The indifference interval and the filled duration illusion : a study of temporal experience with durations between 200 and 1100 msec
by Edward Joseph George

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology
Montana State University

Abstract:

Three experiments investigated phenomena related to the concept of the indifference interval and the filled duration illusion from an information processing viewpoint. In Experiment 1 an increasing linear function between nontemporal stimulus information and subjective duration was found when subjects judged 300 and 330 msec durations, but not 500 and 550 msec durations. In Experiment 2 an additional level of nontemporal stimulus extent was used, and a quadratic function between nontemporal events and duration judgments was found.

In Experiment 3 a wider range of durations was used, but with the same number of levels of nontemporal stimuli employed in Experiment 1. The relation between nontemporal stimuli and duration judgments returned to an increasing linear function. In all three experiments the effects on nontemporal stimuli tended to disappear as the durations became longer.

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A thesis submitted in partial fulfillment
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ABSTRACT

Three experiments investigated phenomena related to the concept of the indifference interval and the filled duration illusion from an information processing viewpoint. In Experiment 1 an increasing linear function between nontemporal stimulus information and subjective duration was found when subjects judged 300 and 330 msec durations, but not 500 and 550 msec durations. In Experiment 2 an additional level of nontemporal stimulus extent was used, and a quadratic function between nontemporal events and duration judgments was found. In Experiment 3 a wider range of durations was used, but with the same number of levels of nontemporal stimuli employed in Experiment 1. The relation between nontemporal stimuli and duration judgments returned to an increasing linear function. In all three experiments the effects on nontemporal stimuli tended to disappear as the durations became longer.

INTRODUCTION

For more than 100 years psychological research directed towards understanding the singular human experience of time has often encountered a curious and largely unexplained phenomenon known as the <u>indifference interval</u> (II). The II is conceptualized as a rather specific length of time for which human subjects show a maximum "sensitivity" in terms of the experience of duration. In this regard, sensitivity is defined in terms of accuracy of temporal judgment. Characteristically, experimental subjects are able to produce, reproduce, and estimate the II's duration with more accuracy than any other duration of greater or lesser length. More recently, another phenomenon related to the human experience of time, has resulted in the concept of the <u>filled duration illusion</u> (FDI). The concept of the FDI stems from the discovery that nontemporal events which occur during the presentation of a duration affect a subject's subjective experience of its length. In other words, a duration filled with nontemporal sensory stimuli will be judged as longer in passing than an empty duration of the same length. Theoretical comparison of these two concepts (II and FDI) is made difficult in that they were generated out of contrasting methodological traditions. Verification of the II phenomenon is derived mostly from ongoing psychophysical research with empty intervals. In contrast, verification of the FDI phenomenon is derived from the outgrowth of information-processing oriented research with filled durations. The purpose of the research reported here was to study the characteristic phenomenon of the FDI against the backdrop of the range of short duration lengths that are most commonly ascribed to be at or near the II point. Until recently, information processing research on the FDI has generally ignored short durations like the II in favor of experimentation with longer time lengths. Given these considerations, a strategy of cross-concept comparison of experimental outcomes is integrated into the present anylysis. A brief review of the literature related to II and FDI is followed by a description of a series of three experiments. These experiments were designed to study the influence of nontemporal stimulus events on temporal judgment, when durations between 200 and 1100 msec are used. Theoretical analysis of experimental outcomes is weighed in favor of information-processing considerations. The greater emphasis is placed on durations that are shorter, but similar in length to the II point. Each successive experiment marks a broadening of the range of durations experimentally employed.

The origin of the concept of the indifference interval can be traced back to the psychophysical literature of the 1860's. The II is functionally associated with another principle which came into being about the same time. Horing, an understudy of Vierordt, experimented with a range of short intervals (.3 to 1.3 sec) and found that the longest of these were underestimated and the shortest were overestimated. This phenomenon (according to Fraisse, 1963) came to be known as "Vierordt's Law" and "led directly to the concept of the indifference point or zone corresponding to a duration for which there is no systematic error" (p.118). Over the years, many researchers attempted to pin-point the actual duration of the II. The methods used were based on psychophysical principles and employed estimation, comparison, production and reproduction of predetermined "clock time" standards of duration length. Woodrow (1934) did a comprehensive review of the literature and concluded that an II of somewhere between .59 and .62 sec is most often reported. However, the specific research results tend to be influenced by the sensory modality and the experimental methods used. On some occasions no II was found at all. On other occasions a range of .2 to as long as 180 sec has been reported (Treisman, 1963). As a result, the generality of the II concept is a controversial issue to this day (Pew & Nickerson, 1972; White, 1964; Woodrow, 1934).

In those studies that did find an II, several outcomes tended to consistently occur. First, there is a tendency for the II to be near the middle of the range of intervals used (Woodrow, 1951). Second, subjects tend to underestimate intervals longer than the II and overestimate those which are shorter (Vierordt's Law). Fraisse (1963) attributed these combined outcomes to an "anchoring effect," which is facilitated by the influence of a reference point on duration estimates. Yet, Woodrow (1934) used a different group of subjects for each selected interval, and an II (.6 sec) was still obtained. The same characteristic overestimation and underestimation at the extremes of the continuum was present. Fraisse (1963) reviewed the literature and concluded that a conservative identification of the II would place it in a zone between .5 and .8 sec. As early as 1886, Wundt (cited by Fraisse, 1963) identified the II as being between .71 and .75 sec. This he regarded as a very specific unit of time that correlated with a diverse variety of functions, such as the time needed in the process of association or the movement of a leg in rapid walking. Fraisse (1963, 1978) expanded on this idea and attributed the .5 to .8 sec range of intervals to be a point of transition, where the perception of rhythm is superseded by the perception of duration. A variety of researchers, particularly "internal clock" theorists, tend to conceptualize the II as corresponding to an optimum rhythm in the nervous system, which marks a spontaneous tempo for various functional activities, such as perception, respiratory processes, and general physical movements. Their ongoing attempts to link the II to some specific internal periodicity (sometimes called the quantum) have been very inconclusive, and are only of secondary interest to the present review. For relevant references, see Anlikor, 1963, 1966; Poppel, 1975; Stroud, 1955; Vroon, 1970; Wiener, 1948.

Experimentation with the phenomenon of the II has been largely based on the principles of psychophysical methodology. Early research employed the Weber differential sensitivity law, which refers to a subject's ability to discriminate between two stimuli of different intensity. Later, Fechner suggested a generalization of this formula in advocating a logarithmic relation between the perceived and actual stimulus. The Weber-Fechner formulation was modified by Stevens when he suggested the relation between actual and perceived stimuli was exponential rather than logarithmic. All three of these formulations have been applied to the broad spectrum of sensory experience. Often, the issue is not "Which formula is most valid?", but rather, "Which formula fits best under what conditions?" The factors contributing to this variance in appropriateness are scaling methods, sensory modalities, and stimuli (Andreas, 1972; Brown & Hitchcock, 1965; Doehring, 1961; Richards, 1964).

When the Weber law is applied to the perception of short durations the results are conflicting. Deviations from this formula, expressed as a percentage of error, become greater as one goes to the extremes of the continuum used (Gilliland & Humphreys, 1934; Henery, 1948). Woodrow (1951) reported a differential threshold of 7 to 10 percent between .2 and 2 sec, with an optimum sensitivity at .75 sec. However, this is not an exceptional outcome from the standpoint of general sensitivity to changes in stimulus intensity. In the experimental situations where the Weber law has been shown to apply, it shows a best fit towards the middle of the range of stimulus intensity, but tapers off towards the extremes (Andreas, 1972). Further, it is difficult to directly equate intensity levels with duration lengths. Problems such as these led many researchers to conclude that Weber's law was not applicable to temporal intervals (Woodrow, 1951; Triesman, 1963). Similar problems are encountered with application of the Weber-Fechner formula (Edgell, 1903; Fraisse, 1963). A number of studies have demonstrated that discrimination of short time intervals can be accounted for by the Stevens power function (Michon, 1967; Stevens & Galanter, 1963). Michon (1967) extended this research to a fine-grain analysis of durations from .1 to 2 sec. Although the results conformed to the power function, perception of durations from .1 to .5 sec tend to increase with the square root of the actual durations; whereas, perception of durations from .5 to 2 sec increase linearly with the durations. The change in the slope of the function Michon concluded:

> "Represents a genuine characteristic of time perception. It can probably be equated to the point of maximum sensitivity and the 'indifference interval,' i.e., the point where, subjectively, intervals change from 'short' to 'long' and where, . . . the perception of rhythm is superceded by the perception of duration." (p.360).

