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Incidental probability learning: Effects of task-relevant vs. irrelevant stimulus dimensions

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Relative effects of probabilities associated with task-relevant and irrelevant stimuli were studied in a probability learning paradigm. Four groups of 24 subjects each received different training experiences prior to sequentially predicting 200 occurrences of a green or yellow color. For 200 training trials subjects predicted the shape of arrows outlined on a green or yellow background. During training the two arrow shapes and background colors varied on independent probability distributions (i.e., each dimension either 75:25 or 50:50); during testing the colors varied on a 75:25 schedule. Regardless of the distribution of background colors during training, subjects who received a 75:25 distribution of arrow shapes during training predicted significantly more occurrences of the more probable color during testing than did subjects who received a 50:50 distribution of arrow shapes. Thus, the frequency bias associated with task-relevant stimuli in a probability learning paradigm influenced subsequent predictions of another stimulus dimension, but the probability distribution of the irrelevant stimulus dimension in the first task did not affect subsequent prediction strategies for the same dimension.

Recently the renowned probability learning paradigm introduced by Humphreys (1939) was extended to study incidental processing of frequency information. Specifically, Geller and Whitman (1972) presented subjects with stimuli differentiated into two separable, binary dimensions; the relative frequencies of the two stimulus alternatives of each dimension varied on constant, independent probability distributions. Prior to each of 200 training presentations, subjects predicted the stimulus alternatives of only one dimension; then for 200 test trials subjects predicted the stimulus alternatives of the other dimension. Subjects who predicted the alternatives of one dimension for 200 training trials showed faster probability learning when predicting the alternatives of the second dimension than did subjects who did not receive the training experience. Furthermore, the test predictions of an "intentional-learning" group (i.e., subjects who predicted the same dimension throughout training and test trials) were not reliably different from subjects' predictions in the "incidental-learning" condition (i.e., when the irrelevant stimulus dimension during training was relevant during testing). With these observations, Geller and Whitman concluded that "perceptual learning occurred incidentally during training" (p. 398).

The present experiment was designed to distinguish between effects of the relevant and irrelevant probability schedules presented during the training phase of the paradigm introduced by Geller and Whitman to study unintentional probability learning. For all of the training and test conditions in the Geller and Whitman experiment, the more frequent alternative of the relevant dimension occurred on 70% of the trials (i.e., a 70:30 probability schedule). Thus, the incidental learning observed in that study could have been due to the frequency bias associated with the task-relevant stimulus dimension rather than the irrelevant dimension. For example, the facilitated probability learning during testing could have resulted from subjects learning to predict according to a 70:30 frequency distribution (i.e., a learned response bias) rather than from incidental perception of the probability information conveyed by occurrences of the irrelevant stimulus dimension.

The present design separated potential effects of relevant and irrelevant frequency distributions by independently varying the probability schedules of both the relevant and the irrelevant stimuli prior to testing. More specifically, the stimulus alternatives of two binary training dimensions occurred on either a 75:25 or a 50:50 probability distribution, and, therefore, the independent manipulation of the schedules associated with both the relevant and irrelevant training dimensions defined four experimental conditions: (1) relevant dimension 75:25/irrelevant dimension 75:25, (2) relevant dimension 75:25/irrelevant dimension 50:50, (3) relevant dimension 50:50/irrelevant dimension 75:25, and (4) relevant dimension 50:50/irrelevant dimension 50:50. When subjects predicted the alternatives of the irrelevant training dimension (i.e., during testing), particular group comparisons enabled a differentiation of effects due to the relevant and irrelevant training stimuli. While the test predictions of Group 1 (defined above) reflected advantages due to a frequency bias for both the relevant and irrelevant training

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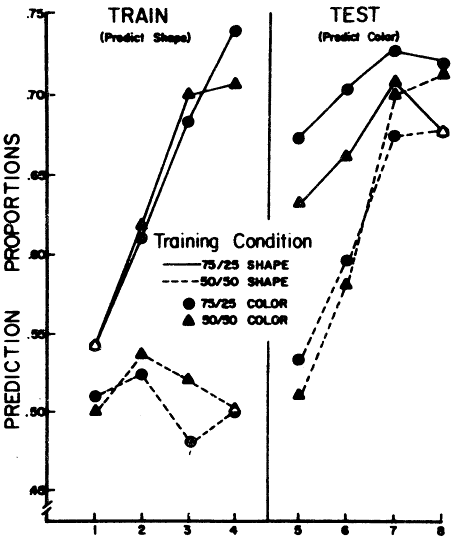

Figure 1. The group prediction proportions for the more frequent stimulus alternative within each consecutive block of 50 trials. For each condition the task-relevant dimension was shape (up vs. down) in training and color (green vs. yellow) in testing.

dimensions, comparisons between the test predictions of Groups 2 and 3 indicated relative effects of task-relevant stimuli (i.e., transferring the learned frequency bias from one stimulus dimension to another) and task-irrelevant stimuli (i.e., incidental perception of the frequency bias associated with irrelevant stimulus presentations).

