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Facilitation by Alcohol of Active Avoidance Acquisition Performance in the Goldfish[1]

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BRYANT, R. C., F. PETTY, J. WARREN AND W. L. BYRNE. *Facilitation by alcohol of active avoidance acquisition in the goldfish.* PHARMAC. BIOCHEM. BEHAV. 1(5) 523–529, 1973.– Common goldfish *(Carassius auratus)* were exposed for 3 hr or 6 hr to alcohol solution (628 mg per 100 ml) or were treated identically but never exposed to alcohol. Following pretraining exposure, fish were given 20 trials of active dark-avoidance training in individual shuttle boxes. Alcohol-treated fish obtained significantly higher mean levels of correct responding during acquisition. The enhancement of acquisition performance was not appreciably altered by 6-hr compared with 3-hr pretraining exposure. Neither was the enhanced acquisition performance attributable to increased general shuttling during the 10-sec shock-free conditioned stimulus period. There was some evidence that alcohol-treated fish, compared with controls, swam into and out of the electrified compartment more often during training; however, this sort of responding correlated with correct responding no better for alcohol-treated than for control fish. In another experiment, alcohol was shown to increase sensitivity to light in goldfish. The explanation of the observed facilitation by alcohol of acquisition performance in goldfish may involve an effect on stress or anxiety; an effect of increased sensitivity to electric shock; or an effect of acute increased availability of central monoamines.

Alcohol Learning Goldfish

IN A series of experiments, Ryback [24, 25, 26] has studied the effects of alcohol (ethanol) on learning and memory phenomena in the common goldfish, a hardy and versatile vertebrate [3, 11, 14, 22]. In Ryback's work, alcohol was reported either to impair initial acquisition performance [25], or to have no effect on it [24, 25, 26], although nonsignificant improvement of acquisition was suggested in some experiments. Ryback's results were obtained by use of a continuous Y-maze in which fish were trained to criterion on a left–right discrimination, being punished for an incorrect choice only by bumping into a transparent barrier. We have previously argued that such a procedure may not be optimal to demonstrate alcohol-associated facilitation of acquisition performance in goldfish [21].

Using a shuttle box, we showed that alcohol, in a dose-related manner, facilitated acquisition performance in goldfish trained on dark avoidance (i.e., shock-reinforced active conditioned avoidance cued by dark-onset in the fish's compartment). In that work [21] fish were exposed to alcohol before and during the 20-trial training session. The period of pretraining exposure we used was 3 hr, since it has been reported that steady-state equilibrium is attained between alcohol in the medium and blood alcohol in the goldfish at 3 hr [27]. However, the question has been raised, both in our own considerations and implicitly by the work of others [24,26], whether the behavioral effects of alcohol observed by us might be significantly modified by longer exposure, specifically by 6-hr pretraining immersion [24,26].

In Petty *et al.* [21], the first correct shuttle response after the onset of the 10-sec shock-free CS-period (CS = conditioned stimulus) was used to gauge the level of acquisition performance in alcohol-treated and nonalcohol-treated fish. Although we demonstrated in that work [21] that a score representing "other responding" in the training situation (total shuttle responses – correct shuttle responses) did not differ significantly with alcohol treatment, the possibility remained that increased general locomotor activity specifically during the shock-free CS-period might account for increased acquisition performance in alcohol-treated fish. We were particularly interested in this question since we know that alcohol, in the doses used in our work, significantly elevates general locomotor activity in non-training situations, whether activity is measured in the shuttle box apparatus or in an open-field for fish (Bryant, Petty, and Byrne, unpublished data).

Correct responding in our procedure involves learning to

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swim out of the darkened compartment into the lighted compartment; therefore, a third question we considered was whether the facilitation of correct dark-avoidance performance could be explained by decreased sensitivity to light in alcohol-treated fish, an effect which in itself would probably facilitate correct dark-avoidance responding. In fact, one report [12] has indicated increased sensitivity to light in alcohol-treated goldfish. However, since our procedure differed in several general ways from theirs [12], we considered the question worth investigating directly. The relation between alcohol-treatment and responsivity to electric shock (which we are continuing to investigate) is perhaps affined to the question of light-sensitivity. Scobie and Herman [28] have reported that alcohol decreases aversive thresholds in goldfish. Nonetheless, it is also known that alcohol – whose pharmacological properties are generally considered to be those of a short-acting sedative-hypnotic [18] – has analgesic effects [23,29]. Hence our interest in the analysis of shock-related responding in our procedure.