Current opinion favors the idea that perception undergoes rather abrupt changes somewhere in the zone between .5 and .8 sec. A more unresolved issue concerns the generality of the II concept in accounting for these perceptual changes. Anomalies created by differences in experimental procedure (scaling methods, sensory modalities, stimuli, and statistical treatments) tend to make the task of answering this question quite difficult. Furthermore, ongoing research with durations (from very short to very long) have implicated a wide variety of physiological, cognitive, and motivational factors affecting temporal judgment (see George, note 1). These factors are not adequately dealt with by current psychophysical procedure. This is not to say that alternative methodologies are not beset with problems of their own. Moreover, there are procedural problems related to time research, that go beyond any given methodology. For instance, a pertinent aspect of these more holistic problems, can be illustrated by contrasting the typical experimental conditions under which the experience of short and long durations are studied. The study of very short durations lends itself well to a repeated measures design where many data samples are taken on each subject. Under these circumstances a prospective paradigm is mandatory, as the subjects must know a priori that temporal judgment is required. As the durations employed become longer, a retrospective paradigm can also be employed, where the subjects do not know that a temporal judgment will be required until after the duration has been presented. However, the use of a retrospective paradigm requires that a single measure design be employed. As the experimental durations become very long, it becomes increasingly difficult to employ anything but a single measure design, regardless of the paradigm used. Consequently, it is often difficult to compare the outcomes of research across the continuum from very short to very long durations. Research with the very short durations characterizing the II zone have exclusively employed a repeated measures prospective design. This is true, regardless of the specific methodological orientation of the experimenters. The research reported in the present study reflects this tradition. Although this situation creates difficulties in generalizing research outcomes to the experience of longer durations, it does provide a basis for cross-methodology comparison of research with very short durations.

In contrast to the psychophysical method, an alternative approach has resulted from the development of information processing approaches to the experience of time. A basic premise of information processing theory is that cognitive processes directly influence temporal judgment. A factor central to most information processing approaches is the postulated role of memory in the experience of duration. Ornstein (1969) proposes that it is not the information registered in immediate perception, but rather the information stored in memory that determines the subjective length of the interval. Burnside (1971) expanded on this idea and suggested that subjective duration is determined more by the memory of the type of processing rather than gross interval content. Distinctions between actual stimuli and stored stimulus information, implicate processes of attention and attentional selectivity in duration experience as they relate to research with very short durations near the II point.

Research linking the II concept to information processing theory is rather meager. Blumenthal (1977) speculates in parallel to Vierordt's Law that the II is the result of an intrinsic buffer delay in information storage processes that cause short events to be subjectively prolonged and longer events to be constricted. Many information processing approaches advocate that we must look at the more specific nature of the events that occur during the interval in order to understand temporal experience. Psychophysical experimentation has shown that an interval filled with constant stimuli is judged longer than an empty interval of the same length. Furthermore, an interval divided by discontinuities in the nontemporal stimuli filling it is judged longer than an equal interval filled with constant stimuli (Anderson, 1936; Brown & Hitchcock, 1965; Goldstone & Goldfarb, 1964, 1946). Confirmation of Vierordt's Law and the II concept stems mainly from experimentation with intervals that are either empty or filled with constant stimuli. Explanation of these outcomes is usually based on a direct time estimation process where nontemporal factors are not taken into account. It has been found that temporal judgment of divided intervals is an increasing function of the extent of the nontemporal stimulus information filling it. This has implicated spatial factors, such as the complexity of figure and ground relations in duration experience. Complexity in such cases is equated in terms of the number and size of stimulus elements, their quality, the number of stimulus changes, etc. (Buffardi, 1972; Frankenhouser, 1959; Ornstein, 1969; Rai, 1973; Thomas and Weaver, 1975). Psychophysical research with divided intervals has not been extensive in regard to the II concept.

The lengthening of subjective temporal experience with increases in nontemporal stimuli has been termed the <u>filled duration illusion</u> (FDI). Current information processing explanations of this phenomenon have rejected complete emphasis on direct time estimation processes. Rather, a substantial emphasis is placed on the influence of nontemporal cognitive processes in duration judgment Gomez and Robertson, 1979). For instance, Thomas and Weaver (1975) have developed a model of visual time perception for short durations that takes into account the interaction of spatial and temporal information in the production of temporal judgments. This visual encoding model makes a distinction between two different facilities of attention and parallel information processors. One processor is a visual stimulus encoder, and the other is a temporal information encoder, or timer. The encoding model is related to Ornstein's (1969) storage size hypotheses, which suggests that temporal judgment is an increasing function of the load placed on memory by the size of the storage space needed to process nontemporal stimulus events. From this viewpoint (Ornstein, 1969) direct temporal estimation plays no role in duration judgment when the interval is filled with nontemporal events. Thomas and Weaver (1975) diverge from this position in advocating that temporal judgment is based on the amount of attentional priority given to the separate visual stimulus and time encoding processes.

According to the Thomas and Weaver (1975) encoding model, the amount of attention that can be given to either visual stimulus information or the experience of duration, is variable from situation to situation. If visual information is extensive, attention may be completely directed to visual encoding processes. If visual information is slight more attention can be allocated to the time encoder. Resultant temporal judgments are based on a weighted average between the amount of attention given each encoding process. The reliability of either encoder as a measure of duration is a function of how much attention is allocated to it. When attention is directed almost entirely to visual encoding, its relative influence on temporal judgment increases, due to the increased unreliability of the timer. In some cases, the subject is completely dependent on the cues given by the visual encoding processes. Thomas and Weaver (1975) suggest that at durations shorter than 100 msec attention cannot be switched between visual information and duration experience.

Avant et al. (1975) offer a parallel explanation to Ornstein's (1969) storage size hypothesis in suggesting that temporal judgments are based more on the memory of the time spent processing stimulus information. Given the variable amount of visual information an interval can be filled with, processing time can be relatively independent of and actually exceed the duration of the interval. Thomas and Weaver (1975) produced a theoretical integration of these two divergent positions. They suggest that temporal judgment of a duration containing nontemporal stimuli is a weighted average of visual information processing time and perceived duration. If the visual information is encoded before the duration is over, some attention can be alloted to the timer. As the experimental durations become longer and the extent of visual information stays the same, FDI effects should disappear due to the increased attention given to the timer. Cantor and Thomas (1977) used durations of 30 and 70 msec and found the expected FDI effect. When they presented the same levels of nontemporal stimulus information at 500 and 600 msec, no filled duration illusion was found. It was concluded that this was evidence that the FDI was solely the result of visual encoding processes being given attentional priority. At durations below 100 msec the time needed to process even simple stimulus information is greater than the duration length. As a result it is not possible to switch attention from the visual encoder to the timer.

