tually mask the observation of important relationships. For example, the presence or absence of retention deficits may be inferred from our data, depending on the variable one chose to examine. The potential usefulness of both autonomic and behavioral variables in consolidation research might be applied to the problem of determining the nature of the process or processes that are disrupted by ECS, and whether "task" or "emotional" components, or both, of memory processes are being modified by ECS in aversive tasks.

Some of the current controversy about the concept of consolidation appears to be directed more to describing the range of conditions under which behavioral disruption will be produced by traumatic agents than to the assessment of the validity of the concept itself. Perhaps, even the question of validity will disappear as more specific postulates about memory mechanisms are developed. Both the judicious use of behavioral techniques and concurrent study of physiological mechanisms seem necessary if this goal is to be successfully approached.

BROMFIELD HINE
RONALD M. PAOLINO
Department of Pharmacology and Toxicology, Purdue University, Lafayette, Indiana 47907

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7. It is important to note that animals were habituated to the SC only and not to the large compartment where training to FS took place.
8. Since the variability of these groups' latencies was zero, nonparametric (distribution free) statistics were used for the analysis of the latency data.
9. R. D. Fitzgerald and T. J. Teyler, *J. Comp. Physiol. Psychol.* **70**, 242 (1970); L. de Toledo and A. H. Black, *Science* **152**, 1404 (1966).
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11. Additional evidence for single-trial cardiac conditioning was provided by the data from a shock-sensitization control group of nine rats. These animals were habituated and tested for retention in exactly the same manner as the other confined groups. On the training day, each animal was removed from the apparatus 1 minute after entering the open field from the SC, and was then returned to its home cage. One hour later, a 1.5-ma, 1.5-second alternating current shock was delivered to the tail of the restrained animal. The shock was administered outside of the training apparatus, and the rat was returned immediately to its home cage. The retention test was given 24 hours after tail shock. During retention testing, these animals exhibited an average increase of 17 beats per minute with respect to rates produced during the last habituation session (the group mean of 413 beats per minute for the habituation session was not significantly different from other habituation group means). This increase was similar in direction to that displayed by nonshocked and ECS controls. The retention heart rate of these sensitization controls was significantly greater than that of the FS learning group ($t = 1.61$; d.f. $= 16$; $P < .05$, one-tailed).
12. While this report was in press, D. Quartermain, B. S. McEwen, and E. C. Azmitia, Jr. [*Science* **169**, 683 (1970)], independently proposed a similar mechanism to account for the finding that a reminder shock would produce recovery of an ECS-disrupted passive avoidance response. According to these authors, however, the basis for the retained fear is an incomplete weakening, by ECS, of the association between specific training cues and fear, rather than the inability of ECS to disrupt a rapidly conditioned generalized fear response, as we suggest.
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Emotionally Induced Increases in Effective Osmotic Pressure and Subsequent Thirst

Abstract. *Following a brief period of handling or enclosed rotation, rats increased the frequency of drinking relative to eating. Handling also delayed or eliminated eating behavior in hypoosmotic rats. Osmometric analysis revealed a rapid increase in serum osmolality during stress which may account for the emergence of thirst and disruption of eating.*

The incremental effect of stress, anxiety, and emotional excitement on the consummatory response of drinking has been discussed with respect to the induction of primary thirst (*1*) and to an increase in general drive, as hypothesized by Hull (*2*). Siegel and Siegel (*1*), who found an increase in water intake following faradic stimulation, explained their results by assuming that the supposed hemoconcentration resulting from emotional stress had produced primary thirst through a loss of water from the body cells. Similar results reported by Amsel and Maltzman (*3*) were attributed to a strengthened drive which augmented the learned response of drinking. Later, Siegel and Brantley (*4*) presented evidence that, in a situation somewhat more contrived than the Siegels' original conditions, food consumption could also be increased by emotional excitement. The original suggestion that emotional stress induces primary thirst remained, however, and recent research in support of an osmotic theory of thirst and hunger renews its relevance.

