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# A test for response summation with key-projected stimuli

ROBERT J. HAMM
*Virginia Commonwealth University, Richmond, Virginia 23220*

**Four pigeons were trained to discriminate between four stimuli. There were three stimuli correlated with reinforced responding and one stimulus correlated with nonreinforced responding. Stimuli were compounds of form (either square or triangle) and background color (either red or green) projected on the response key. Compound stimuli were constructed in such a way that some components of the form-color compound stimulus were more frequently associated with reinforced responding than other components. Results showed that the compound stimulus formed of components most frequently associated with reinforced responding did not consistently control a higher response rate than other stimuli less frequently associated with reinforcement. This finding raises the question of the importance of the stimulus restrictions placed on the investigation of the response summation phenomenon.**

Additive response summation refers to the increase in response probability observed when stimuli which have been separately conditioned to the same response are presented simultaneously. One method of investigating the summation phenomenon is to use multiple schedules of reinforcement. For example, Weiss (1964) reinforced rats for barpressing on a multiple variable-interval 30-sec, variable-interval 75-sec, extinction schedule (abbreviated mult VI 30-sec, VI 75-sec, ext), with light (or more precisely, light plus no-tone, abbreviated as $L + \overline{T}$) and tone (no-light plus tone, $\overline{L} + T$) being associated with the respective VI components and no-light plus no-tone ($\overline{L} + \overline{T}$) being associated with the extinction component. After stable differential responding was established, a test for response summation was conducted which involved presenting the two VI-associated stimuli (i.e., $L + \overline{T}$ and $\overline{L} + T$) simultaneously. The results showed that this compound test stimulus, $L + T$, controlled a higher response rate than either of the VI-associated stimuli.

Although the response summation phenomenon has been frequently investigated (e.g., Weiss, 1972), the conditions under which it has been demonstrated are rather restricted. For example, combinations of light and tone stimuli have been extensively used. In fact, there have been only two investigations of response summation which used intramodal stimuli. Miller (1971) separately associated two spacially separated cue lights as signals for reinforced responding. The summation test involved simultaneously turning on both cue lights. This intramodal test stimulus produced response summation.

This report is based on a thesis submitted by the author in partial fulfillment of MS requirements at Southern Illinois University, Carbondale, Illinois. Reprints may be obtained from the author, Department of Psychology, Virginia Commonwealth University, Richmond, Virginia 23220. Donald Meltzer sponsors this paper and takes full editorial responsibiltiy for its content.

An experiment by Hamm and Meltzer (1972), using pigeons as subjects and compounds of line orientation on the response key and houselight on or off, found no evidence for additive response summation. Thus, the summation phenomenon has been primarily investigated with intermodal stimulus compounds, and there have been no demonstrations of response summation with intramodal spacially contiguous stimuli. The purpose of the present experiment is to determine whether response summation can be produced with stimuli which are compounds of form and color projected on the response key.

## METHOD

### Subjects

The subjects were four individually housed pigeons approximately 2 years old at the outset of the experiment. Twenty days prior to the start of the experiment the pigeons were brought to and maintained at 80% of their free-feeding weight. Water and grit were freely available in their home cages throughout the experiment.

### Apparatus

The apparatus was a standard two-key experimental chamber with interior dimensions of 50 x 35 x 35 cm. The keys were located 25 cm above the grid floor and were 20 cm apart, center to center. Both keys were 3 cm in diam. An Industrial Electronic Engineers one-plane digital readout (Model 10-0229-1820-L) permitted transillumination of the response keys with both color and form simultaneously. The lines of the forms measured .2 cm wide. Forms were designed to fit within a 2-cm diam circle. An effective force of .15N was required to activate the key. The food magazine was located 9 cm above the grid floor and was centered on the midline of the stimulus panel. The sources of illumination were the two keys and the food magazine light. In addition, two lamps behind a 75 x 35 cm piece of white Plexiglas were mounted over the stimulus panel and served as a houselight. White noise was introduced into the experimental chamber to mask extraneous auditory stimuli. Electromechanical programming and recording equipment were located in an adjacent control room.

