Reversal Learning as a Function of Changed Reward Location or Changed Drive

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In two experiments, rats were trained with food in one location (e.g., black alley) and water in another location (white alley) under hunger or thirst. Subsequently, either the locations of the rewards were reversed, or the drive was changed (from hunger to thirst or thirst to hunger). Reversal of instrumental responses took considerably longer when drive was changed and rewards remained in the same locations than when reward locations were reversed. These results were interpreted as indicating that the animal's internal representations of the rewards received in each location transfer when drive is changed. These internal-reward representations interfere with reversal learning by eliciting the responses which were conditioned to them in Phase 1. Because the values of food and water reverse when drive is changed from hunger to thirst or vice versa, it was suggested that the reward representations surviving the drive shift are cognitive representations of the specific events received (food or water), independent of the value of the rewards under either hunger or thirst.

Many theorists have found it useful to postulate that when a cue consistently precedes reward, the cue comes to elicit some internal representation of the reward in the animal (e.g., Bolles, 1972, expectancies; E. J. Capaldi, 1970, memories; Spence, 1956, anticipatory goal responses). An additional useful assumption is that the internal stimuli produced by these reward representations develop become conditioned to instrumental responses. These assumptions have allowed explanation of many otherwise puzzling phenomena characteristic of instrumental learning, such as the partial-reinforcement effect. An important current research direction is the specification in detail of the properties of these representations.

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The term representation is employed as a general term reflecting what an animal stores about a reward when a stimulus is paired with a reward, e.g., an anticipatory goal response, an expectancy, a memory (what has been referred to as the "second learning process" by Trapold & Overmier, 1972).
internal reward representations. Much progress has been made along these lines. It has been shown, for example, that the animal's representation of small reward differs from that of large reward (Bloom, Williams, & Metze, 1973; Capaldi, Hovancik, & Friedman, 1976), and that the animal represents nonreward differently from reward (e.g., Amsel, 1958; E. J. Capaldi, 1970). The question of interest here was whether reward representations reflect only the value of the reward to the animal (affective reward representations), or whether representations of reward also reflect the specific event received (cognitive reward representations).

Previous results measuring transfer from one drive to another suggested that internal reward representations may be, at least in part, specific and cognitive (Capaldi & Hovancik, 1975). Interestingly, when reward representations were first proposed, they were assumed to be specific anticipatory goal responses, differing at least when different consummatory responses were made. Spence, Bergmann, & Lippitt (1950), for example, proposed $r_{g\text{eat}}$ and $r_{g\text{drink}}$ as anticipatory forms of two different consummatory responses. But gradually over the years the subscripts for $r_g$ were dropped, probably in part because anticipatory goal responses were viewed more as theoretical constructs than specific observable responses (Rescorla & Solomon, 1967). Also, drive research decreased in popularity. Most recent research has involved food reward and hunger, with quantitative rather than qualitative variations in reward. Perhaps related to this decline in drive research, the most common assumption has been that reward representations reflect the value of the reward, with these representations producing incentive motivation (e.g., Mowrer, 1960; Rescorla & Solomon, 1967).

But when only a single drive is used and reward is varied, cognitive and affective characteristics of the reward vary together. Results obtained when reward is varied and drive is held constant are thus consistent with either the hypothesis that reward representations reflect only the value of rewards to the animal (affective reward representations), or the hypothesis that reward representations also reflect the specific event received (cognitive reward representations). For example, the animal's differing representations of small and large reward, which have been demonstrated under hunger, could reflect the differing values of the rewards to the animal. Under hunger, large reward is presumably of greater value than is small reward. Alternatively, the animal's differing representations of small and large reward could reflect the specific rewards employed (e.g., 2 vs 22 pellets).

If reward is held constant, however, and drive is varied, the affective and cognitive characteristics of reward can be separated. A cognitive representation of, say, two pellets would be the same whether drive was hunger or thirst, because cognitive representations depend only on what the reward event is. Cognitive representations are independent of reward
value and thus are independent of drive. Under hunger, however, two pellets is positively valued, while under thirst, two pellets is not positively valued. Any representation of reward value (affective representation) is thus dependent on drive. As can be seen, one of the main differences between affective and cognitive reward representations is that affective representations are dependent on drive (because reward value is dependent on drive), while cognitive representations are independent of drive. This fact was taken advantage of in the present experiments, which varied both drive and rewards to determine if internal reward representations are at least in part specific and cognitive.