Briefly, we have reported that the initiation of drinking which follows food consumption in food-restricted rats is accompanied by a significant increase in serum osmolality (*5*), and the evidence suggests that primary thirst emerges during food ingestion following an increase in body-fluid osmolality. Similarly, the initiation of eating which follows water consumption in water-restricted rats is accompanied by a significant decrease in serum osmolality, and the suggestion was made that primary hunger results from a decrease in body-fluid osmolality (*6*). It follows, then, that if emotional stress were to change the effective body-fluid osmolality of an animal, the consummatory response which followed the stress would indicate the direction of that change. Also, the change should be measurable in the serum osmolality of the animal. A series of experiments reveal both of these expectations to be so.

The purpose of the first experiment was to determine if rarely handled rats would differentially increase one or the other consummatory response following a period of presumably stress-producing activity. If increased body-fluid osmolality elicits drinking and if stress increases body-fluid osmolality, stress should lead to increased drinking. Twenty-two male Holtzman albino rats (75 to 105 days of age and maintained with free access to food and water) were observed in their individual cages for three 2-hour periods, each period separated from the last by 7 days. In the first session, the rats were observed for the first hour, removed from their cages, individually handled (that is, held in the crook of the arm with no attempt to aggravate or hurt the animal) for 1.5 minutes, returned to their cages, and observed for 1 hour. The second session was a replication of the first, except that instead of being handled each animal was placed in a weighing container from an O'Haus animal scale and rotated slowly about several axes for 1.5 minutes before being returned to its cage. In the third session, no activity intervened between the 2 hours, and the observation provided control data. During all three sessions, each instance of eating and drinking was recorded for each animal. Table 1 presents the frequency of animals which ate or drank or both in the 2 hours of observation in all three conditions. The decisive data were provided by subjects which responded during the second hour but not during the first as compared to those which responded during the first hour only. No significant increase in eating was found in any of the conditions, but the number of animals which drank following handling and rotation increased significantly (*7*). If stress increased arousal level only, the expectation would be an equal increment in both eating and drinking. However, both handling and rotation increased drinking significantly while having no incremental effect on eating behavior.

Table 1. The number of animals that responded by eating or drinking or both during the observation periods in each of the three conditions and the significance level (P) of the increase in responding in the second hour. A, subjects not responding in either hour; B, subjects responding in both hours; C, subjects responding in first hour only; D, subjects responding in second hour only; E, significance level of increase.

Condition	Response	A	B	C	D	E
Handled	Eating	5	1	8	8	.5000
Handled	Drinking	13	1	1	7	.0356
Rotated	Eating	12	1	4	5	.5000
Rotated	Drinking	11	3	0	8	.0039
Control	Eating	8	2	7	5	*
Control	Drinking	14	1	4	3	*

* Decreased.

The next set of experiments was conducted to determine if handling could eliminate or delay eating in hypoosmotic animals (*8*). Increased body-fluid osmolality, such as that which follows food consumption, has been shown also to follow the ingestion or injection of a NaCl solution and to significantly reduce subsequent eating behavior (*9*). Thus, if stress increases the body-fluid osmolality, it should likewise have a decremental effect on eating. In the first experiment, 11 male Holtzman albino rats, 180 days of age, were maintained on a water-restriction schedule, in which each rat received four 4-ml portions of water daily, for a period of 45 days preceding the experimental day. None of the animals had been removed from their cages during that time. The 11 animals were randomly assigned to two groups: the handled group, which included six subjects, and the control group with five subjects. All rats received their first portion of 4 ml of distilled water for the day. The five rats in the control group were removed from their cages 0.5 minute after finishing their portion and immediately returned. The handled group was likewise removed 0.5 minute after consuming the water portion, but each rat was handled for 1.5 minutes before being returned. Previous research has shown that when rats are habituated to this schedule eating consistently occurs following the ingestion of a water portion. All of the animals in the control group initiated eating during the subsequent 60-minute observation period (with a mean latency to the initiation of eating of 27 minutes), whereas none of the six handled animals ate ($P < .01$) (*10*). Thus, in older animals which have had practically no experience with being handled but much experience with the equal-portion water-restriction schedule, handling eliminated the eating behavior which otherwise follows water ingestion.

