DOCUMENT RESUME

ED 133 663 CG 011 024

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TITLE Classification of Line Location and Orientation in Continuous and Discrete RT Trials.
PUB DATE [May 76]
NOTE 19p.; Paper presented at Annual Meeting of the Midwestern Psychological Association (Chicago, Illinois, May 6-8, 1976)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Classification; *Cognitive Processes; *Psychological Patterns; Psychological Studies; *Reactive Behavior; Tachistoscopes; *Task Performance; Visual Discrimination; *Visual Stimuli
IDENTIFIERS *Gating

ABSTRACT

The efficacy of gating in the processing of simple, multidimensional stimuli was investigated. In Experiment 1, a continuous classification task was used, with subjects sorting cards according to binary dimensions of line orientation and location. Results suggested that orientation and location are integral dimensions, facilitation occurring with correlated dimensional combinations and interference with orthogonal combinations. In Experiment 2, discrete reaction time (RT) trials were given, requiring classification of tachistoscopically presented stimuli with large Response-Stimulus intervals (13 sec). Interference, but not facilitation was found. Analysis of sequential effects revealed no support for the hypothesis that interference is due to the greater frequency of stimulus change in orthogonal conditions. It is suggested that long RSIs induce a set to process stimuli beyond psychological similarity and to analyze the dimensional structure of integral dimensions. Such dimensional analysis would eliminate facilitation effects, and interference might be due to response competition. (Author)

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Abstract

The efficacy of gating in the processing of simple, multidimensional stimuli was investigated. In Experiment I a continuous classification task was used, with subjects sorting cards according to binary dimensions of line orientation and location. Results suggested that orientation and location are integral dimensions, facilitation occurring with correlated dimensional combinations and interference with orthogonal combinations. In Experiment II, discrete reaction time (RT) trials were given, requiring classification of tachistoscopically presented stimuli with large Response-Stimulus intervals (13 sec). Interference, but not facilitation was found. Analysis of sequential effects revealed no support for the hypothesis that interference is due to the greater frequency of stimulus change in orthogonal conditions. It is suggested that long RSIs induce a set to process stimuli beyond psychological similarity and to analyze the dimensional structure of integral dimensions. Such dimensional analysis would eliminate facilitation effects, and interference might be due to response competition.

Classification of Line Location and Orientation

in Continuous and Discrete RT Trials[1]

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A primary motive for much of the work in our laboratory has been a concern with the processing of multidimensional, visual stimuli. More specifically, we have been interested in how the various visual features, which are presumed involved in the recognition of orthographic characters, are extracted, identified and combined to form a mental representation of the stimulus. Our concern with featural processing has dictated our choice of stimulus materials. Typically, we have used very simple stimuli, such as displaced and/or tilted straight line segments, which may be assumed to involve only the simplest processing mechanisms.

One of our research strategies has been in investigate the efficacy of gating (Posner, 1964) in the processing of such simple, but nonetheless multidimensional stimuli. The question in such studies is whether the subject does or even can ignore variation in an irrelevant dimension, selectively processing and basing his classification response only on variation in a relevant dimension. The efficiency of gating is assessed by comparison with performance when variation is restricted to the relevant dimension, the irrelevant dimension being experimentally held constant. Gating failure may appear either as interference in choice reaction time when relevant and irrelevant dimensions vary orthogonally, or as facilitation of reaction time when relevant and irrelevant dimensions covary.[2]

Successful gating has been interpreted as indicating flexible, serial encoding, perhaps hierarchically organized such that encoding can be terminated once sufficient information has been accumulated (e.g., Biederman, 1972). Gating failure may be interpreted as indicating automatic or non-attentional, parallel encoding of stimulus dimensions. For example, Morton (1969) has suggested that the decision regarding the appropriate response is facilitated by a commonality of elements between encoded, redundant dimensions. Egeth (1967) has argued that interference with orthogonal dimensions arises from competition when the same response is indicated by different levels of both relevant and irrelevant dimensions.

More recently, Garner (1970; 1974) and others (e.g., Lockhead, 1972) have suggested an alternative explanation to parallel encoding for instances of gating failure. Garner argues convincingly, that many stimulus dimensions are fundamentally integral in the way they are processed by the perceptual system. For example, two nominally separate, binary dimensions may be processed integrally, such that the four possible stimuli may be treated as four different points along a single dimension in psychological space. Integral processing is intuitively most appealing in those cases where it is not possible to specify a value on one dimension without also specifying a value on the other dimension. So, for example, a straight line must have both a location and an orientation.