Gomez and Robertson (1979) called into question both the storage size and encoding models. They advocate that the FDI is a product of the experimental environment within which temporal judgments are made. In other words, the existence of the FDI arises out of an interaction between changes in visual stimulus extant and the differences in length between the durations used. They found that when stimulus size is held consistent across experimental trials the FDI disappears. As both the storage size and encoding models are based on the nature and extent of stimulus elements, neither one would predict this outcome. This would suggest that the FDI only occurs when different levels of nontemporal stimulus information are contrasted in the experimental situation. Gomez and Robertson also found that the effect of visual stimulus size on the magnitude of the FDI is an increasing function of duration uncertainty. When stimulus size is varied across trials a large FDI is found; when experimental durations are separated in length by 15 msec (e.g. 15, 20, and 45 msec) the FDI is highly attenuated. This outcome is predicted by the encoding model, as nontemporal stimulus events should exert less influence as the durations become longer and more attention can be allocated to the timer. However, Gomez and Robertson performed an additional experiment where durations in a set were again separated by 15 msec, but at 155, 170, 185 msec. The magnitude of the resultant FDI was as great as when 15, 30, and 45 msec were used. This outcome suggests that the magnitude of the FDI is a direct function of the difficulty encountered in discriminating between durations in an experimental set. From this viewpoint, the FDI is not sensitive to large changes in the amount of actual time provided for stimulus encoding, but is sensitive to the differences between durations that must be compared.

The information processing oriented research cited above was primarily concentrated on the range of durations below 200 msec. The FDI and the factors that affect its occurrence have not been thoroughly researched across a wide range of short durations. Moreover, the FDI has not been systematically examined within the context of the range of durations that characterizes the II zone. As current theory implicates an interaction between duration length and nontemporal information in temporal experience, lack of research in the II zone marks a gap in the existing literature. Evidence for the existence of the II stems from psychophysical research with intervals that are empty or filled with constant stimuli. In contrast, evidence for the FDI stems from information-processing research with durations filled with heterogeneous nontemporal stimuli. Some interesting questions arise in contrasting II and FDI phenomenon against the backdrop of a range of durations that span the II zone. Would defining characteristics of the II be present in an experiment which employed different levels of nontemporal stimulus extant? In other words, what influence do the factors that produce the FDI exert on the phenomenon of the II? The II zone has been designated a range of durations where the processes affecting the perception of time undergo considerable change. The more specific nature of these process changes has never been well demonstrated. From this viewpoint it can be asked, "Can the nature of these changes in process be detected through an analysis of the effects of nontemporal stimuli on temporal experience at different duration lengths?" In all probability, if process changes are occurring accross the II zone, they will be reflected in differences in FDI effects at different duration points along the span of the II zone. The series of three experiments described in the present paper used duration lengths between 200 and 1100 msec in investigations of these issues.

Polzella et al. (1977) used a paradigm based on a method developed by Mo (1971) and found duration judgment to be an increasing function of the number of dots in a visual stimulus display. They used five stimulus numerosity levels between one and five dots in conjunction with a set of five durations between 16 and 100 msec.

The level of discriminability is roughly comparable to those used by Gomez and Robertson (1979). Mo (1971) used durations of 300 and 330 msec and found that presentations of three or five dots, are judged to be present for the longer duration more often than are presentations of one dot. As such, it can be concluded that variance in the number of stimulus elements across experimental trials will produce an FDI effect when using durations as long as 300-330 msec. According to Gomez and Robertson (1979), if the level of difficulty in discriminating between durations in a set is held constant across duration groups, the magnitude of the FDI should remain relatively constant. This conclusion was based on durations below 200 msec. A relevant question concerns the generality of this discriminability hypothesis to durations longer than 200 msec. Also, the II concept suggests that accuracy of temporal judgment should increase as the durations used approach the length of the II. Further, Vierordt's Law postulates that there should be a tendency toward overestimation of time at durations below the II point. Experiment 1 was designed to test the validity of these assumptions, using sets of durations which lie mostly on the shorter end of the II zone.

EXPERIMENT 1

Experiment 1 was primarily a replicative one designed to check a number of procedural modifications against the results of the original study of Mo (1971), and to obtain data for a wider range of durations (300 to 550 msec). Mo reported that duration is judged longer as the number of dots in a visual stimulus display is increased. Analysis of this phenomenon was restricted to a discrimination task using only one pair of short durations (300 and 330 msec). In Experiment 1 two pair of durations were used (300-330 and 500-550 msec). Gomez and Robertson (1979) controlled duration discriminability according to the absolute difference between durations in a set and held this difference constant across the sets of durations used. The present experiment controls this variable by employing a constant ratio of the difference between durations, and maintains this ratio across duration pairs. Differences in the various outcomes of research on differential thresholds for time perception make questionable which strategy is the more exact measure of discriminability. According to Fraisse (1978) in most studies the differential fraction was nearly constant between 400 and 2000 msec, and increased sharply below 200 msec. Given this evidence, an absolute difference in length may be more appropriate for durations below 200 msec, while a ratio difference may give a better fit above this point. However, this conclusion is based on data derived from research within the auditory modality. Other researchers using a signal detection approach to visual discrimination have found a constant value between 70 and 1020 msec (Fraisse, 1978). This evidence supports the conclusion that a ratio approach to temporal discrimination is appropriate for the range of durations used in the present experiment.

Method

Subjects. A total of 20 male and female undergraduates were recruited from an introductory psychology class and randomly assigned to two groups of 10 subjects each. The groups differed in terms of the duration pairs used. Group 300 was presented with 300-330 msec durations, and Group 500 was presented with 500-550 msec durations.

Materials. The stimulus materials consisted of 60 4 x 10 inch white index cards at each stimulus level. Black dots that were 5mm in diameter were randomly distributed around on a 4cm radius from the center of each card; no two cards were identical. For both treatment groups each card was rotated between two durations across subjects. A different random ordering of the card sequence was used for each subject. The sequence of stimuli was random, subject to the restriction that neither the same numbers of dots nor the same duration occur more than four times in a row. This was done in order to control for stimulus adaptation effects.

The stimulus materials were presented using a Gerbrand's two-field tachistoscope with a remote control console and an electrically activated card changer. A white noise generator was used to mask manipulation of the tachistoscope control console. The auditory masking was 37db at the position of the subject.

Procedure. Each subject was tested individually. At the outset each subject was told that he or she was participating in a time perception experiment. Subjects were then asked to make an indentification judgment concerning which of the two durations was used for each of a series of trials. They were asked to perform the task by saying either short or long after each presentation. Six practice trials were administered in such a way that each subject experienced both durations at each of the three stimulus levels. Subjects were asked not to remove their faces from the tachistoscope aperture until the experiment was over. This was done in order to insure uniform light adaptation across subjects. Each experimental session lasted about 15 min.

Results and Discussion

The number of long responses as a function of the number of dots and duration length for both Group 300 and 500 are shown in Figure 1. Trend analysis, an analysis of variance technique (Grant, 1956), was performed using bias-corrected untransformed data.

