

# Associative symmetry: I. Position learning in the gerbil

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Mongolian gerbils were trained to position in a Y maze, escaping the receipt of punishing heat by making an appropriate turn. A backward run from the positive goal was interpolated on every sixth trial, with the animal reinforced for going to either the negative goal or the start. A significant number of animals chose to return to the startbox, indicating that a bidirectional connection was formed between the start and positive goal during forward training. In addition, backward criterion was achieved significantly faster than forward criterion. The unexpected superiority of backward to forward performance was explained in terms of the relative massing of the forward trials, as well as the intrusion of curiosity behavior during frontward training. Accordingly, it was concluded that symmetrical connections are formed during forward learning.

According to trace or gestalt theory, the phenomenon of associative asymmetry, or unidirectional connections, is apparent rather than real. Kohler (1947) maintained that temporally and spatially contiguous stimuli are organized into a single trace so as to be unitary in experience. When these stimuli are separated in time so as to lead to the formation of two or more traces, certain laws of organization may then function to result in a fusion of the traces (Kohler, 1938). Because fusion implies a bilateral interaction between elements or traces, the apparent superiority of forward to backward learning is particularly devastating to trace theory. Accordingly, the gestalt position has been to accept associative symmetry as a fact in learning and to attribute asymmetry to an artifact such as the operation of a bias or set. This line of reasoning derives directly from Kohler (1947) who proposed that the main principle governing the organization of traces is the intent to learn. Therefore, the successful recall of learning could occur only if the original intent were reestablished during the test, thereby permitting the Hoffding function<sup>1</sup> to operate. If the set to learn in a forward direction constitutes part of intention, then it logically follows that a test for backward recall would result in poor performance by virtue of a failure in the Hoffding function. Hence, asymmetry is attributed to a failure of recall rather than association.

In accord with this point of view, Asch and Ebenholtz (1962) proposed that asymmetry in verbal learning is due to a lack of stimulus availability, perhaps induced by a set to learn directionally. That is to say, all standard training procedures implicitly direct the subject to go from the stimulus to the response term. Accordingly, the subject minimizes his task by utilizing only those cues within the stimuli which enable him to emit the appropriate response items efficiently. It is this partial learning of the

stimuli, as opposed to associative asymmetry, which may be responsible for relatively weak backward performance. To document this position, Asch and Ebenholtz (1962) demonstrated that the method of anticipation favored the recall of response items, in a paired-associate task, even when associative learning was not required. However, when controlling for stimulus and response availability by use of a prefamiliarization procedure, forward and backward associations were found to be of equal strength. In addition, nondirectional paired-associate training techniques (Asch, Ceraso, & Heimer, 1960; Asch & Ebenholtz, 1962, Experiments 2-4) invariably resulted in associative symmetry. Although the concept of symmetry has been supported by a variety of other studies (Arnold & Bower, 1972; Asch & Lindner, 1963; Dolinsky & Juska, 1967; Horowitz, Brown, & Weissbluth, 1964; Horowitz, Norman, & Day, 1966; Kanak & Neuner, 1970; Segal & Mandler, 1967), the issue still remains open to controversy.

From the standpoint of the connectionist, it has been maintained (Wolford, 1971) that backward associations are the epiphenomenal outcome of backward rehearsal. That is to say that sufficiently long interstimulus intervals promote practice from the response term to the stimulus item, resulting in apparent backward learning. Therefore, symmetry may be the product of two forward connections, one binding the stimulus to the response and the other the response to the stimulus. It logically followed that backward learning should diminish with reductions in rehearsal time (Ekstrand, 1966). Accordingly, Wollen (1968) found that minimal rehearsal selectively affected backward learning in a negative fashion, even under maximal stimulus availability.

Although the symmetry controversy is presently taking place on a verbal learning level, it has its roots in the classical and instrumental literature. In the classical situation, a backward conditioning

procedure has been used in an attempt to demonstrate symmetry. Although backward conditioning generally has been unsuccessful (e.g., Porter, 1938; Cason, 1935), in some instances backward learning has been found to develop in the initial stages of training, only to decrease as a function of added trials (Switzer, 1930; Spooner & Kellogg, 1947; Fitzwater & Reisman, 1952). In other cases (Bernstein, 1934; Harris, 1941), the backward response was found to be stable but relatively weak, and in one study (Wolfe, 1930) the backward conditioning of a finger flexion response to shock was found to be more effective than forward conditioning. Wolfe's findings have been partially substantiated by Champion and Jones (1961) and Zeiner and Grings (1968) who found no difference between forward and backward GSR conditioning, with shock used as the UCS.

