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CONSUMMATORY RESPONSE STRENGTH IN THE ANALYSIS OF TASTE-AVERSION LEARNING

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ABSTRACT

CONSUMMATORY RESPONSE STRENGTH IN THE ANALYSIS OF TASTE-AVERSION LEARNING

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Pavlovian conditioning has primarily employed motivationally neutral events as conditioned stimuli. Taste-aversion conditioning studies, on the other hand, use as conditioned stimuli flavored solutions with distinct motivational or response-determining properties. It is possible that many of the differences between taste-aversion conditioning and other forms of Pavlovian conditioning are related to this difference in the nature of the conditioned stimuli. This possibility was examined with regard to the nature of flavor salience in aversion conditioning. One flavor may appear more salient than another because of a difference in associability with illness, or because the more salient flavor supports a weaker, more easily disruptable consummatory response. If the second possibility is the case then the salience relations found in taste-aversion conditioning studies should correspond to the pattern of decrease in consummmatory responding produced by a second, independent, rate-reducing operation. Salience relations may reflect nothing more than strength of consummatory responding for a given flavor.

In the first three experiments the correspondence between taste salience and response strength was examined. For a set of five flavors commonly employed in taste-aversion studies, consummatory response strength was assessed by measuring the decrease in consumption produced by either a water preload or hypothermic shock. In general the correspondence was strong. Stronger or less changeable responses were those typically found to be less salient in aversion-conditioning studies.

Taste salience is significantly reduced by a period of flavor preexposure. If salience is in fact determined by consummatory response strength, then flavor exposure should increase response strength. In the fourth experiment this was tested by comparing the resistance to change of consumption of a familiar or a novel casein solution. The familiar solution was shown to be associated with a far stronger consummatory response, consistent with the previous analysis.

In the final experiment bar pressing and licking were reinforced with coffee and vinegar solutions. Comparisons were then made of the pattern of suppression produced by taste-aversion conditioning, prewatering, and a conditioned suppression procedure. Agreement across the different response suppression procedures was obtained. Responding for vinegar was more suppressed than responding for coffee in all procedures and across all response measures. The

correspondences in the measures of changeability suggest that flavor salience is best conceptualized in terms of the strength of consummatory responding. This interpretation, consistent with a general process approach, is shown to be able to integrate findings on flavor salience, flavor preexposure, neophobia, enhanced neophobia, extinction, and deprivation effects. It is concluded that taste-aversion conditioning may be profitably studied within the context of a general process approach.

I. INTRODUCTION

It is now well over a decade since the pioneering work of Garcia (Garcia, Ervin, & Koelling, 1966; Garcia & Koelling, 1966) focused attention on taste-aversion learning. This research raised serious doubts about the existence of general principles of behavior, both across different species (Seligman, 1970) and across different motivational systems within a species (Rozin & Kalat, 1971). Studies of taste-aversion learning, along with other biologically-oriented lines of research (see Seligman & Hager, 1972), suggested that the prospect Skinner (1938) called the botanizing of behavior and hoped to avoid, was now unavoidable (Herrnstein, 1977).

Claims for the distinctiveness of taste-aversion learning have become less frequent, with more recent literature stressing the similarities between flavor-aversion learning and standard Pavlovian conditioning (Bitterman, 1975; Logue, 1979; Revusky, 1977; Testa & Ternes, 1977). These accounts stress the qualitative similarity between flavor-aversion learning and other procedures for Pavlovian conditioning, while accepting considerable quantitative differences. Nevertheless, these attempts at reconciliation yield little reason to feel secure about the ability of the "general" principles of behavior to accommodate new findings.