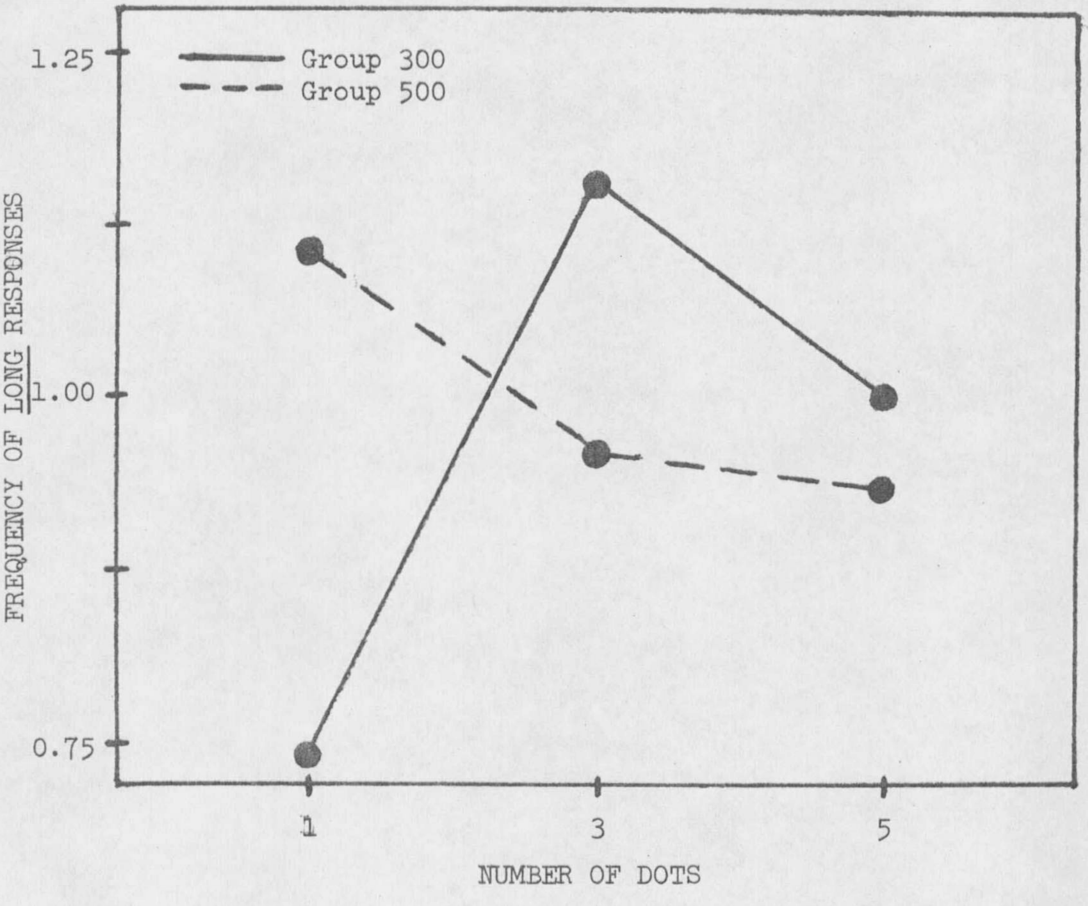

Figure 1. Bias corrected frequency of long responses as a function of the number of dots and duration length for each of the two groups (300 and 500), Experiment 1.

Mo's (1971) data analysis used an arcsin transformation, which compensates for any inhomogeneity of variance between groups. In the present analysis a bias-correction was used, based on the assumption that preferential tendencies to answer either short or long are based on factors that are not entirely intrinsic to the experimental situation. An examination of the data did in fact show such an unequal distribution of judgments in favor of answering short. To compensate for this effect each subject's response frequencies were corrected by using a posteriori probabilities. For each subject, the percent of long responses at each of the three data points was divided by the overall percent of long responses.

Planned comparisons showed a significant interaction between duration groups and dot numerosity [$F(2, 36) = 5.71$, $MSe = .073$, $p < .01$], with a significant linear component [$F(1, 18) = 5.73$, $MSe = .045$, $p < .05$]. These results clearly show an effect of duration length on the tendency to answer long as a function of the number of dots. The most pronounced change between groups occurs between one and three dots, with the tendency to answer long about the same for both groups at five dots (Figure 1). Group 500 showed no linear trend in long responses as a function of the number of dots ($F > 1$). However, the linear trend for Group 300 was significant [$F (2, 18) = 4.16$, $MSe = 15.9$, $p < .01$]. The results of Experiment 1 support the findings of the reference study (Mo, 1971) for the 300-330 msec duration level, but the proposed tendency to show an increased frequency of long responses as the number of dots increase did not generalize to the 500-550 msec durations. Group 500 did not show any effect of the FDI. As a result, the Gomez and Robertson (1979) hypothesis that the FDI would maintain its robustness across groups if duration discriminability is held constant, was not confirmed for the range between 300 and 550 msec.

A rather surprising result was generated out of a post-hoc test for a quadratic component of the interaction between group trends [F (1, 18) = 5.67, MSe = .05, $P < .05$]. This outcome is most apparent in the 300-330 msec durations group (Figure 1). Rather than showing a pure mononotonically increasing function of dot numerosity, the tendency to answer long reaches a peak at three dots and drops off between three and five dots. No quadratic trend is shown in the 500 - 550 msec group.

Separate t-tests were computed for each group to determine if accuracy of response was above chance expectation. The test for Group 500, which had a mean proportion correct of .571, was significant [$t(9) = 2.63$, $SE = .027$ $P < .05$]. However, the test for Group 300, with a mean of .551, was not ($P > .05$). Yet a t-test for a significant difference in accuracy between the two groups was negative ($P > .1$). As a result, it can be concluded that the level of difficulty of duration discrimination for both the 300-330 and 500-550 msec pairs was about the same.

The results of Experiment 1 conflict with the Gomez and Robertson (1979) position that the FDI is a result of the difficulty of discrimination between durations in a set. The level of discriminability was held constant across the sets of durations used in Experiment 1. Yet only the 300-330 msec group showed in FDI effect. The longest durations used when either Cantor and Thomas (1977) or Gomez and Robertson (1979) found an FDI was below 200 msec. Perhaps an increasingly more stringent level of discriminability is required to produce an FDI as the durations used become longer. Where a ratio of 1.1:1 was sufficent to produce an FDI at 300-330 msec, it was not at 500-550 msec. As Gomez and Robertson (1979) have advocated an interaction between duration uncertainty and nontemporal stimulus attributes, it may also be that either more complex visual stimuli, or greater differences in visual stimuli across trials, are required to produce an FDI at the level of discriminability used in the present experiment. Cantor and Thomas (1977) used durations of 500 and 600 msec with nine combinations of area and perimeter value, and also found no FDI effect.

At any rate, the results of Experiment 1, conform more to what would be predicted by the encoding model. In this respect, the disappearance of any FDI in Group 500 is interpreted as the result of the timer gaining greater reliability. More interesting is the fact that the FDI is partially attenuated, in as far as it is not a linear function across the dot numerosity levels. A similar leveling off of the FDI at the upper end of the not numerosity continuum was found in the reference study (Mo, 1971) and by Polzella et al. (1977). A parallel outcome was found by Thomas and Weaver (1975) across visual stimulus levels. Several factors potentially contribute to this outcome. Thomas and Weaver (1975) identify the 100 msec zone as representing a critical threshold duration where attention can first be switched from the visual encoder to the timer. However, the supersession of timer reliability over visual encoder reliability is not an all or nothing process. Rather, it occurs in increments as duration lengthens, and nontemporal stimulus events stay the same. At the 300-330 msec duration level experienced duration is given increased weight, but not enough to be substantially more reliable than visual encoding time. The relative differences in required visual encoding time across the dot numerosity levels are still great enough to exert considerable differential influence over the tendency to answer <u>long</u>. The question then becomes, "What are the characteristics of the visual stimulus display that affect encoding time?" From one viewpoint, part of the information encoded is the position of the dots in the visual stimulus display (Attneave, 1957). Using a formula (Log2n) to convert the number of possible combinations of dot positions that can occur for each numerosity level, "bit" values for the amount of information presented can be derived. The outcome for this computation show that the ratio of the difference in bits between one and three dots (2.99:1) is greater than between three and five dots (1.22:1). However, the actual change in bit value is almost a straight increasing function when graphically plotted across the dot numerosity levels.[1] As a consequence, it is doubtful that the dip in the slope of the line between three and five dots shown in Group 300 (Figure 1) can be explained in terms of the raw quantative changes in information across dot levels. One possible answer relates to the independent dimensional properties that are embodied in the visual stimulus display.