In Experiment 1, animals were trained in parallel black and white alleys with food in one alley and water in the other alley. Group D’s drive was changed from hunger in Phase 1 to thirst in Phase 2. In Phase 1, under hunger, Group D was expected to run faster in the alley containing food than in the alley containing water, while in Phase 2, under thirst, the reverse was expected. Consider each alley as a cue, and assume an internal representation of the reward received in each alley is formed in Phase 1. For Group D the value of the reward received in each alley changes from Phase 1 to Phase 2, while the actual rewards received in each alley do not change. Accordingly, any cognitive reward representation will be maintained from Phase 1 to 2, while any affective reward representation will be changed from Phase 1 to 2. Group R was trained under thirst in both phases, with the locations of food and water being reversed from Phase 1 to Phase 2. For Group R, then, both cognitive and affective reward representations must reverse from Phase 1 to Phase 2. Temporarily ignoring all other differences between the groups, the groups differ in terms of reward representations in that cognitive reward representations for Group D remain constant from Phase 1 to Phase 2, while for Group R cognitive reward representations must change. If Group D and Group R differ in reversal performance, this could indicate that cognitive reward representations exist. Other differences between the groups, such as the difference in drive experienced in Phase 1, could, of course, also be responsible for any difference in reversal performance. But before considering the effects of these other differences, the first question to be answered is, do Group R and Group D differ in reversal performance? This was the question posed in Experiment 1.

EXPERIMENT 1

Method

Subjects. The subjects were 20 naive male albino rats, about 90 days old upon arrival from the Holtzman Co., Madison, Wisconsin.

Apparatus. The apparatus consisted of two adjacent runways, one painted black and one painted white, plus a common gray startbox which
could be placed in front of either runway, total measurements being $144.8 \times 8.9 \times 10.2$ cm. The entire apparatus was covered with 1.3-cm hardware cloth. The startbox was separated from the runway by a metal door which was dropped by pushing a button. Dropping the door started the first of three .01-sec clocks. Clock 1 was stopped (start time) and Clock 2 started when the rat interrupted a photobeam 30.5 cm from the door. Clock 3 started when the rat broke the second photobeam located 43.2 cm from the first. Interruption of the third photobeam stopped Clock 3 (goal time). The third photobeam was 30.5 cm beyond the second photobeam and 7.6 cm in front of an appropriately colored block of wood with a mounted half teaspoon used as a food or water cup. A manually lowered guillotine door, 34.3 cm from the rear of the goal compartment, served to confine the rat to the goal area. Times from the three clocks were summed to produce total time.

Procedure. Rats were assigned to two groups matched on weight. Group D was brought to and maintained at 74–76% of its original ad libitum weight (3-day average). Group R was maintained on a 23-hr water-deprivation schedule, with food ad libitum. When first placed on water deprivation, Group R’s weights dropped to 91% of their original ad libitum weights. By the beginning of Phase 1, 14 days later, Group R’s weights had increased to 97% of their original ad libitum weight, and they increased gradually to 100% of their original ad libitum weight by the end of Phase 1. On each of the 3 days immediately prior to Phase 1, animals were handled individually for 90 sec. In Phase 1, each rat received two food and two water trials per day for 20 days. Half of each group received food in black and water in white, while the other half received the reverse alley-color-reward combinations. On any given trial, all rats were run in the same alley, all possible orders of black- and white-alley trials being employed in a random order. On food trials, animals received 20-sec access to 22 pellets, on water trials animals received 20-sec access to 1.5 cc of water. Animals were run randomly within squads of four composed of two rats from each group. A given squad was fed its daily ration or given its 1-hr access to water 15 min after completion of its trials. At the completion of Phase 1, Group D was placed on a 23-hr water-deprivation schedule. Phase 2 started 12 days after the end of Phase 1 when weights no longer differed between groups, both groups weighing 100% of original ad libitum weight, where weights remained throughout Phase 2. In Phase 2, there were two food and two water trials per day for 14 days. For Group D, food and water were given in the same locations as in Phase 1; for Group R, food and water locations were reversed. On each trial each rat was given 60 sec in each alley section before it was moved to the next section and 60 sec was recorded for the untraversed section. The start door was dropped after the rat oriented to the alley for 2 sec.
Results