Garner (1974; see also Lockhead, 1972) suggests that classification of stimuli produced by correlated combinations of integral dimensions is facilitated because the stimuli are more discriminable. Integral dimensions are presumed to combine according to the rules of Euclidian geometry, and when stimuli differ on two nominal dimensions simultaneously, they have a functional interstimulus difference which is greater than either dimension alone provides.

Felfoldy (1974) has offered an explanation of interference with integral dimensions in terms of sequential effects in the reaction time process. Orthogonal combination of two binary, integral dimensions, because the dimensions are integral, produce four functionally distinct stimuli, whereas control conditions, where one dimension is held constant, involve only two different stimuli. Therefore, from trial to trial, stimulus repetitions are less frequent in orthogonal conditions than in single-dimension control conditions. It has been known for many years that reaction time to a stimulus is faster if the stimulus is a repetition of the previous stimulus than if the stimulus represents a change from the last trial (e.g., Hyman, 1953; Kornblum, 1973). Thus, Felfoldy argues that interference in classification of stimuli produced by orthogonal combination of integral dimensions occurs because stimulus repetitions are less frequent. That is, the greater frequency of stimulus change inflates the average reaction time in orthogonal conditions relative to control conditions where stimulus repetition and stimulus change are equally frequent.

The experiments we want to report to you today were not designed to test directly between parallel and integral processing. Rather, they were intended to meet the less ambitious goal of providing a test of Felfoldy's sequential effects explanation of interference. The first experiment employed the continuous classification, card-sorting task, previously used by Garner and Felfoldy (1970), to empirically establish the integrality of line location and orientation. The second experiment used discrete trials, with large response-stimulus intervals (13 secs) to test Felfoldy's hypothesis. At such large intervals repetition effects tend to disappear (Keele, 1969; Smith, 1968; Williams, 1966). The question is, do interference effects also disappear.

In the first experiment, the basic task consisted of sorting decks of 32 stimulus cards (white, 12.75 cm high X 7.65 cm wide) into lefthand and righthand piles, corresponding to the two levels of the relevant dimension. Each subject was instructed to sort the decks as fast as possible, consistent with only an occasional error. Sorting time and number of errors was recorded for each deck.

The first slide (Figure 1) illustrates the four decks used. Frequency of each kind of card within each deck is indicated in parentheses below each card. The stimuli were straight line segments, 2 cm in length, tilted 30° clockwise or counterclockwise about their centers, and/or with their centers displaced 1 cm right or left from the center of the upper half of the card. Two of the decks were single dimension controls, variation occurring only in the relevant, sorted dimension. The other two decks were experimental conditions in which the two dimensions varied in a correlated or orthogonal manner. These experimental decks were sorted by either orientation or location on different occasions. Thus, there were six basic conditions in the experiment, defined by the combination of which of the two dimensions was relevant on a given trial and three kinds of stimulus sets; single, correlated, or orthogonal dimensions.

Twelve undergraduate volunteers performed six times under each of the six conditions, each condition appearing once in each of six successive trial blocks. Each subject received a different order of the six conditions, specified by Latin squares, and the order of conditions was reversed on successive trial blocks. Thus, ordinal position was counterbalanced for all conditions across subjects. Data was analyzed only for the last five trial blocks, the first trial in each condition being considered practice.

The next slide (Table 1) shows results expressed in mean milliseconds per card for each of the six basic conditions. Analysis of error data provided essentially equivalent information. That is, error rate and sorting time tend to be positively correlated, and there is no evidence of speed accuracy tradeoff. Faciliation appeared for correlated conditions, and interference for orthogonal conditions. This pattern is not different when the relevant dimension is orientation and when it is location, and there is no overall difference between the two dimensions.

Thus, the present results agree with predictions from one of the sets of converging operations suggested by Garner (1974) to identify intergal dimensions. It is, therefore, reasonable to assume that line orientation and location are not primarily processed for dimensional structure, but as points along a single dimension of psychological similarity.