It can be argued that application of the traditional analyses to taste-aversion learning has failed to explain any of the features considered most distinctive of taste-aversion learning (Kalat, 1977b). For instance, the long-delay learning of taste-aversion experiments in which the conditioned stimulus (CS) and unconditioned stimulus (US) are separated by hours (e.g., Rozin & Ree, 1969) has been taken by some as mere parametric variation (e.g., Logue, 1979; Revusky, 1977; Testa & Ternes, 1977). This does not address the question of why other conditioning preparations have CS-US delay limits expressed in minutes, while taste-aversion delay-gradients span hours. Labelling long-delay taste-aversion learning as parametric variation may say more about the extreme flexibility of our categories than it says about the power of traditional analyses to explain taste-aversion learning. This type of approach, integrating taste-aversion learning with Pavlovian conditioning by stressing gross overall similarity, fails to explain many of the features that first attracted atttention to flavor-aversion learning. An unfortunate effect of this approach is that it may lead to unresolvable disputes over when a quantitative difference indicates a true qualitative difference. This issue is made more complex, as Schwartz (1974) has noted, by the fact that determination of quantitative differences depends upon the paradigm (e.g. avoidance conditioning versus eyeblink conditioning) selected for comparison. Further complication arises from the lack of agreement over whether taste-aversion learning is properly considered an instance of Pavlovian conditioning (Bitterman, 1975; Gormezano & Kehoe, 1975).

A different approach to the issue of integrating flavor-aversion learning with traditional accounts of behavior attempts to use known principles of behavior as the basis for an experimental analysis of taste-aversion learning. For example, Best (1975) has shown that the so-called "learned safety" effect - the decrease in aversion conditioning to a previously presented taste - is better understood as an instance of latent inhibition (Lubow, 1965, 1973; Lubow & Moore, 1959). Best's research shows how findings that seemed at first to require the introduction of a novel conditioning mechanism - learned safety- could in fact be explained by known conditioning processes. Illustrating the same type of approach, Krane and Wagner (1975) demonstrated that the property of "belongingness" or the differential association of taste cues with illness rather than with electric shock, could in part be explained by differences in "rehearsal" (Wagner, Rudy, & Whitlow, 1973). By inserting a delay between the tasting and the delivery of the electric shock Krane and Wagner (1975) were able to establish a flavor aversion with electric shock as the aversive stimulus, a result that had not previously been obtained (Garcia & Koelling, 1966; Domjan & Wilson, 1972a; Green, Bouzas, & Rachlin, 1972). It is important to note that this finding was obtained, where others had failed, through the application of a "traditional" Pavlovian analysis.

In the same spirit, Gillete, Martin, and Bellingham (1980) have shown that "belongingness" (Garcia & Koelling, 1966) can be manipulated by changing ingestive context. Domestic chicks form poison-induced aversions to solid food on the basis of visual cues, but to solutions on the basis of taste cues. Such cue-to-consequence relations have served as the defining feature of experimental demonstrations of belongingness (Garcia & Koelling, 1966; Domjan & Wilson, 1972a; Shettleworth, 1972). The evidence of Gillete et al. indicates that these cue-to-consequence relations may be explained on the basis of the response topographies occassioned by the stimuli. When the chicks, who normally do not form visually-mediated liquid aversions, were required to peck at their water in a fashion that produced the same response topography as pecking at food, they formed visually based aversions to a solution. This finding is reasonable given that by altering the response topography for drinking, the animals were forced to use visual cues for consumption. These results, and those of Krane and Wagner (1975), show that belongingness can no longer be regarded as a fixed, pre-wired learning specialization. More importantly, these findings show how anomalous findings can be understood in terms of a general process approach to learning.

The present analysis is similar in intent to these researches. An attempt is made to understand and analyze some of the distinctive features of taste-aversion learning by the systematic application of concepts derived from the study of so-called arbitrary behavior. The goal of this research is not to deny or affirm the distinctiveness of taste-aversion learning, but rather to set the stage for a proper appreciation of the ways in which learning flavor aversions may differ from learning in other situations. The puzzle of flavor-aversion learning will not be solved until we can separate what is truly puzzling from what is merely mislabelled or misunderstood. This discrimination requires an attempt to extend the general process account as far as possible. Unfortunately, concern with the distinctiveness of taste-aversion learning, and the broader issue of the generality of laws of behavior, has not promoted this extension. It can be argued that scientific progress may be aided more by exploring commonalities across paradigms rather than points of difference (Sidman,1960).

This viewpoint characterizes the present study. The basic assumption of the present analysis is that studies of taste-aversion must consider the motivational properties of the tastes that serve as conditioned stimuli. When the motivational component of the taste stimulus is taken into account a number of relations emerge between taste-aversion conditioning and learning in other situations with aversive stimulation. These similarities argue for the continuity of learning processes over situations, and reduce the need to introduce principles of conditioning that apply only to flavor-aversion learning.