In the present work, therefore, we have examined whether the effect of alcohol on acquisition performance, previously reported [21], is modified by 6-hr pretraining exposure; and whether the effect can be accounted for by changes in general activity during the CS-period or by a change in sensitivity to light. We have also analyzed shock-related responding in alcohol-treated and nonalcohol-treated fish during training.

EXPERIMENT 1

Method

Animals. Goldfish were obtained, maintained, and handled as described previously [21]. We used 180 common goldfish *(Carassius auratus)*, 8–10 cm in length, obtained from Ozark Fisheries, Stoutland, Missouri, U.S.A. After arrival in our laboratory, fish were placed in large aerated holding tanks and were subsequently placed, for use in the experiment, into shallow home tanks, 2 fish per tank [4]. They were routinely fed commercial pellet fish food in the holding tank but were not fed on the day of the experiment. The laboratory where all fish were housed was constantly illuminated, with temperature maintained at 21 ± 1°C. Fish were obtained and used during the months of March and April.

Apparatus. Training was conducted, as previously described [21], by use of a specially designed fish behavior apparatus [4, 5, 6]. The apparatus consisted of 10 clear polycarbonate plastic tanks (28.5 × 18 × 12.5 cm, lwd) with associated, operationally silent, electronic circiutry controlling stimulus presentations; responses were registered on electromechanical counters. Each shuttle box was halved by an opaque partition allowing 3 cm clearance underneath. Passages completely under the partition (shuttle responses) were monitored by photocell units. Electrodes (Monel wire mesh) covering the ends of the tank and both sides of the central partition could supply electric shock in one end of the tank only (7 V for 0.1 sec pulsed once each sec). Clear stimulus lamps were mounted at each end of the tank. During training, the shuttle boxes were under covers with flat black interiors, isolating the shuttle boxes from each other and from outside activity. Each shuttle box had a houselight mounted centrally in the cover.

Procedure. Alcohol treatment and training were carried out as described previously [21] except that for half of the alcohol-treated fish, exposure to alcohol began 6 hr prior to training, whereas for the remainder of the alcohol-treated fish, exposure began 3 hr before. Alcohol in the fish's water was 628 mg per 100 ml (628 mg%) [21]. For both the 6-hr and the 3-hr alcohol groups, control groups were run which were treated identically with the exception that they were never exposed to alcohol before or during training. Thus, there were 4 groups of 40 fish each: 2 alcohol-treated groups (3-hr and 6-hr) and 2 control groups (3-hr and 6-hr). Following the pretraining exposure period, fish were immediately placed into the individual shuttle boxes of the training apparatus in the same concentration of alcohol (628 mg%), or water only, as during pretraining immersion. (Both the tanks in which fish were given pretraining exposure, and the individual shuttle boxes, contained 4.25 l of water or alcohol solution). Fish were then given 20 trials of active dark-avoidance training. A trial of dark-avoidance training consisted of 10 sec of darkness in the compartment occupied by the fish (i.e., the stimulus light in the unoccupied compartment was illuminated), followed by the addition of electric shock (in the compartment intially occupied by the fish) for 50 sec, after which darkness was again presented to the fish in the occupied compartment, initiating the next trial. The stimulus light in the compartment into which the fish swam to escape or avoid shock remained on during the entire 60-sec trial. The houselight was on only before the beginning of the first trial and after the last trial of a session. A correct response was counted if the fish avoided shock by swimming out of the darkened compartment within 10 sec of the beginning of a given trial. Active dark-avoidance training was used to examine drug effects on learning since we as well as others [2, 5, 7] have found it a more difficult task for fish than active light-avoidance. Furthermore, dark-avoidance training and testing avoids the problem of simple sensitization or pseudo-conditioning with respect to the nonnegligible levels of preexisting, unconditioned, light-avoidance responding in goldfish (Bryant, unpublished data).

In addition to correct responding (CR), total CS-period shuttles (CST) and total shuttles made during the session (T) were recorded. Only one CR could be recorded per trial, as indicated.