Table 1
The Stimulus Assignments for the Subjects

| Subjects | $S^{\Delta}$ | $S^{D1}$ | $S^{D2}$ | $S^{Test}$ |
|---|---|---|---|---|
| S1 | red + triangle | red + circle | green + triangle | green + circle |
| S2 | red + circle | red + triangle | green + circle | green + triangle |
| S3 | green + triangle | green + circle | red + triangle | red + circle |
| S4 | green + circle | red + circle | green + triangle | red + triangle |

**Stimuli**

The four compound (form + color) stimulus displays used throughout the experiment were a white triangle on a red background (red + triangle), a white circle on a green background (green + circle), a white triangle on a green background (green + triangle), and a white circle on a red background (red + circle). See Table 1 for the stimulus displays used as $S^{\Delta}$, $S^{D1}$, $S^{D2}$, and $S^{Test}$ for each subject. The table shows that the various form and color components that comprise the compound stimuli are counterbalanced across subjects. The $S^{Test}$ for each subject has no form or color component in common with $S^{\Delta}$. Each $S^{D}$ has one of its two components in common with $S^{\Delta}$.

**Procedure**

Pigeons were first trained to eat from the food magazine. The keypecking response was shaped and maintained on an FR 1 schecule for 60 reinforcements (4 sec access to grain). During this phase the key was illuminated by white light.

In the next phase of the experiment, the discrete-trial phase, each session involved the presentation of one stimulus, either $S^{\Delta}$, $S^{D1}$, or $S^{D2}$ on the response key. A response to $S^{D1}$ and $S^{D2}$ produced reinforcement, terminated the trial, and initated a 10-sec time-out which preceded the next stimulus presentation. Responses to $S^{\Delta}$ were not reinforced and the stimulus duration was 30 sec. Termination of the $S^{\Delta}$ started a 10-sec time-out before the next stimulus presentation. Each daily session consisted of 16 presentations of $S^{\Delta}$ and 8 presentations each of $S^{D1}$ and $S^{D2}$. The order in which the various stimuli were displayed was randomized. This procedure was followed for 12 sessions.

In the next portion of training, the stimulus presentations were lengthened to a constant 1-min duration by having responses to $S^{D1}$ and $S^{D2}$ no longer terminate a trial. Responses to $S^{D1}$ and $S^{D2}$ were now reinforced on a VI 15-sec schedule. Responses to $S^{\Delta}$ remained nonreinforced. Every stimulus presentation was separated by a 10-sec time-out. After 12 sessions of VI 15-sec reinforcement, the schedule was changed to VI 30 sec for an additional 5 sessions. Finally, stimulus presentations were lengthened to 2 min and reinforcement for responses to $S^{D1}$ and $S^{D2}$ were given on a VI 1-min schedule. This procedure was followed for 15 additional sessions.

The final phase of the experiment, the summation test phase, involved presenting the test stimulus, $S^{Test}$, along with the other stimuli. Responses to $S^{D1}$ and $S^{D2}$, and $S^{Test}$ were reinforced on a VI 1-min schedule. Responses during $S^{\Delta}$ remained nonreinforced. During this phase, a session consisted of 18 2-min presentations of $S^{\Delta}$ and 6 presentations each of $S^{D1}$, $S^{D2}$, and $S^{Test}$. The order of stimulus presentation was randomized. Summation testing was conducted for 24 sessions.

## RESULTS

Figure 1 shows the mean response rates calculated in blocks of six sessions during the various stimulus presentations for individual subjects. The first two blocks of six sessions show mean response rates to $S^{D1}$, $S^{D2}$, $S^{\Delta}$ on the last 12 sessions before summation testing (Blocks 1 and 2). As can be seen from Figure 1, differential responding to the $S^{D}$s and $S^{\Delta}$ was well established before summation testing began. All subjects demonstrated a relatively stable response rate to each stimulus associated with the components of the mult VI 1-min-ext schedule during Blocks 1 and 2.

Figure 1 also illustrates the mean response rate for individual subjects in the presence of each stimulus condition ($S^{Test}$, $S^{D1}$, $S^{D2}$, $S^{\Delta}$) during summation testing (Blocks 3-6). As the figure illustrates, only S2 consistently showed higher mean response rates during $S^{Test}$ than during the $S^{D}$s over all blocks of testing. Subject 4 demonstrated a higher response during $S^{Test}$ on three of the four blocks. Subject 3 showed con-