The experiment was repeated with 30 male Holtzman albino rats, 70 days of age, that had been maintained on the schedule only 8 days prior to the first experimental day. The animals were randomly assigned to two groups of 15 rats each. After they finished drinking their first 4-ml portion of distilled water on the first experimental day, the rats of Group 1 were merely observed, while the rats of Group 2 were individually handled for 1.5 minutes. On the second experimental day, which followed the first by 2 days, the conditions were reversed: Group 1 was handled for 1.5 minutes and Group 2 acted as a control. On both days each animal's latency to the initiation of subsequent eating was measured and it was found that handling delayed the onset of eating. The overall mean latencies for the unhandled and handled conditions were 9.3 and 12.6 minutes, respectively, a difference which was found to be significant ($P < .01$) (*11*). The behavior again indicated that body-fluid osmolality was raised by handling. It can only be hypothesized that the difference between experiments in the magnitude of the effect was due to the difference in age and background of the two samples used.

Thus, both the increase in drinking and the elimination and delay of eating point to an elevation in body-fluid osmolality resulting from the "emotional excitement" attendant upon handling. Two experiments verify this prediction. In the first, 11 male Holtzman albino rats, 80 days of age and maintained on the water-restriction schedule, were killed at the moment of initiation of eating following the ingestion of their first portion of distilled water. The actual purpose of the study was to investigate biochemical changes in the blood, but in the process several inadvertent delays occurred between the initiation of eating and decapitation. To prevent the animals from eating during these delays, each was "handled," by the earlier definition, and finally killed. Serum osmolality was determined for each animal in a 0.4-ml sample by means of an Advanced Instruments Osmometer, and a correlation coefficient was calculated for the relationship between the delay (ranging from 0.25 to 1.30 minutes) and the serum osmolalities (ranging from 305 to 340 milliosmol/kg). The correlation was found to be positive and significant ($r = +.611$, $P < .05$), and the evidence suggests the possibility of an incremental effect of handling on serum osmolality. The last experiment provides further and more convincing evidence of this effect. Twelve male and 12 female hooded, heterozygotic rats of the Brattleboro strain, 7 months of age, had been maintained with free access to food and water prior to the experiment. Two groups of six males and six females each were formed by random assignment. Each member of the experimental group was removed from its cage, placed in the metal weighing container described earlier, slowly rotated about several axes for 1.5 minutes, and killed by decapitation to provide blood for the determination of serum osmolality, which was made in a 0.4-ml sample of serum from each animal. The rats in the control group were removed from their cages and killed by decapitation as quickly as possible. The mean serum osmolality for the control group was 313.9 milliosmol/kg and the experimental subjects' mean osmolality was 322.4 milliosmol/kg. The difference between the groups was found to be significant ($P < .005$). Thus it can be concluded that serum osmolality was increased by the stress resulting from the experimental manipulation of enclosed rotation (*12*).

In both behavioral and physiological measures employed here, it is clear that stress, anxiety, or emotional excitement increased body-fluid osmolality and induced primary thirst, which, in turn, led to drinking and the delay or elimination of eating.

As the speed with which the effective

osmotic pressure increases during stress appears to be extremely fast, the possible utility of this phenomenon in tracing emotional states is intriguing. But an understanding of the characteristics of stimuli effective in producing this phenomenon, as well as the exact nature of the fluid-solids shifts underlying the increase in osmotic pressure, must await further detailed investigations.

EDWARD DEAUX

Department of Psychology, Antioch College, Yellow Springs, Ohio 45387

JAN W. KAKOLEWSKI

Department of Psychophysiology-Neurophysiology, Fels Research Institute, Yellow Springs, Ohio

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8. M. R. A. Chance and A. P. Mead [*Behaviour* **8**, 174 (1955)] reported a significant increase in latency to the onset of eating, following handling, in 24-hour deprived rats.
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10. The chi-square test used assumes a probability of 0.5 that any one subject will begin (or, conversely, not begin) to eat. The chi-square was 7.34 with 1 degree of freedom.
11. Analysis of variance of the data showed $F = 8.85$, d.f. $= 1/28$, for the handling condition; for groups and days, F was less than 1.0 in both cases.
12. Serum glucose levels were also determined for the animals in this experiment, but no significant difference was found between the groups ($F < 1.0$, d.f. $= 1/18$).
13. This research was supported in part by National Institute of Mental Health grant M-4529, research grant NGL 36-005 from NASA, and a College Science Improvement grant from NSF.