There have been attempts to resolve the discrepancies found in the classical literature. On the one hand, it has been argued that backward conditioning may be explained in terms of pseudoconditioning as well as sensitization (Grether, 1938; Harlow, 1939; Osgood, 1953). On the other hand, it may be contended that the failure to produce backward learning is the result of a set to learn unidirectionally. Since the learning consists primarily of utilizing cues for anticipating events to come, the commission of the UCR to the CS is rendered totally inappropriate. The growth in such a set is evidenced by a decrease in backward conditioning as a function of increasing practice. The net result has been an attempt to either explain away backward conditioning or to attribute the failure of symmetry to the operation of a masking artifact.

Research in instrumental learning focused upon the attempt to condition an emitted response to a subsequently presented stimulus. The test for backward learning has been a growth either in a preference established for the CS, compared to a neutral one, or in the tendency for the CS to produce the instrumental response when presented prior to it. Successful backward conditioning (Barlow, 1952; Smith & Buchanan, 1954; Goodson & Brownstein, 1955; Yarborough, 1921) may be dismissed on the basis of the CS becoming a secondary reinforcer by virtue of its contiguity to a subsequently presented reward. To escape the criticism of secondary reinforcement, Brogden (1962) placed cats in a cage which they were able to rotate. Spontaneous cage turning responses on the part of the cats were followed by the presentation of a tone. Brogden (1962) found that after a series of such trials, the presentation of the tone during no activity produced a resumption of the instrumental response, thereby demonstrating backward learning in the alleged absence of reward. It may be argued, however, that no response can occur spontaneously. That is to say that the cage turning response must have been triggered by an internal or

external stimulus which endured throughout the activity period during training. This stimulus, then, would have been contiguous to the presentation of the tone. Therefore, Brogden (1962) may have merely demonstrated the contiguous conditioning of two stimuli, as opposed to backward learning.

In summary, the results in verbal learning, classical, and instrumental conditioning are inconclusive. The question of associative symmetry has yet to be resolved. Accordingly, the following series of studies were aimed at assessing whether learning develops symmetrically in an instrumental task which precludes interpretation on the basis of secondary reinforcement.

## METHOD

### General

Gerbils learned to perform a position response in a symmetrical Y maze. The forward learning sequence (i.e., running from the start to the positive goal) was interrupted on every sixth trial with an interpolated backward run. On the back run, the animal was placed in the positive goal and permitted to choose between the start position and the negative goal, with both choices reinforced. In order to enable the animal to discriminate start- and goalboxes, the interior of the three boxes differed in color. According to the logic of this experiment, if place learning was occurring on the forward trials and a symmetrical connection was being formed between the start and positive goal, then the animal should return to the startbox on the back trial. However, if the animal was merely acquiring a position response instead of structuring the maze, then on the back run the animal should emit the very same turn as before, thereby consistently entering into the negative goal. In the absence of place learning or cognitive structuring, no conclusion could be legitimately drawn about associative symmetry. Finally, purely random backward behavior could possibly be construed as reflecting associative asymmetry. It must be pointed out that since both choices were reinforced on the return run, this study did not assess backward learning performance. Rather, it dealt with preference behavior possibly established through associative symmetry. In addition, the backward trials were specifically interspersed with the forward sequence in order to prevent the buildup of a unidirectional learning set.

### Subjects

Ninety-six Mongolian gerbils, strain Mon/tum were run. They were all females, ranging in age from 5-9 weeks.

### Apparatus

A symmetrical Y maze was constructed of 1/2-in. plywood with the three arms intersecting at 120-deg angles. Each arm was 5 in. wide x 10 in. high x 13 in. long, with the last 5 in. of the arms serving as goalboxes. There was an 8-in. run from the intersection of the Y to the entrance of the 5 x 5 in. goalbox. One of the three boxes served as a start with the others as a positive and negative goal. Each box was created by dividing off a 5-in. section of the arm with a masonite panel which was inserted into vertical grooves cut into the walls of the maze. The masonite had 3-in. square doorways.

The interior of one of the boxes was lined with black leather, the second with white leather, and the third with 2-1/2-in.-wide black and white vertical stripes. As stated earlier, the boxes differed in color so as to enable the animal to structure the maze. The arms of the maze, as well as the outer halves of the masonite panels, were painted a uniform light gray of approximately 30% reflectance. Leather flaps concealed the entrance to each box, thereby serving as doorways. The color of the inside of the door coincided with its goalbox, while the outside of the door was uniform gray. Therefore,

the animal could not select a response on the basis of color and was unable to see the interior of the goal until making its choice.

The body of the maze sat upon a 1/8-in.-thick aluminum plate floor which was heated from below according to a procedure described by Broscole and Ulatowski (1973). The floor of the startbox and arms were heated to 45°C. The floor of the negative goal consisted of a separate plate which was heated to 50°C. Masonite pads, coated with aluminum paint, were used to insulate the positive goal on the forward runs, and the negative and startboxes on the back trials. Therefore, heat was used as an incentive for leaving the startbox and traversing the arms of the Y maze, with heat avoidance as a reinforcer. The entire device sat upon a lazy susan, enabling the maze to be randomly rotated from trial to trial. This was done to prevent the animal from orienting to stimuli within the testing room.