METHOD

Subjects

The subjects were 96 students recruited from the introductory psychology classes at Virginia Polytechnic Institute and State University. Each student was randomly assigned to one of four experimental conditions, with the restriction that each group contain equal numbers of males females.

Design

In a probability learning task, four experimental groups of 24 subjects each received different training experiences prior to a testing condition during which all subjects verbally predicted the color (green or yellow) of 200 blank slides. For the training conditions subjects predicted which of two possible directions an arrow pointed on 200 trials (i.e., the arrow pointed "up" or "down"). During training the background color of the slide presentations of the arrows was green or yellow.

For the test condition 75% of the presentations were green and 25% were yellow. During training the two arrow shapes (up or down direction) and the two colors (green or yellow background) varied on independent probability distributions. The factorial of two possible shape schedules (75:25 vs. 50:50) and color schedules (75:25 vs. 50:50) defined four different two-dimensional presentation schedules. In other words, with *up* being the more probable shape and *green* the more probable color, the four experimental groups were differentiated according to the training condition as follows: Group 1 = 75% up/75% green, Group 2 = 75% up/50% green, Group 3 = 50% up/75% green, and Group 4 = 50% up/50% green.

Stimuli

The stimulus presentations used in the training conditions were similar to those used earlier (Geller & Whitman, 1972), i.e., slide projections of black-outlined arrows pointing up or down on a background of green or yellow. Unlike the test presentations used earlier by Geller and Whitman, the test slides in the present paradigm did *not* contain an up or down arrow but rather were blank backgrounds, either green or yellow in color.

The sequences of 200 stimulus presentations for the train and test conditions were determined by appropriate filtering of a uniform random-number generator on an IBM 370 computer system. The two-dimensional probability schedules for the four training conditions were derived so that the joint probabilities matched the theoretical probabilities within each block of 100 trials. For example, each 100-trial block of the 75% up/75% green schedule contained 56 up-green combinations, 19 up-yellows, 19 down-greens, and 6 down-yellows. For the test condition the same 75:25 distribution of colors was used for each experimental group, exactly 75 greens and 25 yellows occurring in each block of 100 trials.

Procedure

As in the earlier study (Geller & Whitman, 1972), the stimulus presentations were back-projected on a translucent screen, centered in a plywood partition that separated the subject from the experimenter. A timed shutter apparatus (Lafayette No. 43010) was positioned in front of the zoom lens of a Kodak Carousel projector and used to expose the slide presentations for a 3-sec duration. For each trial the sequence of events was as follows: (a) the subject's verbal stimulus prediction, (b) the experimenter's buttonpress that advanced the slide tray and then opened the shutter, and (c) a 3-sec presentation of the slide.

The task instructions encouraged the subjects to concentrate on their stimulus predictions and informed the subjects that the sequence of stimuli was predetermined by the order of slides in the trays. No information concerning the nature of the stimulus sequence was included in the instructions. When asking the subject to predict the arrow directions (i.e., before training), the experimenter made no mention of the different background colors. After the 200 training trials, the subjects were requested to verbally predict the color of each slide prior to each of 200 additional presentations. Before the test trials, the experimenter reminded the subjects that the order of slides was preprogrammed, but said nothing about the relevance of the training experience.

RESULTS

For each group, Figure 1 depicts mean prediction proportions within consecutive blocks of 50 trials (i.e., the proportions of up predictions during training and the proportions of green predictions during testing). For each condition the proportion of up predictions approximated the relative frequency of the up alternative, regardless of the probability distribution of the irrelevant color dimension. The group differences during the test condition illustrate prominent effects of the shape schedule during training. Both groups that received the 75:25 distribution of up:down arrow shapes during training predicted more occurrences of the green (75%) alternative for the first two trial blocks of testing than did the two groups that received equiprobable arrow shapes throughout training. Only a slight effect of the irrelevant color dimension on test predictions is evident in that the proportion of green predictions is consistently highest for the group that received a 75:25 distribution of both the shape and color dimensions during training.