All times were converted to speeds (1/sec). Analyses included color of S+ as a factor, but because this variable produced no significant effects, it is not mentioned further. Results in all alley sections were substantially the same, so results are presented only for total speeds. Figure 1 shows the mean speed for each group on the last 2 days of Phase 1 and on each day of Phase 2.

**Phase 1.** As can be seen in Fig. 1, in Phase 1, Group R (under thirst in Phase 1) ran more slowly in both S− and S+ than did Group D (under hunger in Phase 1). Also, the size of the difference between S+ and S− speeds was larger for Group R than for Group D. Both the difference associated with Groups and the Groups x S+ vs S− interaction were significant (F's(1,16) = 18.62 and 4.53, p's < .001 and .05, respectively).

**Phase 2.** In Phase 2, the locations of food and water were reversed for Group R and the drive remained thirst, while for Group D food and water remained in the same locations and drive was changed from hunger to thirst. As can be seen in Fig. 1, Group D was considerably retarded in

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**FIG. 1.** Mean total speed for each group in Experiment I on the last day of Phase 1 and each day of Phase 2.
reversal learning as compared to Group R. While Group R began to run consistently faster in their new S+ than in their new S− on Day 4 of Phase 2, Group D never ran consistently faster in their new S+ than in their new S−. This difference is reflected in a significant Groups × S+ vs S− interaction in Phase 2 ($F(1,16) = 11.47, p < .01$). Newman–Keuls tests indicated Group R ran significantly faster in S+ than in S− in Phase 2 ($p < .001$), while Group D did not.

Discussion

Keeping food and water in the same locations from Phase 1 to Phase 2 severely retarded reversal of instrumental responding. Group D never ran significantly faster in S+ than in S− in Phase 2. Group R, for which reward locations were changed, ran consistently faster in S+ than in S− beginning on Day 4 of Phase 2.

One possible reason for this difference between Group D and Group R is the difference between them in cognitive reward representations. If cognitive reward representations of food and water are formed in Phase 1, these representations will still be present in Phase 2 for Group D, but not for Group R. These representations will directly elicit inappropriate responses for Group D in Phase 2, interfering with reversal learning.

There are other possible reasons for the difference between Group D and R, though, which must be eliminated before it can be concluded that cognitive reward representations were formed and are responsible for the difference in reversal performance. First, the groups differed in the drive experienced in Phase 1. Group D was trained under hunger in Phase 1, while Group R was trained under thirst. Perhaps the difference in reward value between food and water is greater under hunger than under thirst, even though this difference wasn’t evident in running speed in Phase 1. Then Group D’s difficulty in reversal could be due to their having a greater difference in response strengths to overcome than Group R. To eliminate this possibility and to establish the generality of these results, Group D was trained with the opposite drive shift in Experiment 2, from thirst to hunger, with Group R being trained under hunger.

Another difference between Group D and Group R is that for Group D in Phase 1, food was consumed in the same alley where it occurred in Phase 2. In Phase 2 the food alley is to be avoided. Perhaps Group D continued to eat in Phase 2, making S− less aversive in Phase 2 for them. In Experiment 2, consummatory responding was recorded to determine if Group D continued to consume the previously relevant reward when it became irrelevant.

A third difference between the groups is that for Group D, drive was changed while, of course, for Group R drive was unchanged. Previous results indicate that, if anything, changing drive should facilitate reversal learning (Bolles, 1958; Wickens, Hall, & Reid, 1949). It seems unlikely,
then, that Group D's reversal performance was interfered with by changing drive rather than by leaving rewards in the same locations. But to further evaluate the effects of changing drive vs changing reward location, two additional groups were run in Experiment 2. For Group DR, drive was changed from thirst to hunger and reward locations were reversed from Phase 1 to Phase 2. When both drive and reward location are changed, the animal will approach the same external stimulus in Phase 1 and Phase 2, but under a new drive and to a new reward. For Group O both drive and reward location remained constant from Phase 1 to Phase 2.