Cantor and Thomas (1977) have implicated the interaction of diminsional relationships such as perceived area and perimeter in temporal judgment. They found that judged duration lengthens with increases in stimulus area, but is shortened by increases in stimulus perimeter. Further, it was speculated that judgments of the independent stimulus dimensions (area and perimeter) interact with judgments of a more global complexity property of the overall stimulus figure. The term "figure" implies a form that can be described in at least two spatial dimensions. The distribution of three or five dots in a visual display, could be described as enclosing an area within a definite perimeter. Yet, the perceptual effect of one dot cannot be described precisely the same, as at least three dots would be required to produce such a two dimensional figure. Given this interpretation additional stimulus dimensions may be perceived in three and five dot patterns that are not perceived in one dot displays. As a result, the complexity of encoding processes for three and five dots may be very similar, but quite different from the encoding of one dot. It can be speculated that as the complexity of visual stimuli increase, greater differences in the independent stimulus dimensions are required in order to discriminate between encoding times. If this were so, a tapering off of the FDI would be expected between three and five dots.

The above analysis does not satisfactorily explain the quadratic component of the interaction between group trends shown in the post-hoc trend test. Any increase in perimeter also means a parallel increase in area for the stimulus patterns employed in Experiment 1. Considering this, it is unlikely that the influence of perimeter at five dots would be great enough to cause a downward trend between three and five dots in Group 300. Cantor and Thomas (1977) offer an alternative explanation in hypothesizing that the extremes of the visual stimulus continuum used capture more attention than the mid-range values. From this viewpoint, it can be speculated that greater attention to timer encoding at three dots in group 300 results in a longer temporal judgment compared to one or five dots.

The results of Experiment 1 clearly reflect the influence of dot numerosity on the defining characteristics of Vierordt's Law. Where overestimation of durations below the II would be expected, underestimation was found. The frequency data for both the 300-330 and 500-550 msec groups was bias corrected for a tendency to answer short. When durations are filled with heterogeneous stimuli, temporal judgment is shortened due to the greater attention given to visual stimuli. Such a phenomenon would not occur when empty intervals are used. Also, the concept of the II suggests that accuracy of temporal judgment would increase as the durations used approach the II point. Although Group 500 was slightly more accurate than Group 300, the difference between groups on this measure was not significant. However, a significant difference in accuracy may occur when the duration pairs are separated by more than 200 msec.

EXPERIMENT 2

In order to study the influence of dot numerosity over a wider range of durations, a second experiment was performed using three duration pairs (200-220, 400-440, and 600-660 msec). In addition, a fourth level of dot numerosity was added in order to provide a finer-grain analysis of the effect of variance in visual information on temporal judgment. In this regard, one, two, three, and five dots were used with each presented 20 times. It was hypothesized there would be a strong effect of duration length on the FDI. As such, it was predicted that the most pronounced FDI effect would be shown at 200-220 msec, with a gradual attenuation through the 400-440 and 600-660 msec duration groups. This prediction was based on the assumption that visual encoding time takes on increasingly less weight in temporal judgment as duration increases. Also, it was predicted that there would be a substantial increase in accuracy of temporal judgment between the 200-220 and 600-660 msec groups, as the influence of visual stimuli lessens and discrimination between durations becomes a less difficult task.

Method

Subjects. A total of 60 male and female undergraduates were recruited from an introductory psychology class and randomly assigned to one of three groups of 20 subjects each. Each group is designated by the lower of the durations used (Group 200, Group 400, and Group 600).

Materials. The stimulus materials were the same as in Experiment 1 with the exception that an additional 20 cards, each containing two dots, were included; thus each subject was exposed to a series of 80 trials rather than 60 trials as in Experiment 1. The same technique of random ordering was used, with the exception that the card deck was so arranged that half of the cards at each dot level occurred in the first forty trials. This was done in order to insure fairly uniform stimulus exposure over the entire set of trials used. Also, a technique of tachistoscope control console manipulation was developed that adequately masked changes in duration settings. As a result, the white-noise generator was eliminated from the experimental situation.

Procedure. The procedure was the same as in Experiment 1, with the exception that the inclusion of a fourth dot level required that each subject be exposed to two additional practice trials and an additional 20 experimental trials. Each session lasted approximately 20 min.

Results and Discussion

In Experiment 2 the linear component of the overall trend test did not reach significance [*F*(1, 57) = .033, *MSe* = .004, *P* >1]. However, the overall quadratic component was significant [*F*(1,57 = 6.53, *MSe* = .062, *P* <.05]. The frequency of *long* responses for each dot level, within each of the three groups is shown in Figure 2. The frequency of *long* responses across dot levels is very much the same for Group 200 and Group 400. The tendency to answer *long* reaches a peak at three dots, and decreases toward the extremes of the dot dumerosity continuum. Although there were no significant differences between group trends [*F*(6, 171) = .624, *MSe*= .054, *P* >1].

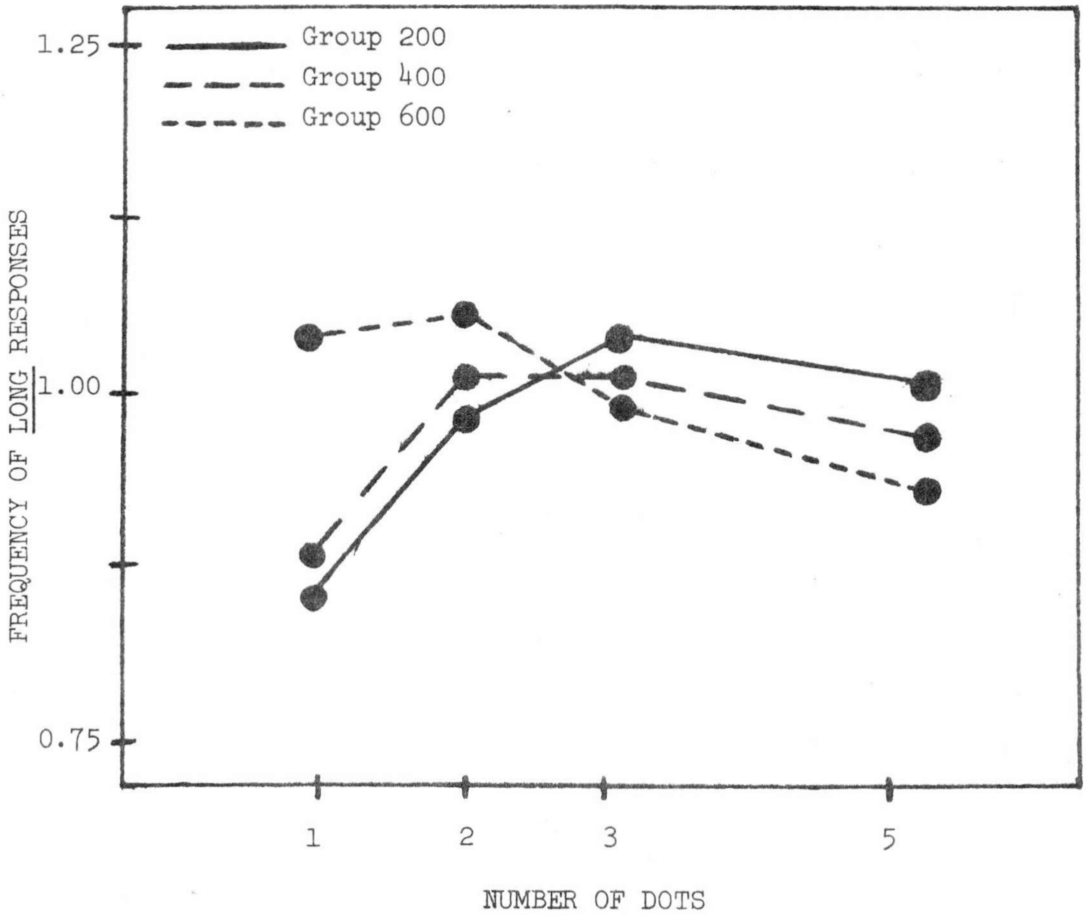

Figure 2. Bias corrected frequency of long responses as a function of the number of dots and duration length for each of the three groups (200, 400, and 600), Experiment 2.