The concept of stimulus salience has been central in systematic accounts of behavior. The term salience refers to the observation that stimuli of equal energy are not necessarily equally effective as conditioned or discriminative stimuli. Those stimuli which come to exert greater control over behavior are said to be relatively more salient. In the systematic accounts of Pavlov (1927) and Hull (1943), salience was explained as a consequence of the pattern of neural response to stimuli of different intensities. In both theories the effective stimulus was not the distal source of energy, but rather the resulting pattern of afferent neural firing. By this maneuver both theorists could state a simple and direct proportionality between stimulus intensity and degree of acquired stimulus control, although the functional stimulus had now assumed hypothetical status. Hull stated this formally (1943, p.68), "Other things being equal, the increment to the strength of a receptor-effector connection resulting from a reinforcement is an increasing function of the associated receptor discharge, or the intensity of the resulting afferent impulse." Although a simple relation between stimulus intensity and stimulus control may not emerge at the environmental level, Hull and Pavlov argued that the relation was obtained at the physiological level. This proposal is attractive because it offers the possibility that differences in salience within and across modalities can be explained by a single mechanism. Unfortunately there is little direct confirming evidence for such a mechanism, and most psychologists have been content to study salience effects more directly, without the application of physiological constructs.

Stimulus salience as a factor in flavor-aversion learning was first introduced by Kalat and Rozin (1970). They presented rats with pairs of novel flavors drawn from a set of four flavors. After the animals had sampled these two tastes they were made ill by lithium chloride injection. Subsequent preference testing revealed that some tastes were consistently more affected by pairing with illness. On the basis of these results it was possible to construct a conditionability hierarchy of the four flavors, with the property of transitivity. For example, if casein solution showed greater acquired aversion than sucrose solution, and sucrose in turn showed a greater conditioned aversion than saline solution, then it was the case that when casein and saline were presented together before poisoning the casein acquired a stronger aversion. This simple and stable relation among the taste stimuli makes plausible the idea that there is some simple determining property. Kalat and Rozin (1970) have called this property taste salience. The question naturally arises as to whether salience in taste-aversion learning procedures is a function of the same factors that determine stimulus salience in other conditioning procedures. The question is whether or not we can do with a single analysis of salience effects. The success of a common analysis may well depend upon our ability to equate relevant dimensions of the stimuli used in the different conditioning paradigms. In the standard laboratory conditioning procedures conditioned stimuli have typically been simple stimuli, with the relevant dimension easily identified. In such cases a measure of stimulus intensity is easily specified, but a similar analysis is not so easily achieved for the conditioned stimulus in a flavor-aversion study. In taste-aversion studies the intensity of the conditioned stimulus could plausibly be argued to be best represented by the concentration strength of the solution, the quantity of the flavor ingested, the duration of consumption, or the rate of consumption. That each of these measures has some plausibility as an intensity index indicates that it will be difficult to subject salience in taste-aversion learning to the kind of analysis envisioned by Hull and Pavlov (but see Lorden, 1976).

One alternative to the physiological approach to taste salience lies in the possibility that taste aversion conditionability could be a function of taste category (e.g., sweet, bitter). It could be the case that some categories are inherently more associable with aversive outcomes than others. This possibility gains plausibility from the observation that rotted and toxic foods, foods an animal would do well to avoid, acquire a bitter taste (Brower, 1969). It has also been noted that toxic prey species often have a bitter, unpalatable taste (Brower,1969; Gillan,1979). Such conditions may have promoted a genetic disposition to learn that bitter tastes signal poisonous or dangerous food sources. Similarly, because high concentrations of sugar inhibit microbial growth and are less likely to contain toxins, there may be a genetic disposition making it difficult to associate sweet tastes with the effects of toxicosis. Certainly it is easy to construct plausible evolutionary scenarios to account for the emergence of such category-salience differences. Unfortunately, there is no evidence which supports the claim that one category is inherently more salient than another (Kalat, 1974; Kalat & Rozin, 1970). Of course, it could be that the relation has not been found because of species differences in taste categories; but this objection raises the additional problem of determining taste categories for another species. Although techniques exist by which one might determine taste categories (Tapper & Halpern, 1968; Wright & Cumming, 1971), the work required for this analysis has not been accomplished.