**EXPERIMENT 2**

*Method*

*Subjects and apparatus.* Subjects and apparatus were of the same description as in Experiment 1. There were 40 rats in Experiment 2.

*Procedure.* All procedures were the same as in Experiment 1 with the following exceptions. Group D was trained in Phase 1 under thirst (23-hr water deprivation) with food *ad libitum*. Under this maintenance schedule, animals weighed 100% of original *ad libitum* weight. In Phase 2, Group D was trained under hunger (74–76% of original *ad libitum* weight due to food deprivation). Group R was trained in both phases under hunger. Two additional groups were run. Group O was trained in both phases under hunger and reward location was not changed from Phase 1 to Phase 2 (no-change control group). Group DR was trained in Phase 1 under thirst; in Phase 2 the group was shifted to hunger and reward locations were reversed. Phase 1 began 11 days after initiation of deprivation. Phase 2 began 16 days after the end of Phase 1, when all rats were within 74–76% of their original *ad libitum* weight. Consummatory behavior was recorded on all trials.

*Results*

Times were converted to speeds (1/sec) for analysis. Results in all alley sections were essentially the same, so only total speeds are presented here. Also, because color of S+ produced no significant effects, this variable is not mentioned further.

*Phase 1.* In Phase 1, all animals ran faster in S+ than in S−. This difference grew larger over days. The difference between S+ and S− running speeds was as large for rats run under hunger (Groups R and O) as for rats run under thirst (Groups DR and D). Analyses of variance indicated significant differences associated with S+ vs S− (*F* = 623.20, *p* < .001) and Days × S+ vs S− (*F* = 114.59, *p* < .001). The S+ vs S− × Deprivation interaction was not significant (*F* < 1).

*Phase 2.* Figure 2 shows the mean total speeds for each group in S+ and S− on the last day of Phase 1 and each day of Phase 2. As can be seen in Fig.
Group R reversed its response strengths more easily than did Group D, while Groups DR and O overlapped beginning on Day 1 of Phase 2.

Analysis of variance indicated that the S+ vs S- x Groups interaction was significant ($F(3,32) = 20.04, p < .001$) in Phase 2. Comparing pairs of groups, the S+ vs S- x Groups interaction was significant for every pair of groups except Group DR vs Group O. The critical comparison of Group D and Group R produced $F(1,32) = 40.74, p < .001$.

Although Groups DR and O did not differ significantly from each other in either Phase 1 or Phase 2, it is clear, as can be seen in Fig. 2, that Group DR was disrupted in performance by the change in drive and reward location. To evaluate this disruption, speeds for Groups O and DR on the first day of Phase 2 were compared to those on the last day of Phase 1. In this analysis, the Group DR vs Group O x S+ vs S- x Phase interaction was significant, indicating Group DR was disrupted by the change from Phase 1 to Phase 2 more than Group O ($F(1,18) = 7.03, p < .02$).

Consummatory behavior, S+. In both phases, all rats consumed the relevant reward on 100% of the trials. In Phase 1, the mean amounts consumed for groups under thirst were: Group DR, 1.26 cc water; Group D, 1.15 cc water. For groups under hunger, the mean amounts consumed were: Group R, 11.50 pellets; Group O, 11.61 pellets. In Phase 2, the mean...
amounts consumed in S+ were: Group DR, 12.73 pellets; Group D, 12.43 pellets; Group R, 12.71 pellets; Group O, 12.36 pellets. As can be seen, the groups did not differ in Phase 2 in either the frequency of eating or the amount of food consumed.

*Consummatory behavior, S−*. For groups under thirst in Phase 1, eating occurred on 28% of the S− trials for Group DR and 29% of the S− trials for Group D. For groups under hunger in Phase 1, drinking occurred on 30% of the S− trials for Group R and 40% of the S− trials for Group O. When consumption of the irrelevant reward occurred, very little of the reward was consumed, and the mean amount consumed did not vary by group: under thirst, Group DR, 3.3 pellets, Group D, 3.6 pellets; under hunger, Group R, .23 cc, Group O, .25 cc.