The trend for Group 600 peaks at two dots, while trends for Groups 200 and 400 peak at three dots. For all three groups the overall tendency to answer long shows itself as a quadratic function across the four dot levels (Figure 2).

Analysis of the frequency of correct responses revealed a significant overall trend across dot numerosity levels [$F(3, 171) = 3.12$, $MSe = .043$, $p < .05$], which is mainly due to a significant linear component [$F(1, 57) = 5.83$, $MSe = .053$, $p < .05$]. The linear component is reflected in a slight tendency toward greater accuracy as the number of dots was decreased. The overall mean proportion of correct responses was 60.3, 61.0, 56.3 and 55.0 at one, two, three, and five dots, respectively. All three groups scored significantly above chance expectation in terms of accuracy: Group 200 showed a mean of .552 [$t(19) = 2.747$, $SE = .019$, $p < .05$)]. Group 400 showed a mean of .570 [$t(19) = 4.176$, $SE = .017$, $p < .001$]. Group 600 showed a mean of .598 [$t(19) = 7.133$, $SE = .014$, $p < .001$]. Yet, between group comparison showed no significant differences on this measure [$F(6, 171) = 1.02$, $MSe = .044$, $p > 1$]. Although separate t-tests showed no significant increase between groups in terms of accuracy, the difference between Group 200 and Group 600 was marginally significant, and in the expected direction ($t(38) = 1.94$, $p < .06$). As in Experiment 1, the results of Experiment 2 indicate that the level of discriminability between duration pairs is about the same for all groups.

The most notable difference between the results of Experiment 1 and 2 is the absence of any significant interaction between groups in regard to the tendency to answer long as a function of the number of dots. In Experiment 1 the 300-330 msec group showed a significant linear increase in long responses as the number of dots increased. In Experiment 2 the 200-220 and 400-440 msec groups showed a similar but nonsignificant FDI effect. As a result the prediction that the FDI would be greater at 200-220 msec compared to 300-330 or 400-440 msec was not confirmed. When Groups 200 and 400 in Experiment 2 (Figure 2) are compared with Group 300 in Experiment 1 (Figure 1), it can be seen that most of the change in slopes of the lines is between one and three dots. It is unlikely that the overall attenuation of the FDI effect in Experiment 2 is due to the differences in the duration sets used. The Thomas and Cantor (1975) encoding model predicts that the FDI would be more pronounced at the shorter time lengths as less attention can be allocated to the experience of duration. For the range of durations used in Experiment 2 (200-600 msec), there was no significant difference between group trends. Yet, in Experiment 1 where the range of durations was 300-550 msec between groups differences were shown.

An alternative hypothesis is that the attenuation of the FDI effect in Experiment 2 is due to the inclusion of an intermediate dot level (two dots) between one and three dots. In the analysis of of Experiment 1 it was suggested that the degree of difference between stimulus dimensions across dot levels may affect the ease of discrimination between visual encoding times. At this point it is further suggested that reduction of the difference between the visual stimulus dimensions of the dot levels adjacent to one another on the dot numerosity continuum may cause visual encoding time to increase. This effect would be due to the increased attention given to visual stimulus discrimination. Due to the position of two dots in the visual stimulus continuum, it would be expected that its influence over encoding time would be greatest in regard to one dot. This may result in an inflated duration judgment at the one dot level. Visual encoding time at two dots would be affected in the same way by the contrasting stimulus properties embodied in three dots. As no intermediate dot level was included between three and five dots, no parallel effect was shown on the higher end of the dot numerosity continuum. As in the analysis of Experiment 1, the above interpretation is not well grounded in existing theory, and data should be regarded as preliminary.

The significant outcome of a post hoc test for a quadratic component of the interaction between group trends in Experiment 1 suggests that the influence of dot numerosity was not exclusively linear. The more reliable result showing a quadratic component of the overall trend in Experiment 2 tends to add weight to this conclusion.

In the analysis of Experiment 1 this outcome was explained in terms of the suggestion by Cantor and Thomas (1977) that the extremes of a visual stimulus continuum capture more attention than the mid-range values. The results of Cantor and Thomas (1977) and the present study are not the only research outcomes to show temporal judgment to be a U-shaped function of the range of nontemporal stimulus levels employed. For example, Hogan (1975), who was operating within an adaptation level paradigm, found that time periods containing "too little" stimulation or "too much" stimulation tend to be judged as longer than moderately filled durations of the same length. In all probability, for any given range of durations there is a corresponding range of nontemporal information levels that cause the trend in temporal judgments to conform to either a linear or a U-shaped function in terms of the propensity to choose the longer or the shorter of a pair of alternatives. The analysis of experiments 1 and 2 suggest that the relative ease or difficulty of discrimination between different levels of temporal and nontemporal stimuli will effect the resultant slope of such a function. From the viewpoint of a parallel encoding model (Thomas and Cantor, 1975) the relevant question is, "What encoding process is being stimulated, and how much?" Based on the assumption that for the range of nontemporal information used in Experiments 1 and 2, if temporal judgment of durations above 200 msec is primarily determined by timer encoding, experienced duration would be expected to be longer at the mid-range of the dot numerosity levels.

In Experiment 1, the 300-330 msec group showed the most pronounced quadratic component with the 500-550 msec group showing an almost flat linear function of dot numerosity (Figure 1). In Experiment 2 the 200-220 and 400-440 msec groups showed the most pronounced quadratic component with the 600-660 msec group showing a slightly more linear function (Figure 1). It is hypothesized that as the durations used become longer then the 500-600 msec range, and nontemporal information levels stay the same, the influence of dot numerosity will disappear as the experience of duration captures increasingly more attention.

The results of Experiment 2, when viewed in terms of the II concept, are almost identical to the results of Experiment 1. In contrast to what would be predicted by Vierordt's Law, overall subject response was biased in favor of answering short. As in the analysis of Experiment 1, this bias is explained in terms of the effect of nontemporal stimuli on duration judgment. The influence of nontemporal information is also reflected in the accuracy data. Woodrow (1951) suggests that accuracy of discrimination between two durations separated in length by a ratio of 1.1:1 is normally in the range of 75 to 80 percent. Accuracy of response across the three subject groups used in Experiment 2 ranges between 55 and 60 percent. The reliability of duration judgment is apparently reduced when both temporal and nontemporal factors are involved in temporal experience. The significant linear component of the overall trend in accuracy indicates that the frequency of correct responses is better at the lower dot levels. This in all probability is due to the greater reliability of the timer at the lower dot levels where less visual encoding time is required. The predicted increase in accuracy as a function of increased duration across subject groups did not occur. However, the difference in outcome between the 200-220 and 600-660 msec groups was in the expected direction. It appears that a greater difference between duration pairs would be required in order to produce a significant difference in accuracy.

EXPERIMENT 3

In order to test the effect of a wider range of durations on the dot numerosity phenomenon, a third experiment was performed using three duration pairs (200-220, 600-660, and 1000-1100 msec). In Experiment 3 the number of dot levels employed was returned to the original number used in Experiment 1. Stimulus levels of one, three, and five dots were used. It was suggested that the attenuation of the FDI effect shown in Experiment 2 was due to the inclusion of a fourth dot level between one and three dots. If this hypothesis is correct a strong linear FDI should be shown in the 200-220 msec group. As both the 500-550 msec group in Experiment 1 (Figure 1) and the 600-660 msec group in Experiment 2 (Figure 2) showed almost no FDI effect, it was further hypothesized that the influence of dot numerosity would disappear in the 1000-1100 msec group in Experiment 3. This would be due to the much higher reliability of the timer at this duration level. For the same reason it was expected that the difference in accuracy across duration groups would be significant.

