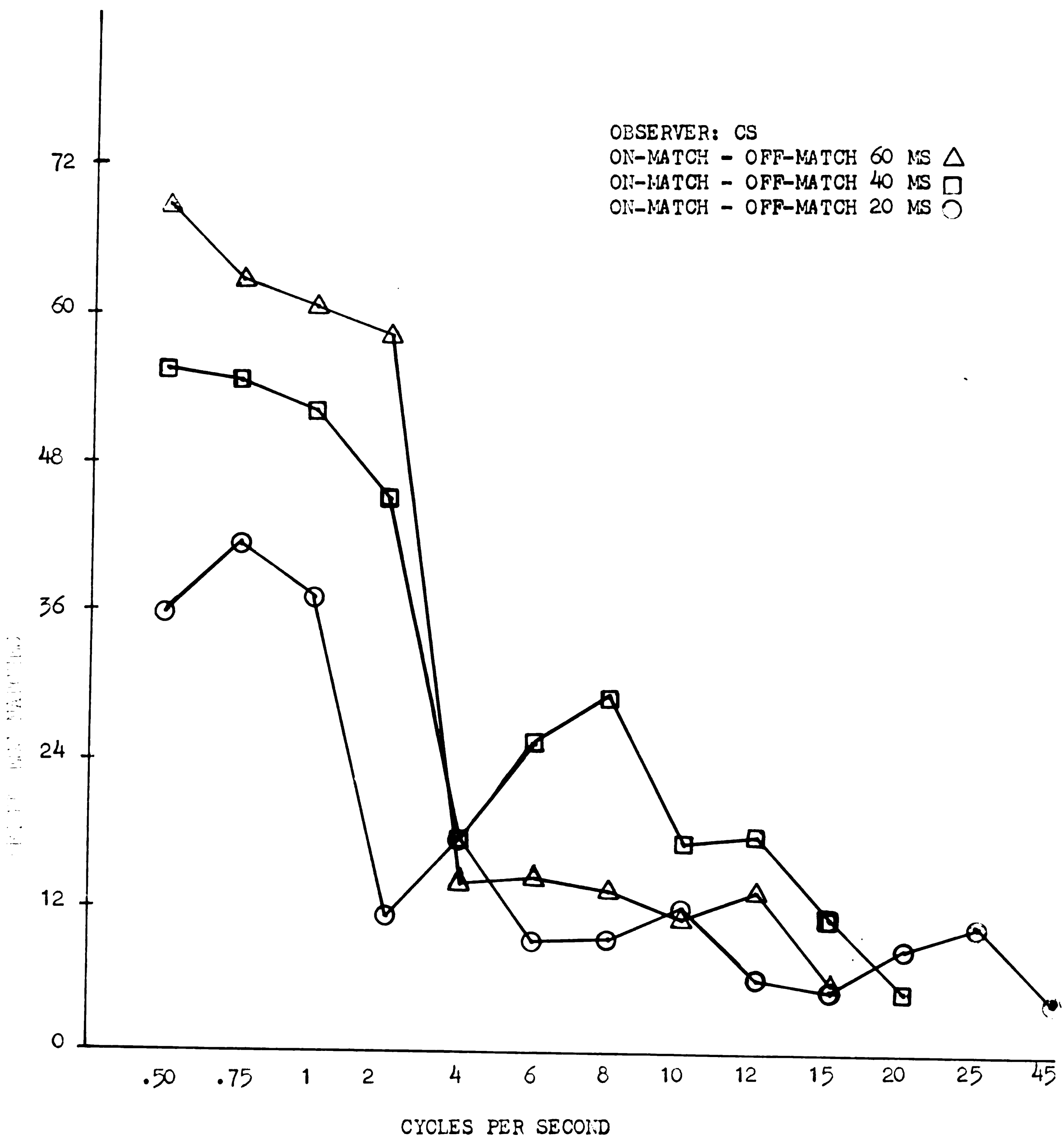


Fig. 10. Brightness differences between on-matches and off-matches for observer CS with each pulse length.



5. The off- match curves are highest for the high SIR's. The off-match curves for the 60 ms pulse are flatter at those SIR's above the drop-off than for the 20 and 40 ms pulses.

Figure 11 compares the two observers with regards to the influence of pulse length and SIR on the zero point of the off-match curves. The two observers agree at the 20 and 60 ms pulse conditions, but the zero point for JK was 1 cps lower than the zero point for CS at the 40 ms pulse length condition. It can be noticed from Figure 5 that JK took only 11 P of T to make an off-match at 2 cps which is the zero point for observer CS.