The overall analysis of variance, a factorial of two shape distributions (75:25 vs. 50:50) by two color distributions (75:25 vs. 50:50) by two prediction conditions (train vs. test) by four blocks of 50 trials (within each condition), indicated significant main effects of the shape distribution, $F(1,92) = 45.85$, prediction condition, $F(1,92) = 97.30$, and trial block, $F(3,276) = 80.22$, all $ps < .001$. Only three interactions were reliable: Prediction Condition by Trial Block, $F(3,276) = 3.14$, $p < .025$, Shape Distribution by Prediction Condition, $F(1,92) = 20.82$, and Shape Distribution by Prediction Condition by Trial Block, $F(3,276) = 46.56$, $ps < .001$.

Using error estimates from the overall analysis of variance, the separate analysis for the training condition showed main effects of shape distribution and trial block, respectively, $F(1,92) = 91.09$ and $F(3,276) = 29.48$, $ps < .001$. Of the interactions, only Shape Distribution by Trial Block was significant, $F(3,276) = 36.48$, $p < .001$. These same terms were also the only reliable factors for testing, i.e., main effects of shape distribution and trial block, respectively, $F(1,92) = 10.65$, $p < .005$, and $F(3,276) = 50.08$, $p < .001$, and a significant interaction of Shape Distribution by Trial Block, $F(3,276) = 15.00$, $p < .001$. Separate analyses for each 50-trial block during testing indicated significant main effects of only the shape distribution for the first two blocks, $ps < .01$; no terms were significant in the analyses for the latter two trial blocks.

DISCUSSION

During each training condition, the prediction proportions eventually approximated the actual probabilities of the stimulus alternatives (i.e., 75% or 50% "up" arrows). Such probability matching has been often demonstrated in single-dimension probability learning tasks (e.g., see reviews by Estes, 1964 and Jones, 1971). The fact that predictions during training did not vary as a function of the distribution of green and yellow background colors indicates a lack of interference from an irrelevant stimulus dimension. This was also the case in the earlier study of incidental probability learning (Geller & Whitman, 1972) and supports the conclusion of other investigators that subjects can selectively attend to relevant stimulus values even when combined orthogonally with irrelevant stimuli (e.g., Egeth, 1967; Garner, 1970). Empirically, the arrow shapes and background colors were separable rather than integral dimensions (cf. Garner & Felfoldy, 1970).

Regardless of the incidental color probabilities during training, subjects' predictions during test trials showed significantly greater probability discrimination when the relevant training and testing probabilities were similar (75:25) than when the relevant training probabilities were unlike the testing probabilities (i.e., 50:50). Hence, as in the study that introduced the incidental probability learning paradigm (Geller & Whitman, 1972), subjects' prediction strategies during testing were significantly influenced by their prior experience in a situation that did not include relevant learning instructions. Such results are analogous to the incidental learning demonstrated with the standard Type II incidental-learning tasks (e.g., see review by McLaughlin, 1965). However, the particular nature of the between-group differences suggests that the incidental (noninstructed) probability learning was not due to perceptions of the *irrelevant* (incidental) stimulus dimension during training, but rather occurred as a function of the probability schedule associated with the *relevant* training dimension.

When the more-probable incidental color of training was the less-probable relevant color during testing, Geller and Whitman observed significantly fewer test predictions of the more-probable color than when the color probabilities were identical in the train and test conditions. This finding does suggest some degree of incidental perceptual learning of irrelevant stimulus probabilities. On the other hand, the subjects who received training trials with irrelevant color probabilities in the opposite direction as those given in testing predicted the more-probable color alternative significantly more often during the initial block of 50 test trials than did subjects who received no training trials. Geller and Whitman state that this group difference "indicates that the (incidental) learning of a 70-30 distribution of two (task-irrelevant) stimulus alternatives was readily transferred to another stimulus dimension even when the probabilities of that dimension had been reversed during incidental observation" (p. 398). However, the results of the present study suggest that the facilitated probability learning following prior prediction experience was largely the result of learning the relative frequencies of the task-relevant training dimension and then transferring that bias to a different test dimension.

In summary, the present findings indicate that probability learning can influence subjects' subsequent prediction strategies even when appropriate learning instructions are absent. However, contrary to the conclusions given by Geller and Whitman, the present study showed predictions of a binary color dimension to vary as a function of the probability distribution associated with a binary shape dimension rather than the same color dimension in a prior task that required subjects to predict arrow shapes. Thus, it is probable that the probabilities associated with a task-irrelevant stimulus dimension were not learned but that a response bias developed in one prediction task was transferred to a second prediction task with a different relevant stimulus dimension. It would be worthwhile for future research to determine the extent that incidental probability learning is influenced by important stimulus variables such as the number of task-irrelevant dimensions, the degree of probability bias associated with task-relevant and/or irrelevant dimensions, the relative salience of task-relevant and irrelevant dimensions, and the integrality between relevant and irrelevant stimulus dimensions.

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