Method

Subjects. A total of 72 male and female undergraduates were recruited from an introductory psychology class and assigned to one of three groups of 12 male and 12 female subjects each. Each group is designated by the shorter of the durations used (Group 200, Group 600, and Group 1000).

Materials. The stimulus materials used in Experiment 3 were the same as those used in Experiment 1; thus each subject was exposed to a series of 60 trials with 20 trials at each dot level. The same technique of random ordering employed in Experiment 2 was used. Half of the stimulus cards at each dot level occurred in the first 30 trials, and half in the second 30 trials.

Procedure. The procedure was the same as that used in Experiment 2 with the exception that three experimenters were used in Experiment 3. The decision to use an additional two experimenters was based partly on the consideration that experimental results can often reflect a single experimenter's biases in terms of some specific outcome.

The use of multiple experimenters tends to reduce the probability of this sort of effect being reflected in the data. Each experimenter ran 24 subjects. Of the 24 subjects, 8 subjects--consisting of 4 males and 4 females--were assigned to each experimental group. Each experimental session lasted about 20 min.

Results and Discussion

The frequency of long responses as a function of the number of dots and group duration level are presented in Figure 3. As in xperiments 1 and 2 separate analyses were performed on the frequency of long and the frequency of correct responses.

None of the tests for a linear or quadratic trend in the frequency of long responses in the individual groups were significant. However, the linear interaction between group trends did reach significance [$F(2, 69) = 3.33$, $MSe = .063$, $P < .05$]. Group 200 showed a slightly increasing effect of dot level between one and three dots with a dip in the slope of the line between three and five dots (Figure 3). Group 600 showed a slight decreasing effect of dot level with onedot yielding the highest frequency of long responses. Group 1000 showed no effect of dot numerosity. As the FDI in the 200-220 msec groups in both Experiments 2 and 3 was attenuated to about the same extent the hypothesis that the magnitude of the FDI is effected by the number of dot levels used was not substantiated.

Analysis of the proportion of correct responses revealed a significant difference between groups means [F (2, 69) = 3.35, MSe = 198.0, $P < .05$]. As the length of the durations used increased the percent of correct responses also increased. Separate t-tests performed on each group reflect this outcome. Group 200 scored significantly below chance expectation in terms of accuracy with a mean score of .442 [$t(23) = 2.67$, $SE = .029$, $P < .05$]. Group 600, which had a mean of .515, did not score above chance expectation ($P > .05$). Group 1000 showed the highest accuracy of response with a mean score of .564 [$t(23) = 3.071$, $SE = .0187$, $P < .01$]. The results of Experiment 3 indicate that the level of discriminability between durations in a pair is not the same across subject groups. The difference in accuracy between the 200-220 and 600-660 msec groups is not significant ($P > .05$); nor is the difference between the 600-660 and 1000-1100 msec groups ($P > .05$). Yet, the difference in accuracy between the 200-220 and 1000-1100 msec groups is significant [$t(46) = 4.67$, $SE = .0283$, $P < .001$].

The most theoretically ambiguous result of Experiment 3 was the absence of any significant difference in the tendency to answer *long* as a function of the number of dots in the 200-220 msec group. It was predicted that the slope of the increase in *long* responses across dot numerosity levels would be more pronounced in the 200-220 msec group in Experiment 2 as compared to the 200-220 msec group in Experiment 3. This prediction was based on the hypothesis that an increase in the difference between the dot levels used will increase the ease of discrimination between visual encoding times. The slope of the lines in terms of long responses for the 200-220 msec groups in Experiments 2 and 3 are very much the same. As Group 200 in Experiment 3 showed no significant change in the frequency of long responses across the dot levels, the reduction of the FDI in group 200 in Experiment 2 cannot be explained in terms of the relative degree of discriminability between dot levels. In fact, the 300-330 msec group in Experiment 1 (Figure 1) was the only group in any of the three experiments to show the frequency of long responses to be a significantly increasing function of dot numerosity. The results of the reference study (Mo, 1971) and the Polzella et al. (1977) study suggest that the dot numerosity effect should be stronger at the 200-220 duration range compared to 300-330 msec. The reason as to why the results of Experiments 2 and 3 are inconsistent with this prediction is not apparent in the information given by the present data. In all probability additional research in the 100 to 400 msec range will be required to resolve the theoretical difficulties imposed by these differences in outcome.

The most interesting result of Experiment 3 was the disappearance of any quadratic effect of dot numerosity. In the analysis of

Experiment 2 it was suggested that the quadratic component of the overall trend in long responses was due to the extremes of the dot numerosity continuum capturing more attention then the mid-range values. If the use of an intermediate level of two dots between one and three dots in Experiment 2 caused a decrease in contrast between dot levels due to greater difficulty in discrimination between encoding times, then a more pronounced quadratic component should have been shown in Group 200 in Experiment 3. The results of Experiment 3 did not support this hypothesis. However, it was also suggested that the visual information levels interact with duration length in producing the linear and quadratic effects shown in the present experiments. The range of durations used in Experiment 2 (200-600 msec) was narrow compared to those used in Experiment 3 (200-1100 msec). The significant linear component of the interaction between group trends shown in Experiment 3 indicates that perception of duration as a function of dot numerosity is undergoing considerable change between 200 and 1100 msec. Comparison of the results of Experiments 1 and 2 (Figure 1, Figure 2) suggest the possibility that durations between 200 and 400 msec mark a critical range (in terms of the visual stimulus levels used) where the contrast in encoding time between the middle and extreme dot levels is the greatest. As Experiment 2 addresses the 200-400 msec range of durations more directly than Experiments 1 or 3, the overall quadratic component shown in the data may reflect this phenomena.

The significant linear component of the between groups trend test in Experiment 2 reflect a change in the processes underlying temporal judgment, as duration length increases between 200 and 1100 msec. The differences in the slopes of the lines between the groups (Figure 3) can be explained in terms of the visual encoding model (Thomas and Cantor, 1975). In the 200-220 msec group, visual encoding time is more reliable than experienced duration and the length of temporal judgment is based mainly on the number of dots. In the 600-660 msec group experienced duration has become the more reliable of the two encoding processes, but visual information still exerts a differential influence. At one dot the experience of duration is long compared to the visual encoding time. This results in the highest frequency of long responses of any of the dot numerosity levels. In the 1000-1100 msec group the weight given to experienced duration is so much greater than visual encoding time that differences in dot numerosity have virtually no effect on temporal judgment.

The results of Experiment 3 are very notable in regard to the concept of the II. Analysis of the frequency of correct responses show that accuracy of temporal judgment is an increasing function of duration length. It is further suggested that the ratio between durations is not the critical factor influencing accuracy or FDI