Figures 12 and 13 compare the mean differences between the on-matches and the mean-matches with the differences between the mean-matches and the off-matches by averaging over SIR's for each pulse length used. In all cases except observer JK at the 60 ms pulse condition, the mean-match is on the average closer to the on-match results. Observer CS had the least difference at this 60 ms pulse length condition. However, mean-matches were not made for the SIR's below the drop-off because of task difficulty.

Table 1 shows that the on-match instructions always resulted in higher brightness values for both observers than the mean-match or off-match instructions when averages are taken over SIR's. This result is in agreement with Colgan's result (1965). It should be noted, however, that in the investigation being reported here brightness values for mean-matches were in some cases higher than

Fig. 11. Comparison of the off-match zero brightness point for observers JK and CS.

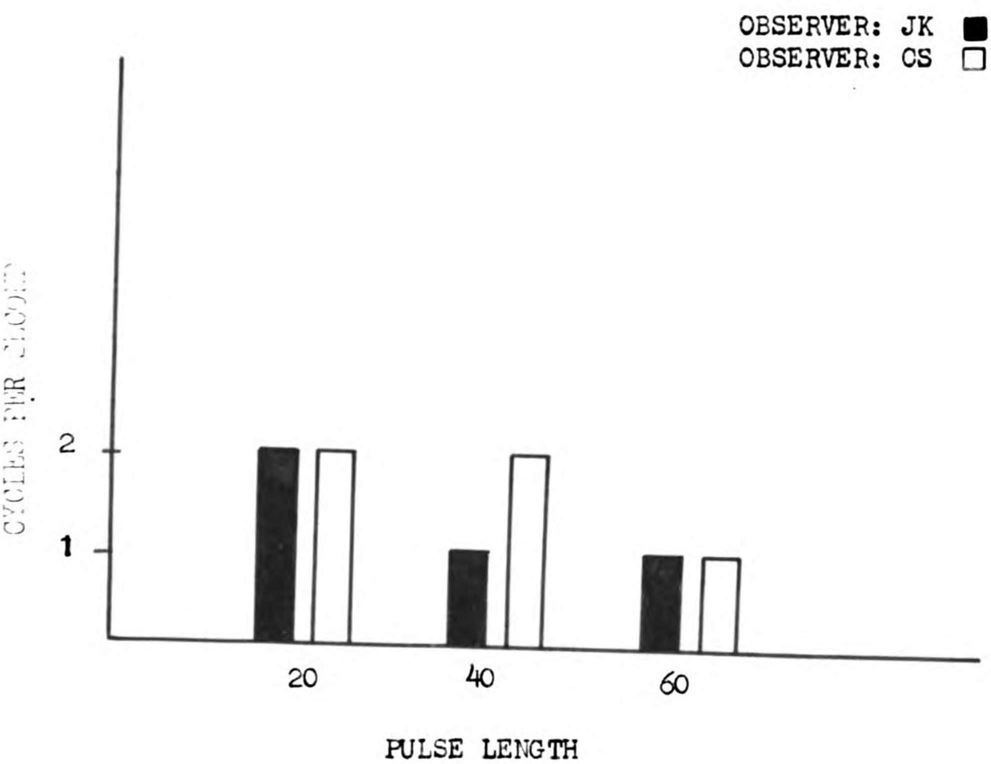


Fig. 13. Brightness differences between on-matches and mean-matches compared with brightness differences between mean-matches and off-matches. Each graphic point represents averaging over all SIR's for a given pulse length and instruction before computing the difference. This figure is for observer CS.