The approach to salience differences proposed by Hull, and the approach based on taste categories both seek to find a physical basis for salience. An alternative approach to salience effects can be cast within a response-response analysis. In such an analysis one seeks relations between salience orderings, a response measure, and a second independent behavioral measure using the same stimuli. A response-response analysis has been profitably pursued in psychophysical research. Applied to the problem of taste salience the task becomes one of finding an independent measure of behavioral reactivity to a set of flavors, and examining the correspondence between this measure and the relative saliences of these flavors in aversion conditioning procedures. One reasonable candidate for this alternative measure of stimulus effectiveness is initial taste preference.

It seems plausible that the degree to which liking for a flavor can be modified should depend on the strength of initial liking. Early studies (Revusky, 1968a; Revusky & Bedarf, 1967; Wittlin & Brookshire, 1968) found initially preferred solutions more readily acquired aversions as a result of pairing with illness. The suggestion that preferred flavors are more salient was directly addressed in a study by Green and Churchill (1970). They found stronger acquired aversions to initially preferred sweetened condensed milk, than to less preferred grape juice. This difference obtains whether absolute suppression of consumption, or the change in consumption relative to initial intake is calculated. Similarly, Sutker (1971) demonstrated that rats with stronger preferences for saccharin develop stronger aversions to saccharin. Contradictory findings have been obtained by Etscorn (1975), who found much stronger aversions to an unpreferred quinine solution than to a preferred saccharin solution. Still other studies have failed to find any relation between preference & salience (Kalat, 1974; Kalat & Rozin, 1970; Lorden, 1976). Lorden (1976) suggests that cue effectiveness in taste-aversion learning is more dependent on primary taste afferent activity, while preference or palatability is more dependent on postingestional consequences (see also Tapper & Halpern, 1968). This would provide a physiological basis for the independence of preference and taste salience.

A physiological explanation of preference and cue-effectiveness independence may be unnecessary. The failure to find a relation between preference and taste salience may be due to the way in which preference is measured in taste-aversion experiments. The simplest method, and by far the most common, is the two-solution choice test. Typically the test is conducted over a brief interval to minimize the influence of post-ingestional factors (Young, 1967). Despite the widespread use of this method and the dependent variable of percentage-consumed, there are logical and empirical grounds for questioning its utility as a general measure of preference. Everyday observation suggests there are many cases in which relative amount consumed does not correspond to relative preference, particularly when the choices differ in post-ingestional consequences. Consuming an ounce of bourbon and then six ounces of water chaser does not mean that water was the preferred beverage. Particularly in cases where substances differ in nutritive value, amount consumed is likely to reflect the operation of regulatory, rather than hedonic, processes.

The logic of the concept of preference requires that preference orderings remain constant over changes in procedure for measuring preference. Without this constancy the notion of preference as a stable behavioral disposition cannot be supported. In this regard consumption-based measures of preference appear limited (Young, 1967; 1968). In a test situation in which rats are offered a choice between hypotonic saline solution and water in the same locale, they display pronounced preference for the saline

(Falk & Titlebaum, 1963). The strength of this preference increases as the concentration of the saline solution is raised to the isotonic level (Young, 1968). Deutsch and Jones (1960) found that when preference was tested by placing the solutions in the arms of a T-maze, rats ran more frequently to the water arm than to the saline arm, a reversal of the saline "preference". Reversal of preference with minor procedural variation has also been found for sucrose-water choices. Beck, Nash, Viernstein, and Gordon (1972), and Cohen and Tokeida (1972) found that as rate of access to the solutions was decreased, animals shifted from a strong sucrose preference to a strong water preference. These results suggest that a relation between taste salience in aversion conditioning and preference has not emerged because of complexities in the measure of preference. Perhaps an improved methodology for preference assessment would yield the type of relation sought here.