In the second experiment, each of 18 volunteers received six blocks of 33 discrete trials, on each of two days. The six trial blocks corresponded to the six basic conditions, defined by two dimensions and three stimulus sets. Order of the six conditions was specified by a Latin square, and both block order and order of trials within blocks was reversed on the second day.

Stimuli were presented tachistoscopically for approximatley 150 msec, and the response-stimulus interval (RSI) was 13 sec. consisting of a 10 sec lighted adapting field and a 3 sec fixation point.[3] Stimuli were similar to those used in the first experiment, but line length (4 cm) and amount of displacement (2.3) were increased such that the visual angle of the stimuli in the tachistoscope matched that in the first experiment when the cards were held at reading distance. Subjects classified the stimuli by pressing lefthand or righthand buttons.

A different within-block stimulus order was used for each of the six conditions, and the orders were constructed to allow analysis of sequential effects. The orders of the 33 stimulus events were generated such that each stimulus followed itself and the other stimuli an equal number of times in each stimulus condition. That is, there were 8 repetitions and 8 changes for each of the two stimuli in single and correlated stimulus sets, and 2 repetitions and 6 changes for each of the four stimuli in orthogonal stimulus sets. Thus, the proportion of repetitions in single and correlated stimulus sets was .50, and .25 in the orthogonal stimulus set. The 8 repetitions of each stimulus in single and correlated sets consisted of four runs of length 2 and two runs of length 3. The 2 repetitions of each stimulus in the orthogonal set consisted of two runs of length 2.

The next slide (Table 2) shows the mean reaction time on errorless trials[4] for stimulus sets by dimensions, averaged over days. Interference effects appeared for both location and orientation, although the magnitude of interference is greater when orientation is the dimension classified. Facilitation was not significant for either orientation or location. Felfoldy also failed to find significant facilitation effects, except at short RSIs (82 msec). Thus, unlike interference, facilitation does not readily occur with discrete trials and large RSIs, and this suggests that interference and facilitation are mediated by different mechanisms.

Felfoldy (1974), using essentially the same procedure except that the longest RSI was approximately 1 sec (1080 msec), found that reaction time on stimulus change trials was greater than on stimulus repetition trials, and this difference was greater with orthogonal stimulus sets than with single dimensions stimulus sets. Moreover, both repetition and interfereance effects tended to decrease with increasing RSI. Therefore, Felfoldy concluded that the overall increase in reaction time with orthogonal combinations of integral dimensions is largely due to microprocesses in sequential processing, i.e., processes which handle trial-to-trial sequential information. The last slide (Table 3) shows the relevant data on this question from the present experiment.[5]

Mean stimulus repetition and nonrepetition reaction times are shown for stimulus sets and dimensions. As expected, repetition effects are virtually nonexistent in this data. In fact, a small, but significant change effect occurred for both dimensions with single and correlated stimulus sets; trials on which the stimulus was repeated being slower than nonrepetition trials. If sequential processing were involved, one would expect that interference should not occur with orthogonal sets, since stimulus change is more frequent in these conditions. However, interference is substantial, and the only effect of sequence is a small repetition effect when orthogonal sets were classified by orientation.[6]

Therefore, in the present experiment at least, interference cannot be attributed to an overall inflation in reaction time for orthogonal sets caused by the greater frequency of stimulus change. For short RSIs sequential processes may contribute to interference, as Felfoldy has suggested. However, with very long RSIs substantial interference effects remain, and the obtained sequential effects appear too small to account for them. This conclusion is further enforced by the fact that reaction time increased in orthogonal sets for both repetition and nonrepetitions, suggesting that the causative factors for interference operate independently of stimulus sequencing.

In conclusion, facilitation and interference remain problematical for us. It may be that long RSIs induce a set to further analyze the dimensional structure of integral dimensions. Such a processing set may preclude respo[illegible] based on psychological similarity, and thereby eliminate facilitation effects.

In the case of orthogonal sets, such dimensional analysis might produce interference through response competition[7] (Egeth, 1967). We believe that further research will resolve these questions, and lead to a more complete model of integral processing than is currently available.

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Footnotes

[1]Paper read by the first author at meetings of the Midwestern Psychological Association, Chicago, Illinois, May 1976. These experiments were supported in part by Research Grant MH 24420-01 from the National Institute of Mental Health. The authors are also grateful for the assistance of Patricia McBurney in pilot work. Inquiries should be addressed to Gordon M. Redding, Department of Psychology, Illinois State University, Normal, Illinois 61761.