Results

Figure 1 (Panel A) presents the mean levels of correct responding for fish exposed to alcohol for 3-hr or 6-hr, and for nonalcohol-treated controls. Alcohol-treated fish obtained a mean level of correct responding significantly higher than that for control fish ($F = 60.87$, df 1/156, $p<0.00001$). The difference between means of alcohol-treated and control fish did not vary between 3-hr and 6-hr ($F = 0.035$, df 1/156), and there was no difference between means of 3-hr and 6-hr groups ($F = 0.079$, df 1/156). For the 3-hr groups, the results reported here are essentially the same, as regards the difference between alcohol-treated and control fish, as those reported previously [21]. However, comparison between mean levels reported in that paper and those in the present work, showed significantly higher levels of correct responding for both alcohol-treated ($F = 5.28$, df 1/58, $p = 0.025$) and control fish ($F = 4.09$, df 1/58, $p = 0.048$), compared with the similar groups in the present study. Although we are unable to account with certainty for this drift, we suspect seasonal differences in fish acquisition performance [2]. In any case, the effect of alcohol

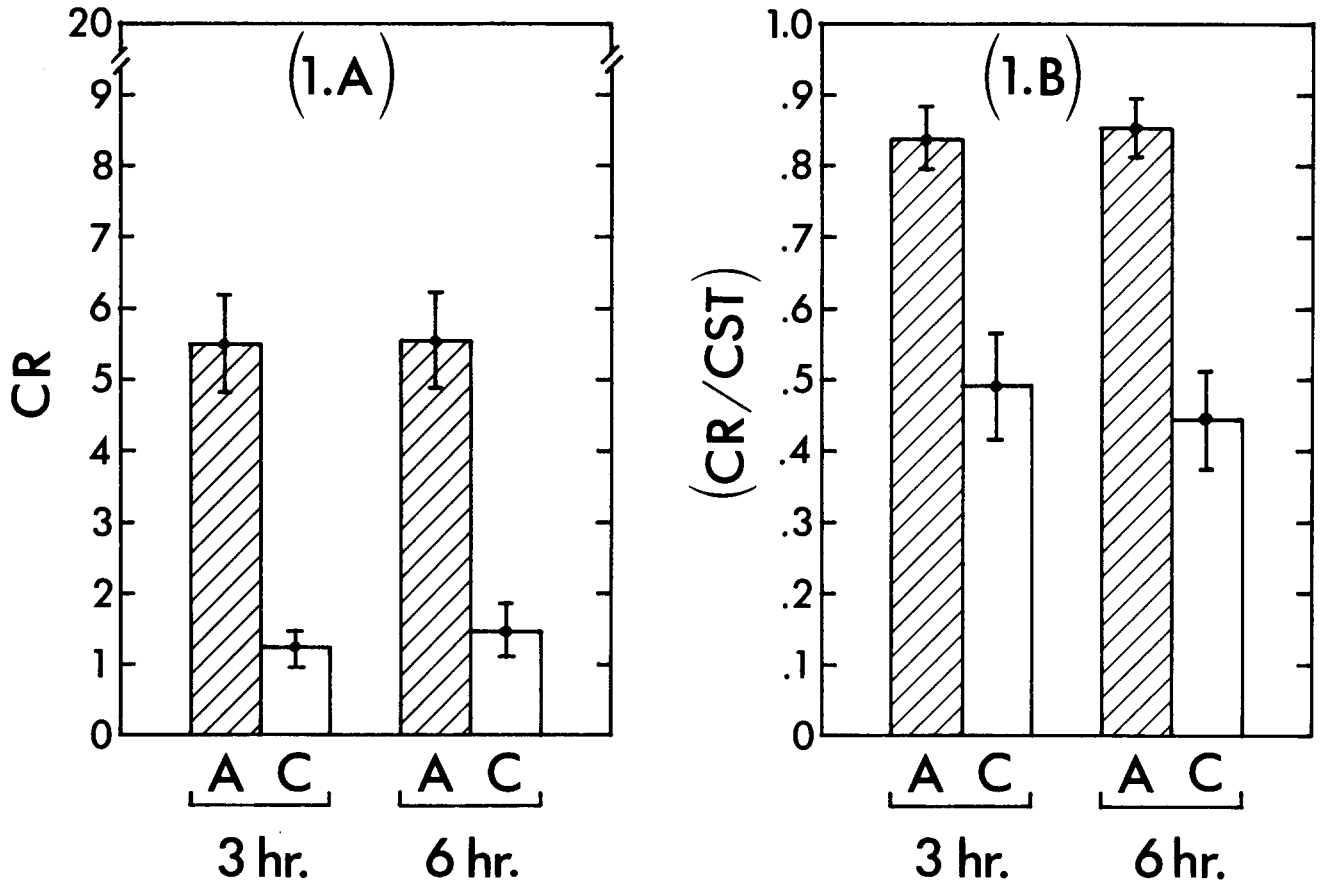

FIG. 1. (A) Mean levels (± standard error of the mean) for correct responding for alcohol-treated (A) and control (C) fish, given pretraining exposure for 3 or 6 hr. (B) Mean levels (± SEM) for alcohol-treated and control fish, given pretraining exposure for 3 or 6 hr, for a score defined as (CR/CST). CR = correct responding. CST = total shuttle responding during the CS-period.

on acquisition may be observed with fish used during September-October [21] or March-April (the present work).

Panel B of Fig. 1 presents, for 3-hr and 6-hr alcohol-treated and control fish, the mean levels of a score calculated for each fish as (CR/CST), where CR is the fish's total number of correct responses, and CST is the total number of shuttle responses during the CS period. This score is the proportion of the fish's total shuttles during the CS period that were correct responses. Analysis of these scores confirmed that alcohol-treated fish obrained a mean level significantly higher than that for controls ($F = 41.45$, df 1/156, $p<0.0001$). Similarly, the difference between means for alcohol-treated and control fish did not vary between 3-hr and 6-hr groups ($F = 0.27$, df 1/156), and there was again no difference between means for 3-hr and 6-hr groups ($F = 0.08$, df 1/156). (Probabilities for an F test for two groups are of course equivalent to a two-tailed t-test. All reported probabilities for F values for given degrees for freedom were obtained by evaluation of a continued fraction of the incomplete beta function [1].)