#### Procedure

The animals were put through 36 trials a day, with 30 forward and 6 back runs. The back runs were interpolated every sixth trial. On the forward run, the animal was placed in the startbox and required to make a position response (i.e., to turn right or left) to escape from the 45°C heated floor. The floor of the positive goal was at room temperature (approximately 25°C); the negative goal was at 50°C. Half of the animals were run to the right and half to the left. The animal was detained in the goalbox of its choice for 10 sec and was then returned to the start for the next trial. Between trials, the device was rotated on the lazy susan in a prescribed fashion. On the back run, the animal was placed in the positive goal which was heated to 45°C and was permitted to choose between the start and negative goal. Both responses were reinforced as the floors of the two boxes were now at room temperature. Again, the animal was detained in the selected box for 10 sec. The animals were tested until the completion of a forward and backward criterion day. Forward criterion consisted of 10 consecutive correct responses on a given day. Backward criterion was achieved when the animal completed 10 consecutive runs to either the start or negative goal. Since there were only six back trials per day, a minimum of 2 days of testing was required.

The color of the start- and goalboxes was counterbalanced over animals. There were 12 possible ways in which the color of the boxes and the position of the positive goal (i.e., right or left) could be varied. Eight animals were assigned to each color-position combination.

## RESULTS AND DISCUSSION

Forward criterion began in a mean of 20.09 front runs with 6.72 errors committed. Dividing the forward training trials into thirds, 68% of the responses were correct during the first third, 86% in the second, and 97% in the final stage. These differences were significant according to the Friedman two-way analysis of variance ( $\chi^2 = 133.95$ ,  $p < .01$ ). Subsequent sign tests indicated that there was a reliable increment from the first to the middle third of learning ( $Z = 8.82$ ,  $p < .01$ ), as well as from the middle to the final stage ( $Z = 6.93$ ,  $p < .01$ ). Therefore, it may be said that forward position learning progressed incrementally.

Backward criterion began in an average of 2.9 back runs, with a mean of 1.19 errors. Being free to choose between the negative goal and the start, 86 of the 96 animals preferred to return to the start position. Thus, a significant number of subjects demonstrated what may be considered either a preference for the start or an aversion to the negative goal ( $Z = 7.76$ ,  $p < .01$ ). Furthermore, it is interesting to note that 89

animals required fewer backward than forward training trials to reach criterion. However, it must be kept in mind that every back trial was preceded by five forward runs, so that the very first back run occurred on the sixth discrete trial. Thus, it was possible for an animal to require fewer backward than forward trials, but yet begin the backward after the first forward criterion trial. So, for example, an animal taking five forward and one back trial to reach criterion would have started its forward criterion run prior to the back run. Looking at the data, then, in terms of the absolute or discrete number of trials to begin criterion, the start of the back preference run was found to occur prior to the first forward criterion trial in 62 instances, or in 65% of the cases. According to the binomial test, a significant number of animals exhibited their back preference prior to forward learning ( $Z = 2.86$ ,  $p < .01$ ).

The return of an overwhelming number of animals to the startbox on the back run indicates that the forward training resulted in the formation of a cognitive map of the maze, as opposed to the acquisition of a mere turn to the right or left. Furthermore, the map must have been internalized, or represented in the memory system of the organism, as there were no distinguishing cues in the arms of the maze to steer the animal away from the negative goal or toward the startbox.

The data indicate that there was a superiority of backward to forward performance, as approximately two-thirds of the animals began their backward criterion run prior to the first forward criterion trial. Accordingly, it is tempting to speculate that there is asymmetry in favor of backward associations. However, it was recognized that there were several factors that may have interfered with forward performance, thereby masking the ongoing learning process. One of these factors was the relative massing of forward practice, and another the curiosity and exploratory behavior that is so characteristic of the gerbil. The curiosity effect was particularly noted on the front runs, where the animals spent an exhaustive amount of time examining the interior of the startbox as well as the alleyways. In addition, it is as if the reward of escaping heat was not sufficient to inhibit the animal from fully exploring the negative goal. As a result, the animal continued making errors, thereby delaying the start of its criterion run. In contrast to this, the back runs were made with relative speed, as if the animals were driven to return to the start.

although we have attempted to explain the relative inferiority of forward training, the argument cannot be extended so as to contend that forward conditioning would be more efficient than backward learning under optimal conditions. It is difficult to conceive of any conditions that would produce position learning in as few as 2.9 trials with only 1.19 errors. Therefore, it may be concluded that training results in symmetrical learning.

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## NOTE

1. The Hoffding function is a retrieval process based upon the structural similarity between the past and present.

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