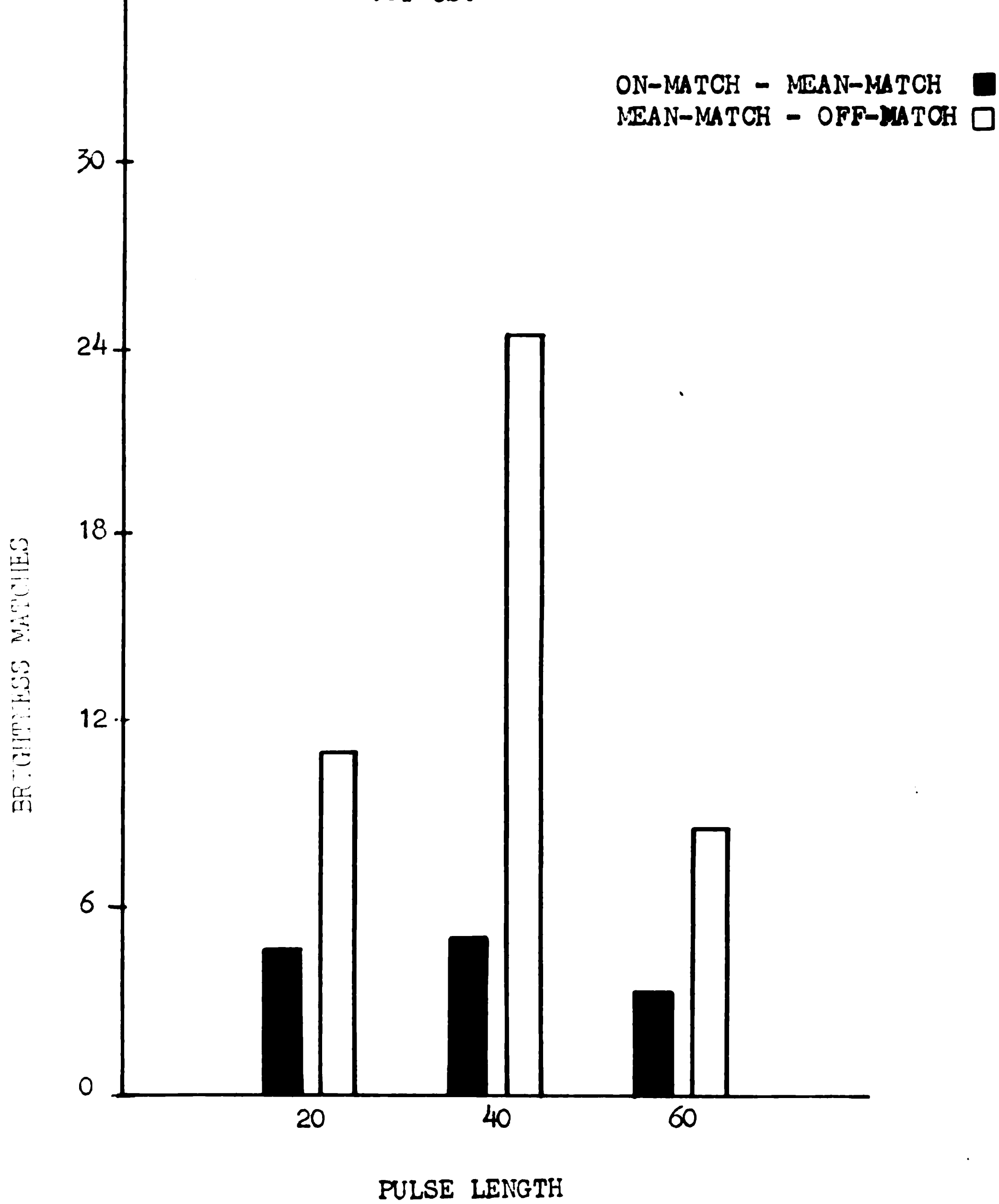


Table 1. Averaged brightness comparisons between instructions over all SIR's at a given pulse length.

Subject	Pulse Length in ms.	On-match Mean Over Rates PofT	Mean-match Mean Over Rates PofT	Difference PofT
CS	20	28.27	23.49	4.78
CS	40	44.78	39.69	5.09
CS	60*	44.29	40.92	3.37
Subject	**Pulse Length in ms.**	**Mean-match Mean Over Rates PofT**	**Off-match Mean Over Rates PofT**	**Difference PofT**
CS	20	23.49	12.30	11.19
CS	40	39.69	14.94	24.75
CS	60*	40.92	32.20	8.72
Subject	**Pulse Length in ms.**	**On-match Mean Over Rates PofT**	**Mean-match Mean Over Rates PofT**	**Difference PofT**
JK	20	29.48	27.69	1.79
JK	40	50.33	46.82	3.51
JK	60*	44.02	39.41	4.61
Subject	**Pulse Length in ms.**	**Mean-match Mean Over Rates PofT**	**Off-match Mean Over Rates PofT**	**Difference PofT**
JK	20	27.69	14.07	13.62
JK	40	46.82	14.86	31.96
JK	60*	39.41	39.76	-.35

* Mean-matches for these stimulus intermittency rates below the drop-off zero point were not made for this pulse length. See text for explanation.

the on-matches.

