# Sense modality switching and serial learning

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*This investigation examined the effect of sense modality switching of information at various positions of a serial learning task. Different numbers of flashes of light and different numbers of "blips" of a pure tone were used as signals in a four-position serial learning task. The design of the study involved a switch in sense modality at each one of the four possible positions in the series. Thus, it was possible to determine if the transmission of information through one sense modality makes it progressively more difficult or more time consuming to switch to another source of information transmitted through another modality. The results generally supported the contention that, as information is received through a particular modality, there is a build-up of the disruption involved in switching sense modality.*

A previous experiment by Chan and Travers (1965) studied the effects of sense modality switching on the learning of elements in a serial learning task. The study involved a task with seven nonsense syllables, each of which could be presented in either the auditory or visual modality. Switching the sense modality of transmission took place with some Ss on the second position and with other Ss on the fifth position. At the higher of the two speeds of presentation used, there was no significant effect on learning produced by switching modality in the second position. However, the switching of modality in the fifth position produced (1) a significant increase in learning in the syllable on which the switch occurred and (2) a significant decrement in learning of the following syllable (the sixth position), which involved a switch back to the original modality. The increment was interpreted as a von Restorff effect, and the decrement was considered to be a result of loss of time involved in switching—a loss established by research that has been reviewed and added to by Reid (1964).

The fact that in the Chan and Travers (1965) study the effect of switching was much more marked in the fifth position than in the second suggests that, as information is received through a particular sense modality, switching to another modality requires an increasing amount of lost time. The present study investigates further this tendency for switching effects to become more marked as a particular sense modality continues to be used for information transmission.

The lack of equivalence of nonsense syllables suggested that it would be advisable to substitute for them signals that would be more nearly equivalent to each other. For this reason, the present study used as signals either brief series of flashes of light or brief series of sound "blips." Each signal consisted of 3, 4, 5, or 6 flashes or blips. Four signals were given consecutively through either the auditory or the visual modality. The task of the S was to report at the end of each series of four signals the number of flashes or blips in each of the signals.

While no recent related study using flashes and blips could be found, Judd (1927) has used a similar task in which adult Ss were to estimate the number of flashes presented at various rates from three to five per second and sound that varied from three to eight per second. His data showed that (1) increasing rates of presentation resulted in increasing errors, (2) errors increased as the number of flashes or sounds increased in number, and (3) auditory signals were more readily estimated numerically than were flashes. The latter finding was attributed by Judd to the fact that adults have had more experience in counting flashes.

## METHOD

### Procedure

The task of the S was to estimate the number of blips and/or flashes in each of four consecutive signals. Each blip or flash within each signal involved a .09-sec exposure of either light or sound followed by a rest interval of .03 sec. Thus three blips and their rest intervals following them occupied .36 sec, four blips occupied .48 sec, and so forth. The blips were produced by recording a 900-Hz sine wave tone on tape. The flashes were produced by a 3-W neon lamp placed 5 ft from the S in a dimly lit room. A single signal consisting of 3, 4, 5, or 6 blips or flashes was transmitted and then was followed by a 1-sec pause before the next signal was transmitted. The 1-sec pause between signals was established empirically by running Ss with intervals between signals that varied from 0.2 sec upwards. Intervals lower than 1 sec did not permit the S to provide any accuracy in estimating the number of flashes or blips.

The experimental facilities consisted of a room with a table and five chairs, a loudspeaker, and a tape recorder synchronized with a relay device connected to a 3-W neon lamp. The auditory stimuli were produced through the loudspeaker, which was placed behind the Ss, while the visual stimuli were reproduced through the neon bulb mounted on a black piece of cardboard located directly in front of the Ss.

As the participants came in they were given written instructions that stated that the experiment they were about to participate in was a study to determine how well they could remember seeing a series of flash signals and how well they could remember hearing a series of blip signals. Each S was told that he would be presented with 30 trials, and each trial consisted of four consecutive series of signals via the auditory channel and/or the visual channel. Each signal was to consist of 3, 4, 5, or 6 auditory blips or visual flashes. After each presentation trial, Ss were given 15 sec to write down the number of blips and/or flashes for each of the four serial positions.

Since the dependent variable was the number of errors on each condition, each response on the S's answer sheet was scored either right or wrong and the magnitude of each error was not taken into account.

### Design

Table 1 presents the 10 conditions used in the experiment. The first eight conditions represent the experimental conditions where switching of the auditory and/or the visual signals in each of the four

**Table 1**
**Position of the Auditory (A) and Visual (V) Signals in Each Condition**

| Condition | Position of Signal 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 Experimental | V | A | A | A |
| 2 Experimental | A | V | V | V |
| 3 Experimental | A | V | A | A |
| 4 Experimental | V | A | V | V |
| 5 Experimental | A | A | V | A |
| 6 Experimental | V | V | A | A |
| 7 Experimental | A | A | A | V |
| 8 Experimental | V | V | V | A |
| 9 Control | A | A | A | A |
| 10 Control | V | V | V | V |

positions is involved. The last two conditions represent the control conditions where no switching of modality is involved. Each S was exposed three times to each one of the 10 conditions.