Another reasonable candidate for a response-based correlate of taste salience is taste distinctiveness or taste discriminability. By this account salience is directly related to the detectability, discriminability, or distinctiveness of a flavor. Flavors which are detectable at lower concentrations, for example, might turn out to be more salient as conditioned stimuli. This approach is essentially one of seeking a cross-situational measure of salience. For instance, a psychophysical procedure might be used to measure the discriminability of a set of solutions from water, and the correspondence of this measure with salience rankings as determined by a taste-aversion conditioning procedure assessed. While such an approach is promising, there are results which indicate that the relation is likely to be be complex. It has been found that removal of the gustatory neocortex produces dramatic changes in flavor-aversion learning (Braun, Slick, & Lorden, 1972; Braun & Kiefer,1975; Hankins, Garcia, & Rusiniak, 1974; Kiefer & Braun, 1979; Lorden, 1976). The changes produced by the operation are most simply described as changes in the salience hierarchy. Only highly salient tastes can be used to establish one-trial aversions, while less salient tastes require numerous pairings (Kiefer & Braun, 1979). The delay interval over which an aversion can be learned is shortened, and the minimally effective concentration of the conditioned stimulus is increased (Lorden, 1976). Despite such major changes in flavor-aversion learning there is no evidence of a change in taste sensitivity, as preference/aversion functions remain unchanged by the removal of gustatory neocortex (Braun & Kiefer, 1975; Kiefer & Braun, 1979).

We are left with the conclusion that salience in taste-aversion conditioning is not a simple function of preference or taste discriminability or taste quality. It may be, as originally suggested by Kalat and Rozin (1970), that salience is nothing more than a term for aversion conditionability, unrelated to any other behavioral dimension. Alternatively, it may be that the proper response-based measure has not yet been applied to the analysis of salience effects. This possibility is considered here, and an analysis based on the concept of response strength is offered. This analysis recognizes that the conditioned stimuli in taste-aversion experiments are not neutral stimuli, and emphasizes their motivational properties (Pfaffman, 1960).

Although the concept of response strength has a long history, an agreed-upon and consistent set of behavioral measures has been lacking (Humphreys, 1943). Recently, Nevin (1974,1979) has proposed a reconception of response strength and an approach to its measurement. In this analysis the strength of one response is measured relative to the strength of another response. One response is stronger than another if it shows more resistance to change than the other. Response strength is equated with the notion of persistence of a response, and is close to what has been refered to as drive strength (Warden, 1931; Miller, 1951) in other contexts. In his work on operant behavior maintained by schedules of reinforcement, Nevin (1974, 1979) has shown how this conception of response strength may be quantitatively formalized, but for present purposes this formalization is less important than the fact that the notion of resistance to change has organized a number of findings in the study of operant behavior. This work has so far been limited to operant behavior maintained by schedules of reinforcement, but there is no reason why the basic rationale and assessment procedures cannot be applied to other conditioning situations.

In taste-aversion conditioning the concept of taste salience can be directly translated into response-strength terms. Consider the basic data which require the term salience. Two flavors are paired with poisoning and subsequent testing reveals that consumption of one solution is greatly reduced, while the second is hardly affected. The solution that shows the greater reduction of consumption is the more salient; in the language of a response-strength analysis this observation indicates that consumption of the "salient" solution was the weaker response. Consumption of the salient solution has undergone a greater change than consumption of the less salient solution in the face of the same operation, and this is the basis for concluding that a difference in response strength exists. Response strength considerations lead to a change in the language of analysis. Taste salience, usually taken to refer to a stimulus property is here used to describe a stimulus-response relation. This leads to a translation in which salient flavors are identified with weak consummatory responses, and non-salient flavors are identified with strong responses. This account emphasizes that the CS in taste aversion studies is a behavioral unit with both stimulus response properties (Solomon, 1977).

In the approach taken here consummatory responses are regarded as discriminated operant responses that may vary in response strength. Consummatory responses are usually described with reference to the notion of drive, but the response strength approach provides an equally satisfactory account of variation in consummatory responding. The concept of response strength does not carry the surplus meaning of the drive concept (Bolles, 1967; Hinde, 1959; Skinner, 1938), and the response strength concept is not open to the same abuses as the drive concept. There is a tendency for drives to be inferred from the observations they are designed to explain that is more readily avoided when consummatory responses are considered in terms of response strength. In one of the earliest and most powerful criticisms of the drive concept Skinner (1938) offered an analysis of consummatory responding similar to the present one. He stated " At any given moment each form of food commands a certain strength of behavior, and all foods may be ranked in order according to their corresponding strengths. In extreme states of hunger the organism will eat practically anything, although it will still eat different substances at different rates. In complete states of satiation it may eat nothing. In any intermediate state it will eat all foods up to a given point in the order of preference" (Skinner, 1938, p.369).

