# CONTEXTUAL EFFECTS AND ASSOCIATIVE PROCESSES IN COMPARATIVE JUDGEMENTS WITH PERCEPTUAL AND SYMBOLIC STIMULI

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#### Abstract

In each of three experiments, participants first learned to associate nonsense syllables (CVCs) with visual extents. In the first two experiments, these labels were then used as standards in the method of constant stimuli. Weber fractions for the remembered standards exhibited endpoint effects and systematically varied with set size, range, and acquisition conditions. In the third experiment, the additive factors methodology was used to permit a strong test of the propositionally based stage models of symbolic comparisons.

Extending the developing area of memory psychophysics, Baranski and Petrusic (1992) applied the classic method of constant stimuli with remembered standards to determine, directly, the precision and the accuracy of the long memory representations of percepts. As in the landmark memory psychophysics experiment (Biorkman. Lunberg & Tarnblom, 1960), participants in the Baranski and Petrusic experiments first learned to associate a label (a CVC) with each element in a set of perceptual magnitudes using traditional paired associate training methods. In the second phase, each of the CVC's was presented as a standard together with a variable perceptual comparison stimulus using the method of constant stimuli. Psychometric functions were then obtained for each subject with each standard (St) in order to obtain estimates of the Just Noticeable Difference (JND), Weber Fraction (WF=JND/St), and the Point of Subjective Equality (PSE).

Baranski and Petrusic (1992) argued that their findings provided considerable support for the view that the elementary, unidimensional, aspects of sensory experience are preserved in memory in a format closely analogous to their representation in perception, albeit less precisely. The present experiments are motivated by a natural extension of this *noisy-analogue* position; namely, that the units representing the long-term memories of unidimensional percepts, such as visual extent, for example, are organized in an array in which underlying perceptual similarity is preserved through proximity of memory analyzers, and neigbouring units laterally inhibit one another, with increasing inhibition with proximity of the analyzers.

The present experiments extend our earlier work by examining the effects of variations in the context of the memory ensemble. The examination of global contextual effects takes two forms. In the first experiment, the number of stimuli in the memory ensemble is varied. Range effects, arising from variations in the spacing of the alternatives along the underlying perceptual continuum, are examined in the second experiment.

Acquisition processes are also studied. Experiment 2 was designed to determine if over learning of the association between label and percept decreases putative lateral inhibition and, consequently, increases memory precision. The third experiment was designed to provide a test of the additive stages models of symbolic comparisons by controlling the degree of remoteness of association from label to percept. Participants learned to associate another label (remoteness level 2) with the label originally associated (remoteness level 1) with the percept and subsequently made symbolic comparisons at each remoteness level.

#### EXPERIMENT 1

Although set size effects are evident in short-term memory (STM) search, the STM distracter paradigm, long-term memory, visual search, and in the classic serial list learning paradigms, they remain to be studied in memory psychophysics. The present experiment was conducted with a view toward determining the precise dependence of the quality of the representation in memory on the number of elements in memory; i.e., on set size. The extended noisy-analogue view, suggests that as the size of the memory ensemble increases, the amount of lateral inhibition any memory unit receives increases, and thus increases in set size must necessarily result in diminished memory precision for each element in the larger ensemble. Perceptual comparisons should not exhibit set size effects since perceptual analyzers are much more finely tuned than memory analyzers Method

In the first phase of the experiment, 15 participants learned to associate a specific label (a CVC) with each of three horizontal lines (31.95, 106.39, and 148.88 mm) and 15 additional participants learned to associate a label with each of six lines (10.54, 31.95, 63.90, 106.39, 148.88, and 202.27 mm). In order to obtain points on the psychometric function, the method of constant stimuli, was used with comparison stimuli differing by -6%. -3%. 0%. 3% and 6% from the standard. for each of the above line lengths as standards. Participants were instructed that on each trial they would be presented, in succession, either two horizontal lines, a line and a CVC, or a CVC and a line. In each case they were to select, according to the instruction, either the longer or the shorter of the two presentations. For the set size three group, each point of the psychometric function for each standard, and each type of standard (perception versus memory, with the standard denoted by a CVC), was based on 24 observations for each subject and in the set size 6 condition, and on 12 observations for each subject.

Results

Weber fractions: Memory precision. Psychometric functions, with z-transformed (Gaussian) response probabilities, were obtained for each subject with each standard and with each type of standard; i.e., memory vs perception. The intercepts (a) and slopes (b), of these psychometric functions, are directly related to the PSE and JND when the variable stimuli differ from the standards by fixed percentages. In this case. PSE=St(1-ca/b), with c=0.03 the conversion constant and St, the standard, JND=(.675)(St)(c)/b and the Weber fraction is given by WF = (.675)(c)/b. The Weber fraction is inversely related to the slope and constancy of slopes is required for the strong form of Weber's law to hold.