In Phase 2, all groups were under hunger. Groups D and DR were shifted to hunger from thirst in Phase 1, and water remained in the same location. Immediately upon the shift to thirst, both frequency of drinking and amount consumed dropped for Groups D and DR. Group DR drank on 53% of the Phase-2 S− trials (mean amount consumed = .25 cc); Group D drank on 42% of the Phase-2 S− trials (mean amount consumed = .23 cc). Considering groups maintained under hunger in both phases, Group O drank on 50% of the Phase-2 S− trials (mean amount consumed = .24 cc); Group R drank on 27% of the Phase-2 S− trials (mean amount consumed = .24 cc). As can be seen, the amounts of water consumed in Phase 2 were very small and were not greater for groups previously run under thirst. Groups did differ somewhat in frequency of drinking in Phase 2, but there was no systematic relationship between frequency of drinking and running speed in S−. Although Group D drank more frequently and ran faster in S− than Group R, Group O drank even more frequently, but ran more slowly in S−, than Group R.

**Discussion**

Keeping rewards in the same locations and changing drive (Group D) interfered with reversal learning more than keeping drive the same and changing reward locations (Group R) both when drive was changed from thirst to hunger (Experiment 2) and when drive was changed from hunger to thirst (Experiment 1). Accordingly, the difference in the effects of drive and reward location shifts cannot be attributed to any factor associated with a particular drive (e.g., a larger difference in reward value between food and water under hunger than under thirst, etc.).

When consumption of water occurred in Phase 2, the amount consumed was very small and did not vary by group. Groups did differ somewhat in frequency of drinking in Phase 2, but drinking frequency in S− was not monotonically related to running speed in S−. Thus, it does not seem that differences in consummatory responding as a function of drive and reward location shifts were responsible for the differences in running speeds.
If the difference between Groups D and R is attributed to internal cues characteristic of specific representations of reward events being conditioned to instrumental responses, then Group DR should be disrupted in performance by the change from Phase 1 to Phase 2. For Group DR, S+ and S− remained the same colors in Phases 1 and 2, but a new reward was experienced under a new drive in each alley. Thus, new cognitive reward representations must be formed in each alley, and instrumental responses must be conditioned to these new reward representations. In Experiment 2, Group DR was disrupted by the simultaneous shift in drive and reward location, but on Day 1 of Phase 2, Group DR ran as rapidly as Group O in S+ and as slowly as Group O in S−. These results are difficult to interpret. It is not clear whether the disruption shown by Group DR is a reflection of the change in drive and reward location producing stimulus generalization decrement, or if Group DR is just shifting to the level appropriate to the new drive of hunger. To further evaluate the effects of a simultaneous change in drive and reward location, a Phase 3 was run. In Phase 3, all groups were shifted to thirst and reward location was reversed; thus, in Phase 3, S+ was the same color as it was in Phase 2 for all groups.

**Method, Phase 3, Experiment 2**

After completion of Phase 2, all subjects were fed *ad libitum* until they attained their original *ad libitum* weight, which required 7 days. Then all rats were placed on a 23-hr water-deprivation schedule with food continuing *ad libitum* for 5 days before Phase 3 began. In Phase 3, all animals were run under thirst with food and water locations for all groups reversed from those in Phase 2. There were two food and two water trials per day for 20 days in Phase 3.

**Results.** Figure 3 shows the mean total speeds for each group on the last day of Phase 2 and each day of Phase 3. As can be seen in Fig. 3, every group's discrimination performance was disrupted by the change in drive and reward location.

To evaluate this disruption, performance on the last 8 days of Phase 2 was compared to that on the first 8 days of Phase 3. In this analysis, the S+ vs S− × Phase interaction was significant (*F*(1,36) = 291.19, *p* < .001), indicating the disruption in discrimination performance by the change from Phase 2 to Phase 3. The size of this disruption did not vary significantly by group (for the S+ vs S− × Phase × Group interaction, *F*(3,36) = 1.17, *p* > .30), every group's performance being significantly disrupted by the shift from Phase 2 to 3.