At a descriptive level the terms of the response strength analysis can be used in place of the terms high salience, non-salient, etc. The more important issue is whether the response strength account can lead the way to an experimental analysis. This possibility rests on demonstrating an independent means of measuring consummatory response strength. If another satisfactory measure of response strength can be found comparisons can be made with measures collected from taste-aversion conditioning studies. By most accounts of stimulus salience any correspondence between the two measures would be merely accidental, but according to the present argument the correspondence is expected. The response-strength analysis would be further strengthened if an independent means for changing reponse strength, one that does not involve flavor-aversion conditioning, could be developed. If a method were available, it would be possible to directly manipulate response strengths and then examine the effects on taste salience in an aversion learning procedure. These problems - developing a means of measuring consummatory response strength and finding procedures to manipulate response strength - are addressed in these experiments.

The response-strength analysis of data from flavor-aversion studies is not confined to salience effects, and can be readily extended to other aspects of the data. One of the most direct extensions is to the CS preexposure effect (Best & Barker, 1977; Kalat, 1977a; Randich & LoLordo, 1979). This effect refers to the retardation of conditioning observed when a taste CS is presented alone prior to pairing with the aversive US. This effect has been the object of a variety of theoretical treatments and described by a number of theoretical mechanisms, including learned safety (Kalat & Rozin, 1973), learned non-correlation (Best,1975; Kalat, 1977a) latent inhibition, observing response habituation, and conditionined inhibition. Despite the variety of approaches there is no thoroughly satisfactory account (Best & Barker,1977). One problem faced by all current accounts is the failure to explain an associated effect of taste exposure - the reduction of flavor neophobia. It is well documented that rats display a shyness to novel foods (Mitchell, 1976; Richter, 1953; Rozin, 1968) and that this shyness decreases over repeated contacts with a food source (Domjan, 1977). What makes neophobia relevant to the present analysis is the close relation between neophobia and magnitude of the conditioned aversion (Caroll, 1975; Nachman & Jones, 1974; Siegel, 1974). When rats display neophobia, pairing a food with poisoning will produce a strong aversion to the food, while pairing poisoning with foods that do not produce a neophobic response is much less likely to lead to conditioned aversion. It is interesting to note that this relation between neophobia and conditioned aversions obtains even when neophobia is manipulated by physiological intervention. A number of procedures reduce or eliminate food neophobia and these procedures invariably impair the acquisition of flavor aversions. Not only does degree of neophobia predict subsequent conditioning, it has also been found that presentation of a standard taste-aversion UCS (lithium chloride, x-irradiation) enhances the expression of flavor neophobia (Caroll, 1975; Domjan, 1977; Mitchell, Scott, & Mitchell, 1977). Together these findings suggest a close relation among neophobia, CS preexposure, and aversion conditioning.

The relation between these can be accounted for in terms of the response strengths of the consummatory acts. If we make the assumption that a consummatory response is a discriminated operant response that can be reinforced, these finding fall into place. For instance, if consuming a bit of banana flavored solution is reinforcing, then the strength of that consummatory response should be increased. Banana consumption should become more probable (reduction of neophobia), and consumption should be more resistant to suppression produced by pairing with poison (taste preexposure effect). Data indicating that consummatory response reinforcement can increase preference for the food consumed have been obtained by Holman (1975), Revusky (1967), and Zahorik, Maier, and Pies (1974).

The adequacy of a response strength analysis of these phenomena is examined in the following studies. In the first experiment a comparison is made between a taste salience hierarchy, from a previously published study of aversion conditioning, and a response-strength hierarchy, determined by measuring the resistance of consummatory responding to change produced by prewatering. The second experiment examines the effects of taste exposure on consummatory response strength, where response strength is again assessed as resistance to prewatering. The third experiment extends this analysis, comparing the effects of taste-aversion conditioning with consummatory response suppression produced by prewatering and presentation of a conditioned aversive stimulus.