Separate analysis of the non-CR shuttling during the CS period (i.e., [CST−CR]) showed no difference between alcohol-treated and control fish ($F = 0.02$, df 1/156); and no difference between alcohol-treated and control fish according to length of pretraining exposure ($F = 1.23$, df 1/156). Reanalysis of the (CST−CR) scores following transformation ($\sqrt{X + 0.4}$) [9] yielded virtually identical conclusions.

(When we use the phrase, "no difference was found between the two groups," or a similar one, in describing the results, we wish this to be understood as indicating we were unable to reject the hypothesis of no difference, not as acceptance of the null hypothesis.)

For each fish, an additional score was defined as (T−CST), where T is total shuttles and CST is total shuttles during the CS period. Analysis of these scores showed no difference between means for 3-hr and 6-hr groups ($F = 0.001$, df 1/156) and no difference between means of alcohol-treated and control fish ($F = 1.01$, df 1/156); the difference between means for alcohol-treated and control fish did not vary significantly between 3-hr and 6-hr groups ($F = 0.47$, df 1/156). It should be noted that this measure differs from the score (total shuttles − correct responses) used in our previous paper [21] in that the effect of CS-period shuttling is completely removed. However, the score, (T−CST), still contains the following components: punished approaches (i.e., responses made swimming into the unsafe compartment); responses which we call primary escapes (i.e., escapes made on trials in which a CR did not

occur); and secondary escapes (i.e., escapes made following a punished approach). In an effort to further partition the measure, (T–CST), the following analysis was performed: The expected number of primary escapes for a given fish was taken to be the difference between that fish's number of CR's and 20 (the number of trials). A score for each fish was then calculated by subtracting this number, (20–CR), from total shock-related responding, (T–CST): i.e., [(T–CST) – (20–CR)]; or be rearrangement, (T+CR) – (20+CST).

Analysis of the score, [(T–CST) – (20–CR)], showed no difference between 3-hr and 6-hr groups ($F = 0.004$, df 1/156) and no difference between alcohol-treated and control fish that varied according to length of pretraining exposure ($F = 0.38$, df 1/156). However, the mean level for alcohol-treated fish ($\bar{x} = 7.74$) was significantly higher than that for control fish ($\bar{x} = 0.25$) ($F = 4.61$, df 1/156, $p<0.03$).