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Megalithic Rings

The megalithic structures of the British Isles and of western Europe continue to attract considerable attention, in part because of their monumental scale and evident regularity of construction and in part because of man's natural curiosity about the builders. Cowan (*1*) has speculated on a grand plan underlying and unifying the design of the rings, at least those of the British Isles. In my opinion his arguments have serious weaknesses.

Suppose excavators were to find a board long buried, and suppose careful cleaning and scrutiny revealed it to be covered by a regular pattern, too regular to have been accidental. A clever scholar might suggest that the board had been used for a game, and he might devise a game to be played on the board, one that might prove amusing, even engrossing. There is no harm in all this, provided the players do not become convinced that their game is the one originally played on the board. Some skeptic might even suggest that the board is not a game board after all, but had some other function.

The megalithic rings are a magnificent game board. Many of the rings have been accurately surveyed, and the results are readily accessible (*2*). The game is to fit simple geometric figures to the plans, and Cowan did so. If he had stopped there, the game would have been well concluded, and playing it would have been a pleasant recreation, as Cowan suggests at the end of his article. But he chose to speculate on the psychology and the scientific abilities of megalithic man, and this seems to me unjustifiable on the basis of present evidence.

Cowan approximated the rings by simple figures composed of arcs of a circle, tangent at junction points. By just such a method, every smooth curve can be approximated to any desired degree of approximation. Scrutiny of the plans of the rings given in Thom's book shows that agreement of Thom's proposed approximations with the actual positions of the stones is often very rough. To judge from the evident irregularity in placement of the stones, Cowan's approximations cannot be much better.

Why arcs of a circle? Granted, they are quite easy to lay out with rope and stake. But Cowan justifies his use of them by going back two millennia, to the Platonists. He states, "To a geometer, probably few things are more intuitively satisfying and esthetically pleasing than an absolutely perfect circle drawn by rotating a radius around a point" (*3*). This esthetic-mystic reasoning led Western cosmology into the quagmire of the epicyclic theory of planetary motion, involving circle upon circle, level upon level. No geometer has believed in the perfection of the circle since Kepler and Newton laid the epicyclic theory to rest. But if the history of science gives any clue to future developments, it is that we may expect epicyclic corrections to Cowan's descriptions. In fact, the first such correction appears in Cowan's article: the cardioid is an epicycloid.

Thom gave involved statistical evidence to support his claim that the rings were laid out in integral multiples of a unit he calls the "megalithic yard." According to Cowan, Thom convincingly argues that the builders were "obsessed with a concern for perfection—so much so that all their measures were laid out in integral units." (In fact, Thom's work contains many instances of adjustment of his measurements to preserve commensurability.) Yet we have no record from the megalithic builders of their intents or motives, no blueprints, no record of a single calculation to justify the assumption of any such compelling psychological drive.

Cowan's article is full of unsupported conjectures about the motivations and psychology of the megalithic builders. What are we to think of a phrase such as, "If the builders were an inquisitive lot, *as no doubt they were*" (italics added)? Or of this, concerning the circle: "undoubtedly discovery of the irrational [*sic*] ratio between the diameter and the circumference was frustrating to the megalithic geometers." The word *irrational* is obviously a misapprehension (perhaps a misnomer for "nonintegral"); if, as claimed, the megalithic geometers found this ratio "irrational," this would have been a mathematical achievement not equaled by Western civilization for another three millennia, until Lambert, in 1761, proved the irrationality of π.

The discovery of Pythagorean triangles can be a very satisfying game. The 3,4,5, right triangle, simplest of all, has fascinated many Egyptologists who were convinced that it could have been, and probably was, used by Egyptian surveyors. They have not