EARLY STATISTICAL PROCESSING OF PERCEPTUAL INFORMATION: SELECTIVE ATTENTION TO THE MEAN AND VARIANCE OF LENGTHS OF LINES

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Abstract

Participants made speeded classifications of the mean (large, small) and the variance (large, small) of collections of physical lines. The selectivity of attention to each statistical moment was gauged by Garner effects. We found that the mean and the variance are integral statistical attributes: People are unable to perceive one without noticing the other. This mutual dependence of the two moments is inconsistent with standard statistical theory. These results also mandate a fresh look on the new wave of studies on representations of statistical properties, on the one hand, and on the classic psychophysical laws by Weber and by Hick, on the other hand.

The new wave of research in statistical cognition probably started with Ariely's (2001) who asked participants to judge whether the mean size of a set of circles was larger or smaller than that of a subsequently presented probe circle. The judgments were accurate. However, when the task was to decide whether the probe circle was a member of the previously presented set, performance was only marginally better than chance. Ariely concluded that observers encode precise information about the mean of a set of similar objects, which is all the more remarkable given the poor representations of the individual objects. Chong and Triesman, (2002, 2005a, 2005b) expanded upon Ariely's initial observation in a series of creative experiments reaching the same conclusion about the early representation of the mean. The perception of the variance was not addressed in the aforementioned studies; we gauged it, too, in this study.

If both the mean and the variance are perceived, does the value of one influence the perception of the other? Recall that in standard statistical theory the mean and the variance are independent properties of a set of items (up to one degree of freedom). Are they in human cognition? Especially as according to Weber's law perceived variance does depends on the mean.

Method

Participants: Fourteen young men and women, undergraduate students at Tel-Aviv University, took part in the experiment.
Stimuli: The stimuli were sets of 5 straight lines presented at a horizontal orientation. The sets of lines divided into 4 groups: large mean and large variance (LL), large mean and small variance (LS), small mean and large variance (SL), and small mean and small variance (SS).
Design: The design followed Garner's (1974) speeded classification paradigm. The participants' task was to decide, while timed, whether the mean of the lines presented for view was large or small. These speeded judgments were made in the following 5 blocks.
Baseline: In one baseline block, the variance of all the sets of lines presented was fixed at a small value. In another baseline block, the variance was held constant at a large value.

Therefore, in this pair of blocks the observer classified mean length of lines characterized by a constant variance.

Filtering: The task of the participants remained the same -- to decide whether the mean length is large or small. However, the task-irrelevant variance also changed from trial-to-trial in a random fashion.

Positive Correlation: Again, the task for the participant was that of speeded classification of the mean length. In this block, the irrelevant variance changed in a corresponding manner to the mean.

Negative Correlation: In this block, the irrelevant variance varied from trial to trial on a non-corresponding manner. When the mean was large the variance was small and vice versa.

The same 5 blocks were presented again this time with the variance as the relevant attribute for judgment. In these blocks, the observers decided, while timed, whether the group of lines had a large or a small variance. As before, the irrelevant mean was held constant at baseline, varied in an orthogonal fashion in filtering, and varied in either a corresponding or non-corresponding fashion in the correlation condition.

Results

Judgments of the Mean

The mean RTs for correct classification of the mean at the baseline, filtering, and correlation conditions are presented in Figure 1. First, consider Garner interference. Average performance at baseline was 453 ms, whereas average performance in the filtering condition was 515 ms. This difference amounted to an appreciable Garner interference of 62 ms in perception of the mean [t(13)=2.53, p=.025]. When classifying mean length, our participants could not ignore irrelevant changes in the variance. This variation in variance took a toll on performance. None of the differences between the other conditions were reliable.

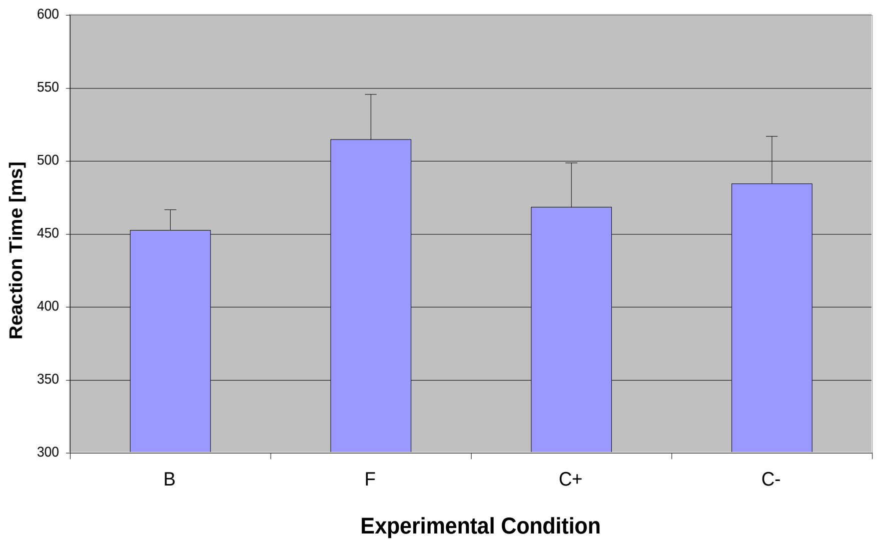

Figure 1: Mean RTs for classification of the mean lengths of lines in the baseline (B), filtering (F), positive correlation (C+), and negative correlation (C-) conditions of the Garner paradigm.