A negative value for the score, [(T–CST) – (20–CR)], is indicative of a failure of primary escape (though the magnitude of the deficit is indeterminate), since if a fish fails to make a primary escape, it will also fail to make any punished approaches or secondary escapes. For alcohol-treated fish, the ratio of animals with negative scores to those with positive scores was 19/61; for controls, 48/32. These proportions differ significantly ($x^2 = 4.86$, df 1, $p = 0.027$). (The ratio was not significantly different between 3-hr and 6-hr animals for either alcohol-treated or control conditions.) Thus, from the foregoing, it may be inferred that for control fish, there was a deficit in primary escapes which was necessarily associated with a lower level of responding in excess of that required to escape shock on trials in which a CR did not occur. (It should be noted that for non-drugged fish, evidence gathered by other means indicates that the deficit in primary escapes is slight, occurring on less than 5% of trials in this procedure.) For alcohol-treated fish, however, the situation is less clear, since a high level of responding in excess of that required to escape on trials in which no CR occurred, could be compatible with either a relatively high number of primary escapes associated with a moderate level of punished approaches plus secondary escapes; or with a moderate level of primary escapes associated with a high level of punished approaches plus secondary escapes. We cannot distinguish at this time between these two possibilities for alcohol-treated fish, nor can we presently dissociate punished approaches from secondary escapes.

Table 1 presents the means and standard errors for 3-hr, 6-hr, and combined groups, both alcohol-treated and control, for the following scores: CR; (CST–CR); and (T–CST). Table 2 shows the product-moment correlation coefficients among these three scores, for all alcohol-treated and all control fish. (The correlation coefficients for 3-hr and 6-hr alcohol-treated fish, and 3-hr and 6-hr control fish, did not differ significantly.) As shown in Table 2, all three correlations were numerically higher for control fish than alcohol-treated fish, even though all coefficients differed significantly from zero. However, the correlation coefficients for CR vs. (CST–CR) did not differ significantly between alcohol-treated and control fish ($z = 0.99$); likewise for CR vs. (T–CST) ($z = 1.59$). However, the correlation between (CST–CR) and (T–CST) was significantly greater for control than for alcohol-treated fish ($z = 7.93$, $p<0.00001$). That is, there was a strong positive correlation for control fish between non-CR shuttling activity during

TABLE 1

MEANS AND STANDARD ERRORS FOR VARIOUS RESPONSE MEASURES FOR ALCOHOL-TREATED AND CONTROL FISH DURING TRAINING

	3 hr	6 hr	Total
Alcohol			
CR	5.50 ± 0.71	5.55 ± 0.67	5.52 ± 0.48
(CST–CR)	0.72 ± 0.20	1.62 ± 0.94	1.22 ± 0.48
(T–CST)	21.05 ± 1.50	23.38 ± 1.91	22.21 ± 1.21
Control			
CR	1.22 ± 0.26	1.48 ± 0.39	1.35 ± 0.23
(CST–CR)	1.48 ± 1.22	0.62 ± 0.28	1.05 ± 0.12
(T–CST)	20.00 ± 5.90	17.80 ± 1.97	18.91 ± 3.07

the CS period and total shuttling during the remainder of the trial (T–CST), whereas for alcohol-treated fish, this correlation was attenuated significantly, though it was still significantly greater than zero. This is so even though mean levels on these two measures did not differ significantly between alcohol-treated and control fish (For (CST–CR): $t = 0.22$, df 156; for (T–CST), $t = 1.00$, df 79 for unequal variance). In other words, for control fish, non-CR shuttling activity during the CS period was a good predictor of shock-related shuttling during the remainder of the trial, whereas for alcohol-treated fish, non-CR shuttling during the CS period did not predict as well the fish's response to shock as reflected by shuttling during the remainder of the trial. The correlation between (CST–CR) and [(T–CST) – (20–CR)] was 0.510 for alcohol-treated fish and 0.946 for control fish; neither of the coefficients is a significant improvement over that obtained between (CST–CR) and (T–CST). For control fish, the correlation between CR and [(T–CST) – (20–CR)] was 0.546, again a value that does not differ significantly from the correlation obtained between CR and (T–CST) (Table 2). However, for alcohol-treated fish, the correlation between CR and [(T–CST) – (20–CR)] was 0.546, a value which was significantly greater than the correlation between CR and (T–CST) for these fish ($t = 14.10$, df 77, $p<0.00001$).Thus, by considering the level of shock related responding in excess of that required to escape on all trials on which a CR did not occur (i.e., the measure [(T–CST) – (20–CR)]), the CR performance of alcohol-treated fish could be predicted significantly better than if one simply considered all shock-related responding (i.e., T–CST). On the other hand, for control fish, either of these two measures predicted CR performance equally well. Nevertheless, two points should be noted: (a) the dependent correlations, between CR and (T–CST), and between CR and [(T–CST) – (20–CR)], are significantly different for alcohol-treated fish and not for controls principally because the former correlation is low for alcohol-treated fish; (b) the latter correlation was very similar for alcohol-treated and control fish (0.545 and 0.546, respectively), and neither was high. Thus, only approximately 30% of the variance in CR scores could be accounted for by knowledge of the score [(T–CST) –