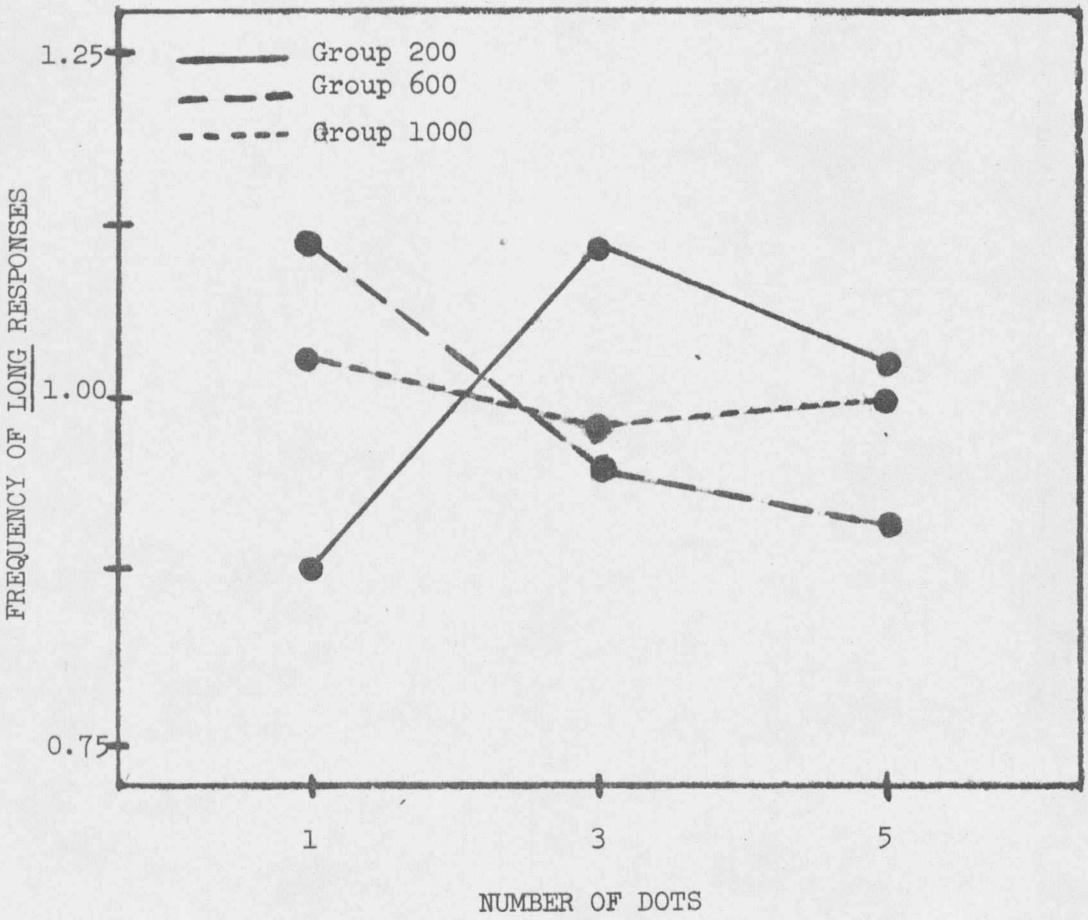

Figure 3. Bias corrected frequency of long responses as a function of the number of dots and duration length for each of the three groups (200, 600, and 1000), Experiment 3.

effects. As such, the results of Experiment 3 are in violation of Weber's Differential Sensitivity Law for the range of durations used. The data also suggests that accuracy at a given duration range is greatly influenced by the extent of nontemporal stimulation occurring during the interval. The highest accuracy of response was obtained in Group 1000; the lowest in Group 200. It is interesting to note that the 1000-1100 msec range is several hundred msec above the II zone where accuracy should be highest. The use of intervals filled with heterogeneous visual stimuli, compared to empty intervals, is causing a shift in the II point toward longer durations. Woodrow (1951) indicates that a ratio of 1.1:1 between durations in a pair is sufficient to allow accuracy levels of 75 to 80 percent with empty intervals. Given the levels of nontemporal stimuli used in the present experiments, accuracy of response may not reach a ceiling until durations above 1100 msec are used. At any rate, it is concluded that time studies dealing with durations at or near the classical II point will only show the II's defining qualities when the durations used employ empty intervals or nontemporal stimuli which are homogeneous and invariant across trials. Only under these conditions can temporal judgment be based almost entirely on the experience of duration. Any change of nontemporal information across trials will produce FDI effects that greatly alter the experience of duration in the II zone.

CONCLUDING REMARKS

Three experiments were conducted to examine perceptual and cognitive factors related to the indifference interval (II) and the filled duration illusion (FDI) as they in turn relate to temporal experience of durations between 200 and 1100 msec. Most theorizing concerning the specific length of the II places it between 500 and 800 msec. The results of Experiment 3, and tentatively Experiments 1 and 2, show that when durations are filled with nontemporal stimuli no point of maximum sensitivity is found within the 500 to 800 msec range. In Experiment 3 it was demonstrated that accuracy of temporal judgment is increasing between 200 and 1100 msec. There is no reason to believe that accuracy won't increase with durations longer than 1100 msec. Research within the 200-800 msec range using the Weber function indicates that differential sensitivity should be relatively constant across the duration continuum (Fraisse, 1977). The results of the present experiments indicate that the Weber function does not hold for durations filled with different levels of nontemporal stimuli. The effect of nontemporal stimuli is to alter differential sensitivity and increase the duration length at which the II point is found. As such it is concluded that the specific duration at which the II point occurs is largely determined by the experimental conditions under which temporal judgments are made.

Vierordt's Law proposes that the II is characterized by overestimation of duration below it and underestimation of duration above it. The present experiments indicate that durations between 200 and 600 msec are underestimated, since there was a high frequency of <u>short</u> responses. The only duration group to show a reversal of this trend was the 1000-1100 msec group in Experiment 3. This reversal of what is predicted by Vierordt's Law may indicate that nontemporal stimulus events filling a duration serve to constrict subjective time relative to the perception of empty intervals. However, this hypothesis is only offered tentatively as the subjects are forced to choose between the alternative responses of <u>short</u> and <u>long</u>. Fraisse (1967) proposes that the II marks a point where the perception of duration changes from <u>short</u> to <u>long</u>. The bias to answer <u>short</u> may simply be due to the fact that the durations employed in the present experiments are very short. An experimental design employing a method other than comparison would be required in order to resolve this issue.

Gomez and Robertson (1979) advocate that when the level of discriminability between durations in a set is held constant, the magnitude of the FDI will be the same for all duration groups. This hypothesis was substantiated for durations shorter than 200 msec. The results of Experiments 1, 2 and 3 indicate that this hypothesis does not generalize well to durations between 200 and 1100 msec. In all probability the magnitude of the FDI at any given duration level is a function of the extent of nontemporal stimulus information rather than simply the level of discriminability between durations in a set. It is also speculated that the magnitude of the FDI at a given duration is influenced by the ease of discrimination between the levels of nontemporal stimuli employed. However, this hypothesis is not firmly grounded in the present data.

Much ongoing theorizing proposes that perception of duration undergoes process changes between 500 and 800 msec. This hypothesis was studied in the present experiments from the viewpoint of the FDI. The resultant outcomes indicate that the perception of duration undergoes rather varied changes between 200 and 1100 msec. In general, the effect of dot nomerosity tends toward a quadratic function between 200 and 440 msec with the frequency of long responses reaching a peak at the mid-point of the dot numerosity continuum (Experiments 1, 2, and 3). This outcome was explained in terms of the extremes of the visual stimuli continuum capturing more attention than the mid-range values. This phenomenon does not appear to extend to durations above 500 msec. Between 500 and 660 msec duration judgment is more a linear function of dot numerosity (Experiments 1, 2, 3). In this duration range the FDI effect shows itself as a decreasing function of the dot levels. This outcome conforms to what would be predicted by the encoding model of time perception (Thomas and Weaver, 1975). In regard to this the experience of duration is greatest at one dot, as the least amount of visual encoding time is needed at this dot level. At 1000-1100 msec (Experiment 3) virtually all effects of dot numerosity have disappeared due to increased timer reliability at all dot levels. It was concluded that the encoding model can account for duration experience between 200 and 1100 msec. A more unresolved issue concerns whether these changes in perception between 200 and 1100 msec are due to the intrinsic nature of time perception in the II zone, or due to the extent of nontemporal stimuli employed in the experimental situation.

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FOOTNOTE

[1] Bit values for the dot numerosity levels were computed based on the consideration that there were roughly thirty positions around the visual stimulus perimeter where a dot could occur. The bit values were 3.32, 9.49, and 14.9 for one, three, and five dots respectively. It should be noted that a problem arises in equating informational content according to a mathematically defined distribution. In this regard the actual perception of differences in information level may not conform with any precision to the distribution.

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The indifference interval and the filled duration illusion