The experiments required that there be 30 sets of four signals each, that is, 30 trials presented, with each trial containing a series of four signals. These were prepared by assigning the numbers 3, 4, 5, and 6 at random to the cells of a 30 by 4 matrix, with the restriction that no number appear more than once in a single row of four cells. Each signal within a set of four signals could be transmitted either through the auditory or the visual modality depending upon the particular condition involved. In addition, since a particular condition might provide an easier task when it occurred in one position than in another in the series of 30 trials, four different orders for the learning conditions within the 30 trials were prepared. For example, Condition 1 in Table 1 provided for three different trials of four consecutive signals—visual, auditory, auditory, and auditory, respectively. One trial of this V A A A sequence may present 5 flashes, 4 blips, 6 blips, and 3 blips consecutively. A second trial in the V A A A sequence may present 3 flashes, 4 blips, 5 blips, and 6 blips consecutively. Finally, a third trial in this V A A A sequence may present 6 flashes, 3 blips, 5 blips, and 4 blips consecutively. Conditions 2, 3, 4, and so forth to Condition 10 would each consist of three different trials of a particular sequence of blips and flashes.

### Subjects

The Ss were derived from undergraduate courses in educational psychology. Forty Ss were divided into four groups (10 Ss in each group), each of which was assigned to one of the four randomized presentation orders of 30 trials.

## RESULTS

The general experimental design called for 40 Ss to be divided into four groups of 10 Ss each, with each group representing one of four different randomized orders of presentations. Each randomized presentation consisted of 10 conditions (eight experimental and two control conditions) as shown in Table 1. As is evident in Table 1, each condition represented the different arrangements of the audio and visual transmission of information in a four-position serial learning sequence. More specifically, each condition consisted of three trials, with each trial consisting of a different sequence and number of blips and flashes. In short, each S participating in the experiment was given 30 total trials.

The dependent variable was the number of errors committed by each S on each condition and on combined similar conditions. The data were analyzed according to the number of errors made on each of the four positions of learning sequence. From the four positions, assessment could be made as to the facilitation or the disruption of learning when switching or switching-back of the modality presentation occurs.

Table 2 presents the mean number of errors and the standard deviations of each serial position of the experimental conditions and the control conditions. It should be noted that these experimental conditions are paired according to which serial position the switch and/or switch-back occurred. For example, if the switch and switch-back presentations occurred in the second and third positions, then number of errors in the experimental conditions involving A V A A and V A V V would be combined. Likewise, the same procedure was used for the other serial positions for the experimental groups. As for the control groups, the number of errors in the A A A A condition and the V V V V condition were combined.

Recall also that each separate condition, e.g., A A A A, was composed of three different trials, each trial using a different sequence of blips and a different number of blips. Thus, any combining of two similar conditions would really involve the *sum of six different trials in terms of their number of errors*, three trials from one condition and another three trials from the other condition.

The nature of the experimental design made possible the use of t tests between correlated means, mainly comparing learning in the switch and switch-back positions with learning in the corresponding control positions. Correlated t tests were also used in determining the significance of the differences in learning when sensory switching occurs in progressively later positions as in the second, third, and fourth positions.

*The switch positions.* Consider Table 2 and note the mean number of errors for the second-position switch involving Experimental Conditions 1 and 2 and 3 and 4. Each mean represented the mean number of errors out of six trials. For example, consider the first entry in the table (0.49 errors). This meant that each S was exposed to Conditions 1 and 2 for three trials each, so the table implies that out of six trials the 40 Ss made an average of 0.49 errors. That is to say, about one response in 12 was wrong. Visual comparison between these means and the mean of the corresponding second position in the control group (1.14 errors and 1.09 errors as compared to 1.11 errors) reveals very little difference. A formal comparison of the data from these switch positions with the control position indicated no statistically significant differences.