There were no significant differences between groups in frequency or amount consumed in S+ or S− in Phase 3.

**Discussion.** In Phase 3, the performance of each group was disrupted by the simultaneous change in drive and reward location. Since the same external stimulus was S+ ("good") in Phases 2 and 3 for each group, and
the same external stimulus was S− ("bad") in Phases 2 and 3 for each group, these data indicate the importance of the internal cues provided by specific, cognitive reward representations and drive.

Phase 3 results also rule out any interpretation of Phase 2 results solely in terms of drive stimuli playing a special role in eliciting expectations of reward value. Recent results from our laboratory (Capaldi, Smith, & White, in press) indicate that drive stimuli do have strong control over expectancies of reward value (i.e., affective reward representations). Thus it could be suggested, in explanation of the difference between Group D and Group R in Phase 2, that only affective expectations of reward are formed (contrary to our hypothesis), and changing drive stimuli produced weakening of these expectations of reward value for Group D. In Phase 2, the expectation of high reward value in their former S+ would be weaker for Group D than for Group R, little frustration would be experienced when S+ became S−, and Group D would be retarded in Phase 2 reversal learning relative to Group R. If this were the only factor producing a difference between Group D and Group R there should have been little or no disruption for Group DR in Phase 3. For Group DR, the external alley colors which were S+ and S− remained constant throughout all three phases. In Phase 1, expectancies of high reward value in S+ and low reward value in S− were conditioned to the drive stimulus characteristic of thirst; in Phase 2, these expectancies were conditioned to the drive stimulus characteristic of hunger. Thus, in Phase 3, neither the reward values nor the drive stimulus are new for Group
Yet the disruption shown by Group DR was as great as that shown by any other group in Phase 3. Also, in Phase 3, Groups R and O which experienced a new drive stimulus were not more disrupted than the other two groups which had previously experienced thirst. Although drive stimuli may play an important role in eliciting affective reward representations, Phase 3 results for Group DR indicate that at least part of the reward representation formed is cognitive and independent of drive.

GENERAL DISCUSSION

In both experiments, changing drive and leaving rewards in the same locations severely retarded reversal learning. This result can be interpreted as indicating that representations of the reward received in each alley survived the drive shift. By continuing to elicit responses conditioned in Phase 1, these reward representations interfered with Phase 2 reversal. Because changing drive reversed the values of the rewards received (food more valued than water under hunger, vice versa under thirst), the representations of reward surviving the drive shift are best interpreted as independent of the value of the rewards under any particular drive. These results thus support the hypothesis that reward representations are at least in part specific and cognitive, independent of reward value.

In support of this hypothesis, it was also found here that simultaneously changing drive and reward location disrupted performance. When drive and reward location are simultaneously changed, the same alley color remains S+ and S− before and after the shift. If only affective representations of reward were formed, this shift would involve a change in drive stimuli and perhaps a change in affective representations (if the difference in value between food and water is greater under one drive than under the other). Because simultaneous shifts in drive and reward disrupted performance whether or not the drive stimulus was new, the source of disruption was not entirely the new drive stimulus. Also, simultaneous shifts in drive and reward disrupted performance whether drive was shifted from hunger to thirst or vice versa. Thus, the source of the disruption does not appear to be a greater difference in reward value under one drive than the other. The disruption in performance with simultaneous drive, reward location shifts can be interpreted to indicate cognitive representations of reward are formed and become conditioned to the response. When drive and reward location are simultaneously changed, cognitive reward representations must reverse, disrupting performance.