II. TASTE SALIENCE AND RESPONSE STRENGTH

Experiment 1A

The first experiment attempts to establish a correspondence between a salience hierarchy determined by taste-aversion conditioning and a response strength hierarchy determined by an independent response-disrupting procedure. Strong consummatory responses, those highly resistant to change, should correspond to flavors labelled as non-salient, while the more readily changeable consummatory responses should correspond to flavors labelled as highly salient. Response strength will be assessed by determining relative resistance to satiation for a set of flavored solutions, while salience values will be taken from published studies of flavor aversion conditioning (Kalat & Rozin, 1970; Lorden, 1976).

As the first experiment is concerned with the determination of the strength of consummatory responses, measurement considerations need to be reviewed. The concept of response strength used here (Nevin, 1974) equates strength of response with response persistence in the face of changing conditions, but this conceptualization does not specify a measurement of the tendency to persist. There are a number of ways in which resistance to change might be measured, and this variety of realizations gives the notion of response strength widespread utility.

Indeed, without the possibility of generality across dimensions of responding, the idea of response strength would be of little value.

With respect to consummatory responses one could plausibly argue for measuring resistance to change by changes in amount consumed, latency to begin eating (Bolles, 1962), rate of consumption, or bout length (Silby, 1975) among others. The choice among these possible measures cannot be settled a priori. In the studies that follow, resistance to change will be assessed by comparisons of amount consumed in a fixed period, by preference measures, and by rate of consumption. In discussing findings from other studies even greater freedom in response dimension will be taken. Although there is no a priori basis for assuming that response strength differences must underlie all dimensions of a response, there is no reason to assume the contrary. The only reasonable guide in this matter seems to be the pragmatic principle - whatever set of response dimensions yields an orderly arrangement of findings is provisionally accepted.

Choice of a response dimension still leaves the problem of establishing a metric for measuring change. Comparisons of resistance to change could be made in terms of the absolute change in response levels, change relative to the initial level of responding, or on the basis of some transformation of change in responding. In previous work on response strength (Jenkins,1978; Mandell, 1980; Nevin 1974, 1979) relative change in responding has been taken as the dependent variable. Scaling response change against baseline level insures that comparisons will not be biased by initial rates of responding. The choice of relative decrease in a response as a measure of resistance to change does not mean that other measures are without value, or that this approach is without problems (see Mackintosh, 1974 and Rilling, 1977). In the present study relative decrease will be adopted as the measure of response strength primarily because it has been found to produce orderly relations in the study of simple operant conditioning.

Response strength measured as relative resistance to change produces a number with uncertain metric properties. There is the possibility that relative resistance to change may yield a metric with interval or ratio properties, but these properties have yet to be demonstrated. Therefore, response strength as used here permits only ordinal comparisons, and for present purposes this is sufficient, as only an ordinal correspondence between response strength and salience is sought.

In the absence of a higher-order metric for response strength all statements about response strength reduce to ordinal comparisons of relative change. Response comparison is the central focus of a response-strength analysis. A fair comparison of the changeability of two responses requires that the two responses be compared under equivalent conditions. Most importantly, the response-changing operation must be applied equally to all responses under examination. It would seem these conditions could most easily be met by making all responses simultaneously available. This is indeed a reasonable approach, and it is among the procedures used in the present studies, yet this choice procedure presents problems for analysis. One troublesome aspect is the possibility of interaction among response alternatives. The value of one alternative may depend upon exposure to one of the other alternatives. This interaction is compounded by the fact that in a free-choice procedure the experimenter does not control access to the alternatives. For the study of consummatory responses this is a real problem as demonstrated by Holman (1973) and Morrison (1974). They found that rats' choice of two flavored solutions was most strongly affected by what solution was last tasted; the rats preferred to alternate between the flavors. This sort of interaction raises serious problems for any approach to the study of consummatory responses.