**Figure 1**. Weber fractions for the memory and the perceptual comparisons with set size 3 and set size 6.

Weber fractions for the memory and for the perceptual standards for set size three and set size six are plotted in Figure 1. Several results are evident in these plots. First, as found by Baranski and Petrusic (1992), serial-position effects (end-point effects) are evident for both set size three and six. Second, these serial position effects are much more pronounced in the set size six, memory condition. Third, memory Weber fractions are smaller for the set size three condition than for the set size six comparable standards. Fourth, the plots also show there is greater precision in the representations (i.e., smaller Weber Fractions) for both the set size three and for the set size six perceptual standards than the corresponding memory standards. Fifth, there is an absence of set size effects with the perceptual standards. Finally, Weber's Law is violated for the perceptual comparisons; Weber fractions decrease as the standard increases.

The slopes of the psychometric functions in the memory condition for the set size 3 condition and those with comparable standards in the set size 6 condition were subjected to an analysis of variance (ANOVA) with set size as the between groups factor and the three standard lengths as the within-subject factor, and level of significance set at 0.05. The main effect of set size was highly reliable [F(1, 28)=8.47, MS(Error)=0.034] confirming reduced discriminative sensitivity with the set size 6 standards. The main effect of standard was reliable [F(2, 56)=5.91, also MS(Error)=0.014] indicating the presence of serial position effects. A comparable ANOVA with the strictly perceptual standards revealed neither main effects of set size nor standard. With set size fixed at six. an additional ANOVA with both memory and perceptual standards confirmed uniformly reduced sensitivity with memory [F(1, 14) = 39.07, MS(Error)=0.0839], and a main effect of standard [F(5,70)=15.45, MS(Error)=0.023], reflecting end-point effects. However, the interaction between whether the comparison involved a memory or a perceptual standard and the particular standard failed to attain statistical reliability.

*PSEs: Memory accuracy.* Points of subjective equality were also obtained from the individual subject psychometric functions and these were used as an index of memory accuracy. The plots in Figure 2 parallel closely those in Figure 1 with the Weber fractions. First, set size effects are evident in memory; PSE's are more likely to be close to the standard in the set size 3

condition than in set size 6. Second, the bowed serial position effect is also evident in both memory conditions, with less accurate memories for the interior standards. Finally, PSE's in the perceptual condition are near their respective standards in every case.



**Figure 2**. Probability that the PSE is within the range of variable stimuli in the memory and perception conditions for set size 3 and 6.

### **EXPERIMENT 2**

Experiment 1 demonstrates a dependence of the *quality* of the memory representation on the *number* of stimuli in the memory set. Experiment 2 was designed to determine if this violation of independence from other alternatives also included the *spacing* of the alternatives on the underlying perceptual continuum. Accordingly, one group of subjects learned to associate CVC' s with a set of narrow range stimuli (10.54, 30.03, 50.16, and 70.00 mm) and a second group worked with a set of wide range stimuli (10.54, 70.00, 140.89, and 200.00 mm).

The noisy analogue view predicts that the effects of range should be evident in larger Weber fractions in the small range than in the large range, primarily, because lateral inhibition in the memory array increases with increases in similarity among the underlying perceptual referents and consequently in terms of proximity of the array of memory analyzers.

Presumably, the amount of lateral inhibition any analyzer in a memory array exerts on its neighbour depends jointly on the proximity of the analyzer and the strength of the vertical connections between the memory analyzer and its referent perceptual analyzer. On the further assumption that lateral inhibition is diminished with increases in the strength of the associative bond between the memory analyzer and its perceptual referent, the dependence of long-term perceptual memory precision must depend on both the underlying range of the perceptual referents and the conditions governing acquisition. *Method.* 

Sixteen participants were randomly assigned to each of the four groups arising from the factorial combination of two range conditions (narrow vs. wide) and two learning conditions (over learning vs. no over learning). Four horizontal line lengths served as standards in the method of constant stimuli with variable stimuli equal to  $St \pm .03k \times St$ , with k=0, 1, 2. In the wide range condition the standards were 10.54, 70.00, 140.89, and 200.00 mm, and in the narrow range they were 10.54, 30.03, 50.16, and 70.00 mm. On half of the trials, participants selected the stimulus corresponding to the shorter line and the longer on the other half and on half of the trials stimuli were presented in the CVC-line order and the line-CVC order on the remaining half. After combining the data over the two instructions and the two presentation orders, each point on the psychometric function was based on 12 observations for each participant. Results

As in the first experiment, Gaussian based psychometric functions were obtained and slopes and intercepts were determined for each participant.

Weber fractions: Memory precision. The plots in Figure 3 demonstrate a range effect in the no over learning condition along with well-defined serial position effects; again the end-point standards show greater precision than the interior standards. It is also clear that extensive over learning sharpens memory precision, eliminates the range effect, and greatly diminishes end-point effects. These findings are substantiated by an ANOVA showing a main effect of the learning factor [F(1, 60)=4.96), MS(Error)=0.069]. In the no over learning condition, the main effect of range is reliable [F(1, 30)=4.81, MS(Error)=0.036] as is the effect of standard [F(3,90)=10.65, MS(Error)=0.016]. In the over learning condition, only the effect of standard is reliable [F(3,90)=3.67, MS(Error)=0.032].