The suggestion that reward representations are at least in part specific and cognitive implies that some of the learning about reward events is drive independent. This conclusion may seem contradictory to previous conclusions reached regarding irrelevant incentive learning. Many years ago a large number of experiments were concerned with whether or not an
animal could learn about the location of a reward for which it was not motivated at the time of learning (irrelevant incentive learning). The conclusion reached at the time was that animals cannot learn the location of an incentive if the only drive present is a strong irrelevant drive (Spence et al., 1950). This conclusion was supported by results obtained by Kendler (1946, 1947) as well as by those of Spence et al. (1950). In 1946, Kendler trained animals under both hunger and thirst, with food on the left of a T maze and water on the right. The animals subsequently chose food when tested hungry and water when tested thirsty, demonstrating that they had learned the locations of the reward events when trained under both hunger and thirst. Spence et al. reported similar findings when training occurred under satiation. In contrast, in 1947 Kendler trained animals under only one drive, e.g., hunger, with food on the left and water on the right of a T maze. These animals continued to choose food whether tested hungry or thirsty. Accordingly, these experiments led to the generalization that when trained under a single strong drive, animals cannot learn the location of an irrelevant incentive. This conclusion followed from these experiments because it was assumed that if the animal "knew" the location of the irrelevant incentive, it would choose the side containing that incentive when it became relevant. Our results indicate that this is not so. Although an animal may have formed a representation of water on the left, say, this representation will be inhibitory if training was given under hunger. That is, although appropriate cognitive reward representations will be formed when training is given under a single strong drive, the representation of the relevant reward will elicit excitation (approach) and the representation of the irrelevant incentive will elicit inhibition (avoidance). These instrumental response connections oppose choice of the appropriate side when testing occurs under a different drive. If training occurs under satiation (Spence et al., 1950) or under both hunger and thirst (Kendler, 1946), habit and inhibition to the two arms of the T maze will be roughly nondifferential, and performance in the test will reflect the current value of the rewards expected in the two arms.

This analysis implies that when no instrumental response is explicitly conditioned during Phase 1, as, for example, when noncontingent pairings of a stimulus with a reward are employed, the effects of the cue should be largely determined by the value of the reward under testing drive. Whether the value of the reward under pairing drive will have any effect depends on what happens to the components of reward representations due to value under Phase 1 drive when a new drive is experienced in Phase 2. The simplest assumption is that when drive is changed any value components of reward representations due to Phase 1 drive are completely and immediately replaced by value components due to Phase 2 drive. Although consistent with this hypothesis, available data are not conclusive. Bindra and Palfai (1967), for example, reported that a cue which was paired with...
food under hunger increased activity only if the animal was tested hungry. This result indicates that the value of food due to hunger was not conditioned during pairings. Rather a cue paired with food produced positive motivation only if hunger was present in the test phase, indicating value due to drive was determined by testing drive, not pairing drive. Similar results were obtained by Pliskoff and Tolliver (1960), who found a cue which was paired with food under hunger to be actually aversive when presented under thirst. Apparent exceptions to this hypothesis are cases where a cue for a given reward has been found to facilitate performance under a new drive (e.g., D'Amato, 1955; Estes, 1949). But this effect would be expected whenever the reward is positively valued under the new drive, or at least positively valued relative to the control stimuli employed, such as a cue for nonreward (Bower & Kaufman, 1963; Lambert & Hammond, 1972). By employing unchanged drive control groups, the value of rewards under testing drive could be determined, and the extent to which value components of reward representations transfer when drive is changed could be measured.

Given the central role assigned to representations of reward in controlling behavior within current theories (e.g., Bolles, 1972), it is critical to answer these and other questions regarding the form in which animals represent rewards. While previous studies have indicated animals form discriminably different expectancies of two different relevant rewards, e.g., food and sucrose under hunger (Trapold, 1970), it would be difficult to demonstrate conclusively that the value of food and sucrose are equal under hunger. Accordingly, this result does not indicate whether these different expectancies reflect the specific goal events received, or two different values of goal event, or both. The present experiments indicate that to manipulate drive is a useful method of separating affective from cognitive components of reward representations and determining the role of these various components in controlling performance.

REFERENCES


Bolles, R. C. A replication and further analysis of a study on position reversal learning in hungry and thirsty rats. Journal of Comparative and Physiological Psychology. 1958. 51, 349.


Bower, G., & Kaufman, R. Transfer across drives of the discriminative effect of the Pavlovian


Trapold, M. A. Are expectancies based on different positive reinforcing events discriminably different? *Learning and Motivation*, 1970, 1, 129–140.


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