[2]Posner (1964) defines gating or filtering tasks as those "which allow subjects to reduce information by ignoring aspects of the stimulus" (p. 495). This definition is best met when relevant and irrelevant dimensions vary orthogonally. When the dimensions covary there is no reduction of information since the irrelevant, "ignore" dimension is redundant. Here, we use the term "gating" more descriptively to indicate instructions to the subject. While this usage violates strict definition, it is not without precident (e.g., Kahneman, 1973).

[3]The 18 subjects were actually divided into three groups, differing in stimulus duration and the immediate poststimulus event. Subjects in two of the groups first fixated a small cross in the center of the field for 3 sec followed immediately by a stimulus alternative for 150 msec. For one of these groups a pattern mask immediately followed the stimulus presentation and was terminated by the response, while for the other a blank, lighted field followed the stimulus. For the third group of six subjects the fixation cross was followed immediately by a stimulus which remained on until a response was initiated. Thus, the stimulus duration and interstimulus interval varied slightly across subjects, but since there were no significant effects involving groups, the design and data are simplified for the present paper.

[4]Errors were few (.03 per trial) and analysis of all of the data revealed essentially the same pattern of results given by only errorless trials. As in the first experiment, error rate and classification time tended to covary, and when data from all trials are included reaction time increases slightly rather than decreasing as might be predicted if speed-accuracy tradeoff were involved. Mean reaction time is lower than in the first experiment (see Table 1), but this may be attributed to the fact that response execution time and error trials are included in the estimates of classification time for the continuous task.

[5]Estimates of the means in Table 2 based on the data given in Table 3 will differ slightly from the actual values shown. This is unavoidably due to differences in the n for the subject means used to compute the values in Table 3.

[6]The means for nonrepetitions include data from trials on which both the stimulus and the response changed and trials on which only the stimulus changed, the response being repeated. The data have been analyzed for effects of stimulus and response repetitions, and transitions for relevant and irrelevant dimensions. Since these analyses do not seem to substantially alter our conclusions we do not present them in this brief report. We hope shortly to report the data more completely in a publication draft.

[7]These predictions regarding interference and facilitation effects are based on the following logic; given an n-dimensional structural analysis, the perceptual system will produce n response signals, one for each dimension. Each response signal functions as an input to the response selector. It is clear that any summative operation on the response inputs to the response selector should lead to facilitation in the correlated condition as well as interference in the orthogonal condition. The assumption here is that the response selector tests for conflicting inputs and, reading no competing signals, simply outputs the common response signal. Thus, there is no differential prediction for

single and correlated conditions. Orthogonal conditions, however, do lead to conflicting inputs to the response selection mechanism, and some routine to call information regarding the relevant dimension is required. The time required to call the additional information appears as interference for orthogonal conditions.