Judgments of the Variance

The mean RTs for correct classification of the variance at the baseline, filtering, and correlation conditions are presented in Figure 2. Average performance at baseline was 534 ms, whereas average performance in the filtering condition was 621 ms. The difference amounted to a large Garner interference of 87 ms in perception of the variance [t(12)=2.48, p=.005]. Clearly, the participants did not attend selectively to the variance and were affected in their judgments by the irrelevant mean.

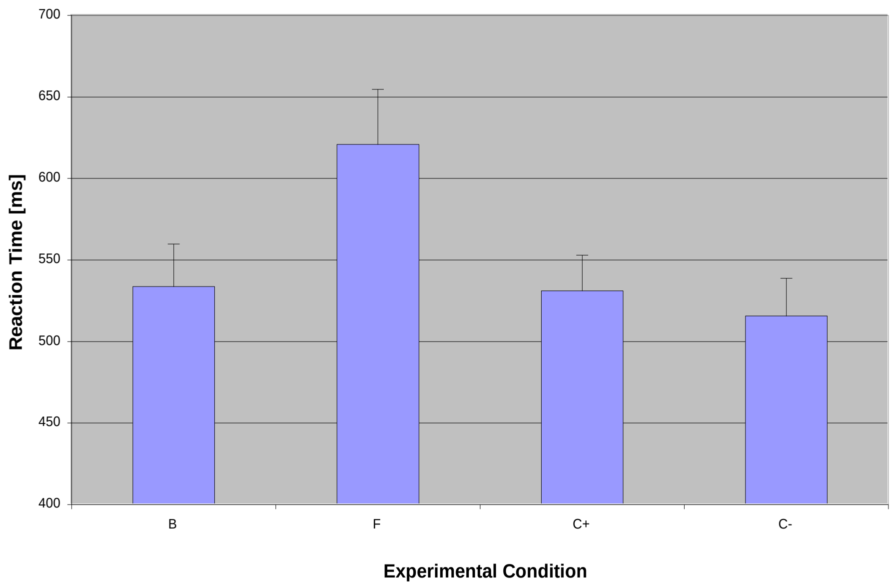

Figure 2: Mean RTs for classification of the variance of lines in the baseline (B), filtering (F), positive correlation (C+), and negative correlation (C-) conditions of the Garner paradigm.

Discussion

The results demonstrate that people are unable to perceive the mean without concurrently noticing the variance. In a complementary fashion, people are unable to perceive the variance without noticing the mean. The first two statistical moments are not separable in human perception although they are in statistical theory. The measure of selectivity known as Garner interference gauged the influence of the task-irrelevant statistic in both cases.

The influence of the task-irrelevant statistic, engendering the breakdown of selective attention to the relevant statistic, comes in a different way. For both the mean and variance, the judgment is easier when the other statistic is at a smaller than at a larger value. However, this pattern derives from different sources for the mean and for the variance.

For the mean, the longer RTs with larger values of variance can be accounted for by an extension of Hick's law (Hick, 1952): RT is proportional to the information (or uncertainty) lurking in an array of stimuli. The variance can be taken to stand for uncertainty when one deals with values on a ratio scale like lengths of lines. In past research (e.g., Levin, 1975; Spencer, 1961, 1963) there is evidence that perceiving the mean is more difficult as the variance of the group of items gets larger. According to an alternative (but not mutually exclusive) interpretation, the effect of variance on stimulus classification is accounted for by an ANOVA model (Rapp, 1993). The difference between the two means presented can be considered as "between-groups variance" whereas the variance of the line stimuli as "within-group variance." Because the ratio of the two variances (between/within) is larger in the line samples with small variance, the discrimination of the mean (which functions to represent a group of stimuli) is easier. In fact, Rapp (1993) showed that this ratio serves to define a group of stimuli in the first place.

For the classification of variance, the intrusion of the irrelevant mean is simply that of Weber's law. According to Weber's law, the perception of a difference (and the variance is a summary of stimulus difference) is proportional to stimulus magnitude (represented by the mean.) Consequently, a given variance is detected faster and identified as larger when the stimuli are smaller.

A notable feature of the present results is the symmetry of the effects of the two statistics. The mean constrained the perception of the variance to roughly the same extent that did the variance the perception of the mean. This symmetry, too, does not fit well with standard statistical theory. The ordinal designation of statistical moments already reflects a hierarchy, i.e., asymmetry. The variance is typically defined based on the mean (although there exists a route that bypasses the mean), but not vice-versa. In textbooks of statistics, the mean is usually presented first. The current results show that this practice is not strictly justified based on early statistical cognition.

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