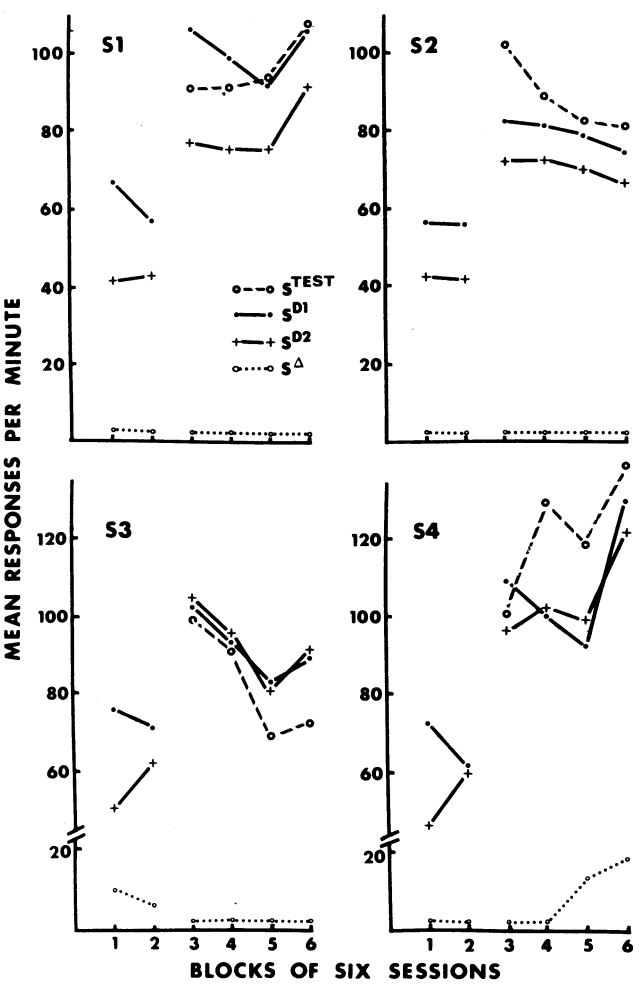


**Figure 1. Mean response rate during all stimuli for the last two blocks of six sessions of VI training (Blocks 1 and 2) and during the four blocks of summation testing (Blocks 3-6).**

sistently *lower* response rates to the $S^{Test}$ than the $S^{D}$s. Subject 1 exhibited a higher response rate to $S^{Test}$ on the last two blocks of six sessions. In summary, then, only one of the four subjects demonstrated a higher response rate to $S^{Test}$ than to either $S^{D}$ across all blocks of summation testing.

An analysis of variance of the response rates during $S^{D}1$, $S^{D}2$, and $S^{Test}$ over the four blocks of summation testing yielded no significant effect of stimuli. Thus, both the individual subject data and the statistical analysis showed that response summation was not obtained.

## DISCUSSION

The results showed that response summation was not obtained with pigeons using compounds of form and color projected on the response key. These data pose a problem for the model of summation proposed by Weiss (1972). In his attentional-process model of response summation, Weiss proposes that when a subject is presented with a compound stimulus, it samples the elements comprising the compound stimulus and the behavior controlled by the compound stimulus is a "mix" of the response rates controlled by each element comprising the compound. Since the summation test stimulus for each subject was a compound of stimulus elements that were (1) discriminative for a response rate increase and (2) associated with an increase in reinforcement frequency, Weiss' (1972) model predicts additive response summation. Response summation was not demonstrated, even though both of these conditions were met in the present experiment. That is, the discriminative stimuli ($S^{D1}$ and $S^{D2}$) controlled a much higher response rate than the extinction-associated stimulus ($S^{\Delta}$) for all subjects. Also, the discriminative stimuli were associated with a VI 1-min schedule of reinforcement, while the $S^{\Delta}$ was associated with nonreinforced responding. Thus, there appears to be no reason proposed by Weiss' model of summation that would predict the nonoccurrence of response summation in the present experiment.

The lack of response summation observed in the present experiment implies that there are other processes which may also influence the occurrence of response summation. For example, Long and Allen (1974) and Meltzer and Hamm (1976) have suggested that response summation will not occur if reinforcement frequency is too high. That is, reinforcement frequency imposes a ceiling beyond which response summation will not occur. The present experiment used a VI 1-min schedule of reinforcement and did not find evidence for response summation with compounds of form and color projected on the response key. Meltzer and Hamm (1976) found consistent response summation with pigeons with a VI 1-min schedule when compounds of light and tone were used as stimuli. Thus, it appears that the particular stimulus used in the two experiments was a more critical factor in determining the occurrence and nonoccurrence of response summation than any possible ceiling effect caused by reinforcement frequency.

The importance of the stimuli used in investigating response summation has largely been ignored. All of the experiments that have reported response summation have used stimuli which vary in some way along an intensity dimension. The present experiment raises the question of whether response summation can be demonstrated when the stimuli vary in qualitative aspects rather than in quantitative intensity In other words, the colors and forms did not vary in intensity but varied in qualitative terms (i.e., hue and geometric shape). This combination of stimuli which vary on two qualitative dimensions did not yield response summation.

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