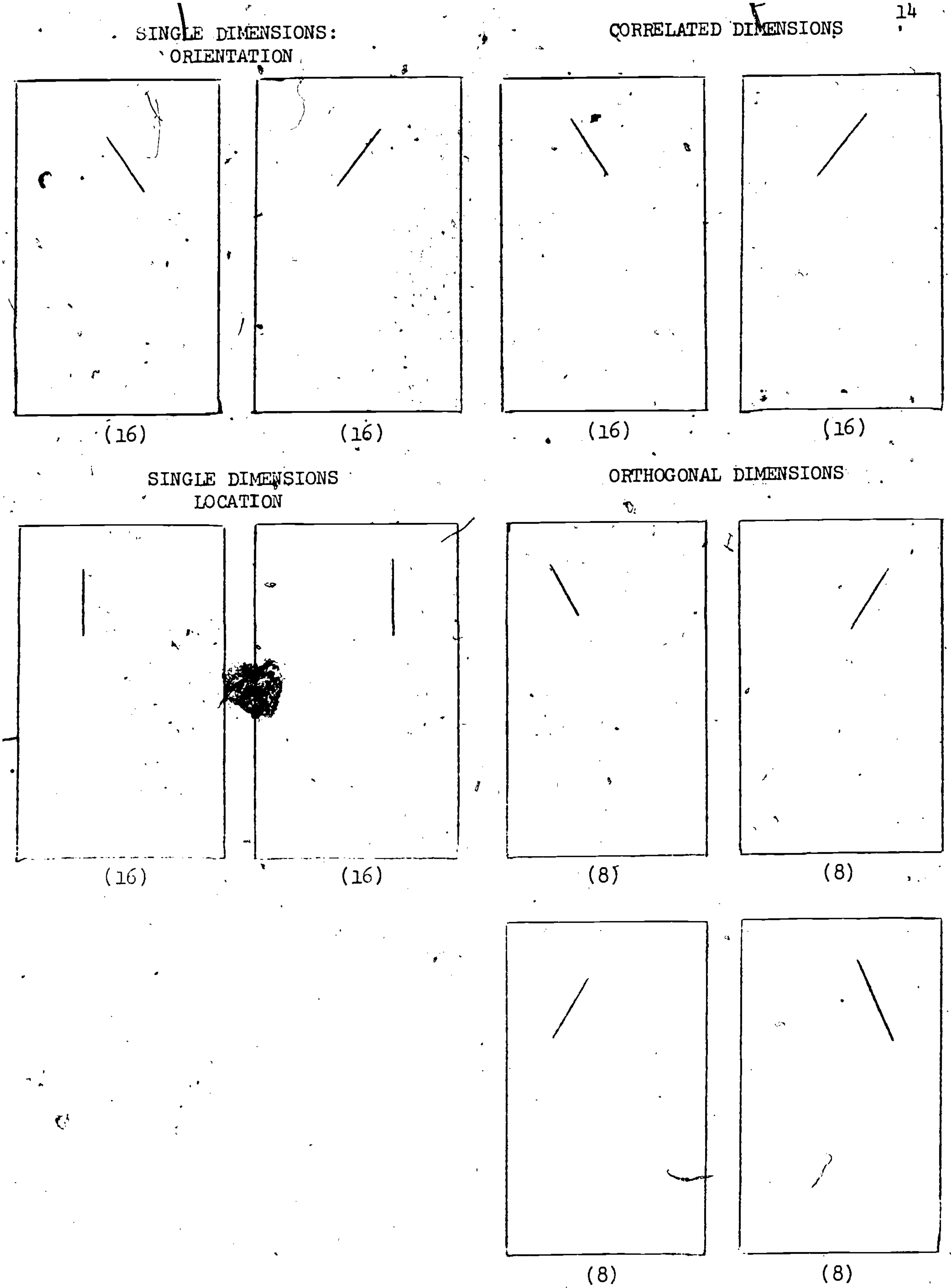

Fig. 1 Four types of stimulus decks used in Experiment 1. Frequency of stimulus alternatives within decks is shown below each card diagram.

Table 1

Sorting Time for Continuous Trials Expressed as Mean Time per Card (msec) and Shown for Each of Two Stimulus Dimensions and Three Stimulus Conditions. Experiment I.

	Type of Stimulus Set			
Dimension Classified	Single Dimensions	Correlated Dimensions	Orthogonal Dimensions	Mean
Orientation	535.6	503.1	561.3	533.4
Location	514.7	499.7	559.4	524.7
Mean	525.3	501.3	560.3	529.1

Table 2

Reaction Time (msec) for Discrete Trials for Each of Two Stimulus Dimensions and Three Stimulus Conditions. Experiment II

	Type of Stimulus Set			
Dimension Classified	Single Dimensions	Correlated Dimensions	Orthogonal Dimensions	Mean
Orientation	463.8	448.8	561.6	491.4
Location	416.8	422.7	444.4	428.0
Mean	440.3	435.8	503.0	459.7

Table 3

Mean Reaction Time (msec) for Each of Two Stimulus Dimensions with Three Stimulus Conditions as a Function of Trials on which the Stimulus Repeated (Rep) or Not Repeated (NRep) Preceding Trial. Experiment II.

Dimension Classified	Type of Stimulus Set and Trial							
	Single Dimensions		Correlated Dimensions		Orthogonal Dimensions		Mean	
	Rep	NRep	Rep	NRep	Rep	NRep	Rep	NRep
Orientation	468.8	449.8	453.0	433.1	538.9	564.0	486.9	482.3
Location	420.2	407.1	435.5	409.7	443.9	438.8	433.2	418.5
Mean	444.5	428.5	444.2	421.4	491.4	501.4	460.0	450.4