TABLE 2

PRODUCT–MOMENT CORRELATION COEFFICIENTS FOR VARIOUS RESPONSE CATEGORIES FOR ALCOHOL-TREATED AND CONTROL FISH DURING TRAINING

Variables	Alcohol (N = 80)	Control (N = 80)
(CR) vs. (CST–CR)	0.404	0.533
(T–CST) vs. (CR)	0.262	0.480
(CST–CR) vs. (T–CST)	0.428	0.938
(CR) vs. [(T–CST) – (20–CR)]	0.545	0.546

(20–CR)] for each fish, whether alcohol-treated or not: this is the best CR could be predicted for either treatment.

EXPERIMENT 2

For the reasons described above, we were interested in examining whether altered sensitivity to light could account for the enhancement of acquisition we observed.

Method

Animals. Sixty-four common goldfish were obtained, maintained, and handled as in Experiment 1.

Procedure. The procedure was identical to that in Experiment 1 with the following exception: (a) no shock was used at any time (i.e., unreinforced testing was used); (b) some fish were tested for light avoidance (i.e., swimming away from instead of into the lighted compartment), some for dark avoidance (the same procedure used in Experiment 1, but here without shock reinforcement): the schedule was the same for both (i.e., 10 sec CS-period followed by a 50 sec period which was identical to the CS-period, since no shock was used); (c) pretraining exposure time was 3 hr for all fish.

Thus 4 groups of fish were used, 16 in each group: light-avoidance, alcohol-treated; light-avoidance, control; dark-avoidance, alcohol-treated; dark-avoidance, control. A correct response in this experiment consisted of swimming out of or into the lighted compartment (as appropriate) within 10 sec of the beginning of the trial. In addition to CR shuttles, total CS-period shuttles and total trial shuttles were recorded.

Results

Figure 2 (Panel A) presents the mean levels of "CR shuttles" for alcohol-treated and control fish subjected to dark-avoidance (DA) and light-avoidance (LA) testing as described above. Analysis revealed a higher mean level of CR shuttles for LA groups than DA groups ($F = 30.80$, df 1/60, $p = 0.000001$); and alcohol-treated groups abtained a mean level of CR shuttles significantly higher than that for control groups ($F = 7.98$, df 1/60, $p = 0.006$). However, both of these effects are qualified by the significant interaction effect ($F = 10.91$, df 1/60, $p = 0.002$); for DA, alcohol-treated fish obtained a slightly but nonsignificantly lower mean level of CR shuttling than controls ($F = 0.36$, df 1/60), whereas for LA, the difference was reversed and significant ($F = 11.61$, df 1/60, $p = 0.002$).

Panel B of Fig. 2 presents, for alcohol-treated and control fish tested on LA and DA, mean levels of a score defined for each fish as (CR/CST), as in Experiment 1. Analysis of these scores (which in effect correct for general activity during the CS-period) showed the mean level for LA groups to be significantly greater than that for DA groups ($F = 14.19$, df 1/60, $p = 0.0004$), as in the analysis of CR shuttles only. However, unlike the case with CR shuttles, the main effect of drug (alcohol or water) was not significant in terms of this activity-corrected score ($F = 0.26$, df 1/60). The interaction effect remained ($F = 5.04$, df 1/60, $p = 0.028$). Further analysis showed that for LA, alcohol-treated fish obtained a mean level significantly higher than control fish ($t = 2.71$, df 1/15 for unequal variance, $p = 0.016$), whereas for DA, this difference, though in the opposite direction, was not significant ($t = 1.01$, df 1/30).