Figure 3. Weber fractions with the wide and the narrow ranges for the no over learning and over learning conditions as a function of standard.

*PSEs: Memory accuracy.* As the plots in Figure 4 show, memory accuracy as gauged from the PSE's, closely parallels memory precision measured by the Weber fraction. The range effect is evident in the no over learning condition, as are end-point effects and accuracy is generally higher in the over learning condition.



**Figure 4**. Proportion of PSEs within the range of variable stimuli at each standard as a function of range for the no over learning and the over learning conditions.

### Discussion

Taken together, the findings from Experiments 1 and 2 provide strong support for the extended noisy-analogue view of memory psychophysics and they provide a clear replication and extension of the Baranski and Petrusic (1992) findings.

#### EXPERIMENT 3

It is clear that memory representations of elementary percepts are activated with properties closely analogous to those in perception when the psychophysical task cannot be solved otherwise, as in the present experiments and as in Petrusic, Baranski, and Kennedy's (1992) similarity comparison task experiment. However, the form of the memory representation in the simple binary symbolic comparison task remains to be unequivocally established. Banks' (1977) propositionally based semantic coding theory continues to provide the most compelling and full account of the available data. The essence of this theoretical position is that the process of comparing two symbolically represented percepts involves discrete, strictly additive stages; i.e., coding of instructions, code activation of stimuli, code comparison and response selection. Experimental manipulations that prolong a particular stage will not interact with other stages. That is, when the additive factors methodology is invoked, the effects of variables known to influence distinct stages will necessarily result in strictly additive effects.

This experiment provides a strong test of the additive stages idea by attempting to prolong the code activation stage of processing. Specifically, let A denote a set of lines, and B and C sets of labels (CVCs). The A-B, B-C paired-associate, chaining paradigm was used to establish two degrees of associative remoteness of the CVC labels from the elements in set A. On the additive stages view, if the times for comparisons within the more remote set are increased, then these effects must be additive over the stimulus pairs in the comparison set. On the other hand, as Petrusic (1992) has suggested, if an experimental manipulation slows the evidence accrual decisional process, then those comparisons requiring a greater number of accruals will be slowed more. Thus, if remoteness of association affects the speed of accrual, then both difficulty and the semantic congruity effects (SCE) should be enhanced. *Method* 

In the first stage of the experiment, 14 participants learned to associate a specific CVC (set B) with each of five horizontal lines (set A). In the next stage, each CVC in set B was paired with a distinct CVC in set C. Following successful acquisition of the two sets of associations, the method of paired comparisons was used with the CVCs in each set. On half of the trials participants selected the CVC in the pair denoting the longer line and the CVC denoting the shorter line on the other half. Each participant made a total of 80 comparisons in each of four blocks. The 80 comparisons in each block arose from 10 pairs in each of the two sets, with each of the two instructions and the left and right positions.

Results



**Figure 5**. Response time for each stimulus pair with the first and second levels of remoteness.

Difficulty effects. An ANOVA with median response time (RT) for each cell of the design as the dependent variable revealed significant effects of degree of remoteness [F(1,13)=9.62, MS(Error) =1,348,046] with substantial increases in overall RTs with the more remote CVC-percept association, as is evident in Figure 5. In addition, and critically, the interaction between pair (difficulty) and degree of

remoteness was reliable [F(9,117)=3.49, MS(Error) =1,105,436.1] contrary to the additive stages models of symbolic comparisons.

Individual differences. If in the initial

CVC-line length acquisition stage, each line length is represented by a simple propositionally based code, then participants may well learn to associate CVCs in the next CVC to CVC acquisition phase with the corresponding ordinal codes. Consequently, access to the ordinal representation of the line length will be equally fast for both levels of remoteness. Thus, the lack of a remoteness effect provides first hand evidence of ordinal coding and support for the additive stages models. Importantly, there was no clear evidence of a remoteness effect for 4 of the 14 participants.

Semantic congruity effects.



**Figure 6.** Semantic congruity index (RT("Longer")-RT("Shorter") for the two levels of remoteness and the end-point pairs.

Figure 6 provides a view of the semantic congruity effect for the 10 participants that show a remoteness effect. It is clear, in violation of the additive stages models, that the SCE is enhanced at the second level of remoteness.

### Discussion

The findings of the present experiment clarify the current status of the propositionally based additive stages models of symbolic comparisons. These models are supported by the data of four participants and the data for the 10 participants showing a remoteness effect provide strong evidence against this class of models. It remains to be established for these participants whether and how differently they access the underlying perceptual representations in tasks such as those in the first two experiments.

# SUMARY AND CONCLUSIONS

Strong evidence for the extended noisy analogue view of memory for elementary is established through percepts the demonstration of a dependence of both memory precision (Weber fractions) and memory accuracy (PSEs) on global contextual set size and range effects, and acquisition processes. Our current work theoretical work is directed to developing a general quantitative model that encompasses the findings of all three of the experiments presented here.

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