However, the third position switch, involving Conditions 5 and 6, seems to have considerably more error than the corresponding position of the control group. A significant difference was found when comparing the two group means ($t = 3.59$, $df = 78$, $p < .01$). A significant difference was also found when comparing Experimental Groups 7 and 8 on the fourth position switch with its corresponding control position ($t = 8.00$, $df = 78$, $p < .001$). In summary, more errors occurred in learning the blips and flashes when the switch occurred in the later serial positions. Thus, in the second position, there was no marked decrement in learning, as measured by number of

**Table 2**
**Mean Number of Errors for Six Trials and Standard Deviations for Each Serial Position of Related Pairs of Experimental Conditions and Control Conditions (N = 40 per cell; a total of six errors is possible for each cell).**

| Experimental Conditions | | Position 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD | M | SD |
| 1 & 2 | VAAA AVVV | 0.49 | 0.79 | 1.14* | 1.53 | 1.10 | 1.43 | 0.84 | 0.84 |
| 3 & 4 | AVAA VAVV | 0.94 | 1.31 | 1.09* | 1.42 | 1.05** | 1.31 | 0.86 | 1.18 |
| 5 & 6 | AAVA VVAV | 0.67 | 1.00 | 0.94 | .97 | 1.11* | 1.05 | 1.01** | 1.20 |
| 7 & 8 | AAAV VVVA | 0.69 | 1.08 | 0.74 | 1.07 | 0.93 | 0.63 | 1.41* | 1.72 |
| Control Conditions | | | | | | | | | |
| 9 & 10 | AAAA VVVV | .86 | 1.36 | 1.11 | 1.43 | .80 | 1.06 | .74 | .99 |

* *switch position* ** *switch-back position*

errors, whereas in the later positions, i.e., the third and fourth positions, considerable decrement in learning occurred.

*The switch-back positions.* There are only two pairs of experimental conditions that yield information about the switch-back position, and these are Conditions 3 and 4 and Conditions 5 and 6. In Conditions 3 and 4, the switch-back occurred in the third position and in Conditions 5 and 6 the switch-back occurred in the fourth position. In comparing the mean of 1.05 errors for the third position switch-back of Conditions 3 and 4 with the mean of 0.80 errors for the third position of the control group, a significant difference was found between these two means ($t = 5.84$, $df = 78$, $p < .01$). A significant difference was also found when the means of the fourth position switch-back of Conditions 5 and 6 (1.01 errors) were compared with the corresponding mean (0.74 errors) of the control group ($t = 2.38$, $df = 78$, $p < .05$).

*Comparison of the auditory conditions with the visual conditions.* The difficulty of the task in the all-auditory or predominantly auditory conditions could be compared with the difficulty of the task in the all-visual or predominantly visual conditions. From Table 3 it is evident that the visual treatments yielded more errors in learning. A significant t indicated the high degree of confidence that could be placed in the difference between the two groups ($t = 3.90$, $df = 799$, $p < .01$).

Table 3
Mean Number of Errors and Standard Deviations of All Audio or Predominantly Audio Conditions and All Visual or Predominantly Visual Conditions

| | M | SD |
|---|---|---|
| Conditions AAAA, VAAA, AVAA, AAVA, AAAV | 0.84 | .88 |
| Conditions VVVV, AVVV, VAVV, VVAV, VVVA | 1.01 | .85 |

## DISCUSSION

Of primary importance is the gradual increment in difficulty that occurs as the position where switching occurs is moved from the second to the third and to the fourth serial positions. This similar phenomenon occurred in the previous study by Chan and Travers (1965) where the later position switching resulted in a facilitation of learning on the switch and then a disruption of learning on the switch-back. The explanation given was that the earlier syllables in the presentation build up an expectation that the information is to be received through the *same* modality and, as a result, the transmission of information through a *different* modality becomes progressively more unexpected and, hence, increases the difficulty of making the switch as well as the time taken to make the switch. This, in turn, leaves progressively less time for processing the information after the switch. This explanation seems to fit very well the results discussed here. The evidence presented seems to suggest that the decrement due to switching is dependent on the serial position of the switch, that is, the amount of disruption increases as the switch occurs later in the series of signals. A similar experiment should be repeated with signals received through one modality over much longer periods in order to determine the extent to which this build-up may progress.

Several features of this study seem to be inconsistent with some of the results obtained in the Chan and Travers (1965) study and in the study by Judd (1927). In the present study, analysis of the data both in the switch position and in the switch-back position clearly indicated a decrement in performance, whereas, in the 1965 study, analysis of the results showed an increment in learning in the switch position and a decrement in the switch-back positions (for the fifth and sixth positions).

The differences in findings could well be attributed to the differences in the tasks in the two studies. The task in the present study places emphasis on perceptual recognition and short-term storage of the information, that is to say, storage for a matter of a few seconds. In contrast, the task in the 1965 study places little emphasis on perceptual processes, for each of the syllables is easily read in the time allotted, but it requires retention for a much longer period of time. The difficulty of the task in the 1965 study comes from the difficulty of discriminating the signals. The difficulty of the task in the earlier study would appear to derive from the requirement that a considerable amount of readily recognizable information has to be retained for a period that may be as long as several minutes.

Finally, the data from the present study are consistent with those of Judd, who reported that Ss found it easier to recognize the number of auditory blips than the number of flashes of light. Judd's explanation that adults have more experience in counting intermittent sounds than they have in counting flashes still seems plausible.

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## NOTE

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