For DA fish, the correlation coefficient for CR vs. (T–CST) was 0.740 for alcohol-treated fish and 0.729 for control fish; for LA fish, the coefficients for alcohol-treated and control fish were 0.131 and 0.164, respectively. For both alcohol-treated and control fish, the coefficients for DA differed significantly from zero ($p<0.01$, df 14, in each case), whereas neither of the LA coefficients differed significantly from zero. Likewise, for both alcohol-treated and control fish, the correlation coefficient for CR vs. (T–CST) was significantly greater than zero in each case ($p<0.0001$). Correlations between CST and (T–CST) showed a pattern in all respects similar to that for correlations between CR and (T–CST): for alcohol-treated fish, the coefficient was 0.713 for DA and 0.181 for LA; for control fish, the coefficient was 0.827 for DA and 0.192 for LA.

Thus, the following inferences may be drawn. (a) Alcohol-treated fish escape (avoid) light more often than control fish, and escape darkness slightly but nonsignificantly less often, in a situation which involves no electric shock. (b) When in a nontraining situation, the relations between CR shuttling and total non-CS-period responding, and between total CS period responding and total non-CS-period responding, are affected strongly by whether fish are tested on LA or DA, and the presence or absence of alcohol has little effect on these relationships.

DISCUSSION

Experiment 1 indicated that the enhanced acquisition performance of alcohol-treated goldfish, which we previously reported [21], was not appreciably altered by 6-hr