At the SIR's below the drop-off, mean-matches were considered by both observers to be extremely difficult if not impossible. For the 20 and 40 ms pulse lengths an attempt was made to make mean-matches in order to determine somewhat of an idea where these matches would fall with regards to the on and off-matches. Figures 3-6 show the mean-matches made at these SIR's to be closely aligned with the on-match curves.

This task was considered too difficult at the 60 ms pulse length conditions, and each observer felt he could match only to the extreme on or off phases of the intermittency.

DISCUSSION

The data show in Figures 9 and 10 that brightness differences between on-matches and off-matches tend to increase as SIR is decreased. As the SIR is decreased while holding pulse length constant, the null period between each pulse is increased by some known amount. Thus, as the null period is increased from CFF for any of the three pulse lengths used in this study the need to specify the criterian for making brightness matches becomes more necessary.

In Figures 9 and 10 we can see that brightness differences between the two instructions is not the same for each pulse length. Figures 3-8 show that the 40 and 60 ms pulse lengths produce greater on-match brightness than the 20 ms pulse at low SIR's. This explains the position of the curves in Figures 9 and 10 at the low SIR's. The position effects at higher SIR's in these figures cannot be empirically explained at this time. The conclusion from these data is that pulse length as well as null period effects brightness match differences.

This study produced data clearly showing two categories of sensory end-results. Too little attention has been paid to this sensory shift. Studies dealing with the brightness of a series of discrete light and dark periods have a different task for the observers to perform than studies dealing with subfusional intermittency where there is a brightness component present at all times. The series of discrete light and dark periods produces a sensory end-result characterized by abrupt changes of light and dark. The next experimental step is to create studies which will systematically assay temporal, intensity, and spacial variables within each of these sensory categories in order to ferret out similarities and differences of brightness within the two categories. This would mean finding the zero brightness point of the off-match curve for a given set of conditions.

The findings here, that there is a general increase in brightness as SIR is decreased from 20 cps does not agree with Bartley's (1937) original finding that brightness enhancement reached a peak at 8-10 cycles per second and then started to decline as rates were lowered to 3.6 cps. Bartley, however, was working with intensity levels around 100 c/ft.^{2}- much different than the 1.8 c/ft.^{2} intensity level used in this study.

Bartley (1951) showed that with a very low intensity level of .007 c/ft.^{2} that brightness increased as rate decreased down to 3.6 cps. The indication is that intensity is a crucial variable in determining the shape of a brightness curve over a wide range of rates.

These findings tally with the neurophysiological studies and the alternation of response theory that brightness enhancement may be absent with low levels of stimulation, because not all channels in the optic pathway are involved in such a way as to produce sufficient channel synchrony.

The practice in the past of not specifying the brightness matching criterian seems to leave much room for improvement. At the low SIR's a naive observer could match anywhere within this range if only told to "match two targets in brightness." While this author would not expect him to make an on-match, he also would not expect an untrained observer to make an off-match. Instead, what the naive observer seems to do as evidenced through casual observation is to vacillate around somewhere between the on phase and off phase of the intermittency. This type of matching has been called making an average or mean-match. Attempts to make mean-matches in this study showed that in almost all cases the mean-matches were closer to the on-matches than to the off-matches even though both observers felt that they were dividing the brightness of the on phase and off phase down the middle. As the SIR's get lower the difficulty of making a mean-match increases according to the verbal reports of the two observers.

The recommendation according to these findings is that observers be instructed to make brightness matches to some criterian specified by the experimenter rather than being told nothing or simply to match the brightness of two targets. It is the opinion of this author that if brightnesses are to be compared over a wide range of intermittency rates, the on phase of the intermittency should be the basis for making a brightness match, but at the same time the nature of the sensory end -result being dealt with should be specified.

SUMMARY

In the past little attention has been paid to the question of instructions relating to the subjective brightness matching of subfusional intermittent photic targets to a steady photic target in a psychophysical situation. There are several qualitatively different sensory end-results over a range of photic intermittency conditions ranging from CFF to isolated flashes of light. This investigation was carried out in an attempt to gain some knowledge concerning the influence of three instructions for making brightness matches.

Two trained observers were instructed to attend to three aspects of subfusional photic intermittency. They were the on phase, the off phase, and a combination of the on and off phases. Pulse lengths were held constant while subfusional intermittency rates were manipulated from conditions very close to critical flicker frequency (high frequencies) to conditions of single flashes of light. The influence of matching instructions on subjective brightness matches was shown to increase as the intermittency rates were decreased. Also, a sensory end-result shift was quantitatively determined within the range of intermittency rates used.

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