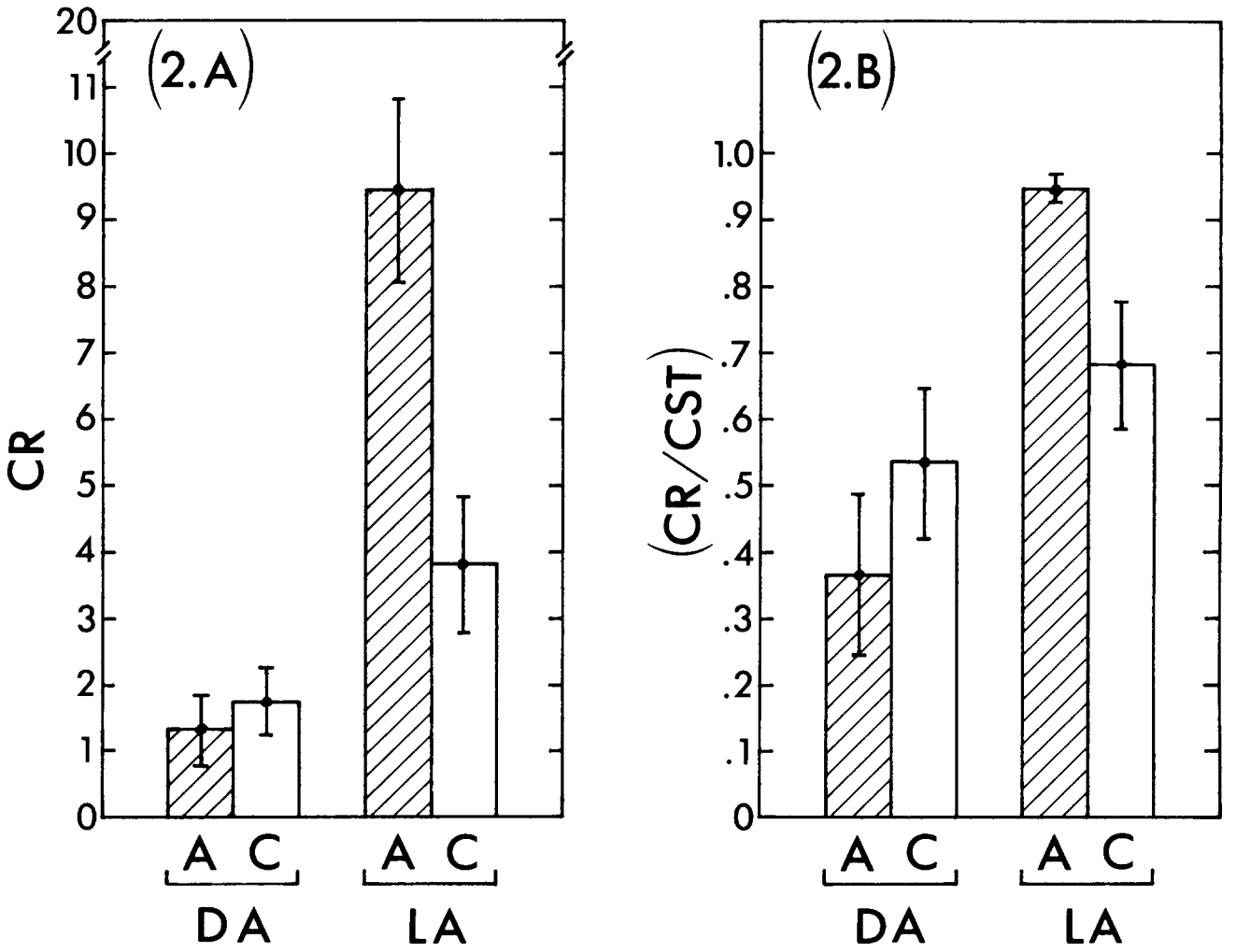

FIG. 2. (A) Mean levels (± SEM) for "light-avoidance" (LA) and "dark-avoidance" (DA) correct responding (as defined in text) for alcohol-treated (A) and control (C) fish. (B) The same animals as in Panel A with their scores expressed as (CR/CST).

instead of 3-hr pretraining exposure. Neither was the enhanced acquisition attributable to increased non-CR shuttling during the CS-period during training. There was some evidence, both in the present work and by inference in Petty, Bryant, and Byrne [21], that alcohol-treated fish swam into and out of the electrified compartment more often during the last 50 sec of the trial (the non-CS portion). However, this sort of responding correlated with correct responding no better for alcohol-treated than for control fish. Although the question cannot be decided at this time, we suspect that further work will show efficient levels of primary escape (as defined above) in alcohol-treated fish, consistent with the report of Scobie and Herman [28]; but that we will also confirm that alcohol-treated fish make more punished approaches into the electrified compartment, consistent with the traditional notion of alcohol's analgesic properties. However, this problem obviously awaits additional work.

Experiment 2 appears to eliminate decreased sensitivity to light as an explanation for enhanced dark-avoidance performance in alcohol-treated fish. We interpret the results of Experiment 2 to indicate increased sensitivity to light in alcohol-treated fish, in agreement with Goodwin *et al.* [12].

How, then, alcohol causes the observed effect on acquisition performance eludes precise specification at this time. We have previously argued that in a high-stress situation (such as initial acquisition training in a shuttle box), learning might be improved by the action of a sedative-hypnotic in reducing stress or anxiety to more adaptive levels [21]. However, some evidence emphasizes the possibility that even higher effective shock levels (i.e., lowered threshold for electric shock) may facilitate instead of impede acquisition [28]. These questions can be tested.

An additional explanation which we have considered is that alcohol may actually be acting in our situation as an excitatory agent or stimulant [19]. Though the traditional pharmacological emphasis has been on the drug's properties as a sedative and hypnotic, the possibility of reconceptualization of this classification has been raised, based on evidence from both humans and lower animals [19]. Alcohol has been demonstrated to interact with central nervous system monoamines in a variety of ways [17]. For example, alcohol depleted brainstem norepinephrine in rats treated

with DL-α-methyl-tyrosine-methylester, which blocks synthesis of norepinephrine and dopamine [10]. Various authors have suggested that alcohol may act to release central catecholamines [23] and perhaps eventually to deplete them [30], possibly by interfering with reuptake [15]. Thus alcohol has been said to activate central monoaminergic neurons [30] – perhaps noradrenergic neurons specifically [13] – by direct or indirect means. Acetaldehyde, the immediate metabolite of ethanol, is a sympathomimetic drug [8,16] whose effects have been reported to be potentiated by cocaine [20].

While the possibility that alcohol may act to facilitate acquisition performance in our procedure by acutely increasing the availability of monoamines at relevant central sites, can only be considered speculative at this time, we consider it an intriguing possibility worth further investigation.

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