A fair comparison of consummatory response change also requires that the response-changing operation be applied equally to the responses compared. In the case of two responses maintained by the same reinforcer, an acceptable choice for a rate-changing procedure is to vary deprivation level. But in the case of responses maintained by different reinforcers the use of satiation becomes problematic. In the first set of studies reported here consummatory responding is examined as a function of its resistance to water satiation. Water deprived animals are presented various flavored solutions, and consumption is measured at different levels of water deprivation. This procedure assumes that changes in water deprivation equally affect consumption of sucrose, saline, casein, vinegar and coffee solutions. In fact this assumption is probably too strong. For instance, it is known that water-deprived animals decrease their intake of dry food. This self-imposed food deprivation most likely increases the value of such nutritive solutions as sucrose more than the value of solutions like vinegar or coffee. These effects were controlled in the present study by keeping the test period brief, and by having food available during the test periods. For the present purposes it is enough to point out that so long as the manipulation of deprivation does not invert ordinal relations the procedure is acceptable.

Method

Subjects.

Nine male Long-Evans hooded rats, 100-150 days old at the start of testing, were used. Previous taste experience for these animals consisted of tap water, Purina lab chow, and for three subjects Noyes food pellets.

Apparatus.

All testing was conducted in the home cages. Solutions were presented in graduated drinking tubes, fitted with stainless-steel spigots and attached to the front of the cages. Consumption could be measured to the nearest .5 ml.

Procedure.

Animals were adapted to a 23.5-hr water deprivation cycle for two weeks. At the start of each daily drinking session animals were removed from their cages while a single drinking tube was attached to each cage. They were then returned to their cages for a 20-min drinking period. Food pellets were available at all times. At the end of the two-week adaptation period daily water intake appeared stable. Following this adaptation period animals were tested on the following flavored solutions (weight/volume) in the order listed: .9% saline, 10% sucrose, 5% casein hydrolysate, 5% coffee (Sanka Instant), and 3% cider vinegar. The solutions were mixed with tap water and were always presented at room temperature. Consummatory response testing was conducted sequentially, such that all tests with a given flavor were completed before going on to the next flavor. Testing with a given flavor consisted of two phases. In the first or exposure phase a solution was presented in place of water for the daily drinking period on four consecutive days. One hour after removal of the flavored solution water was made available for ten minutes. For two days following this exposure period only water was presented to insure that differences in fluid deprivation did not bias any between-flavor comparisons. During the testing phase that followed animals were presented with either 0, 5, 10, or 20 ml of water, 1/2 hour prior to the scheduled drinking period. Exactly 1/2 hour after presentation of the water preload there was a 20 minute test period with the flavored solution. On test days with 0 ml prewatering the dish usually containing the water prelaod was not presented. Testing days alternated with water-only days on which the test solution was not presented. Each animal was exposed twice to each level of pre-watering, in an order that was different for each animal. After completion of the series for one flavor animals were returned to a 23.5-hr deprivation schedule with only water available for at least five days. The cycle was then repeated for each of the flavors. A four-week period intervened between the last casein session and the first coffee session. The animals remained on water deprivation during this period.

Results

Exposure phase. There were consistent increases in the amount consumed across the four days of the exposure period. Figure 1 displays the group averaged consumption for each flavor on each of the exposure days. For all five flavored solutions there was a significant increase in consumption from the first to the fourth day, $p < .05$ for all comparisons (all significance values reported based on Wilcoxon T unless otherwise stated). The increase in amount consumed over the four day exposure period is a measure of flavor neophobia. Comparisons of the neophobic response showed that neophobia was significantly greater to the casein solution than to either sucrose or saline . There were no differences between sucrose and saline in extent of neophobia. Coffee and vinegar solution were not considered in this comparison, because for a number of animals there was no measurable day 1 consumption, making it difficult to compute a meaningful measure of relative increase. The purpose of the exposure period was to familiarize animals with the flavors so that there would be no further increases in consummatory response strength during the course of testing. A check on the adequacy of the familiarization is afforded by the comparison of the last day of the exposure period with the mean of the two days of testing with 0 ml prewatering. Significant

Figure 1. Amount consumed on each of the four exposure days for each flavor in Experiment 1A.
S= Sucrose; N= NaCl; Ca= Casein; Cf= Coffee; V= Vinegar

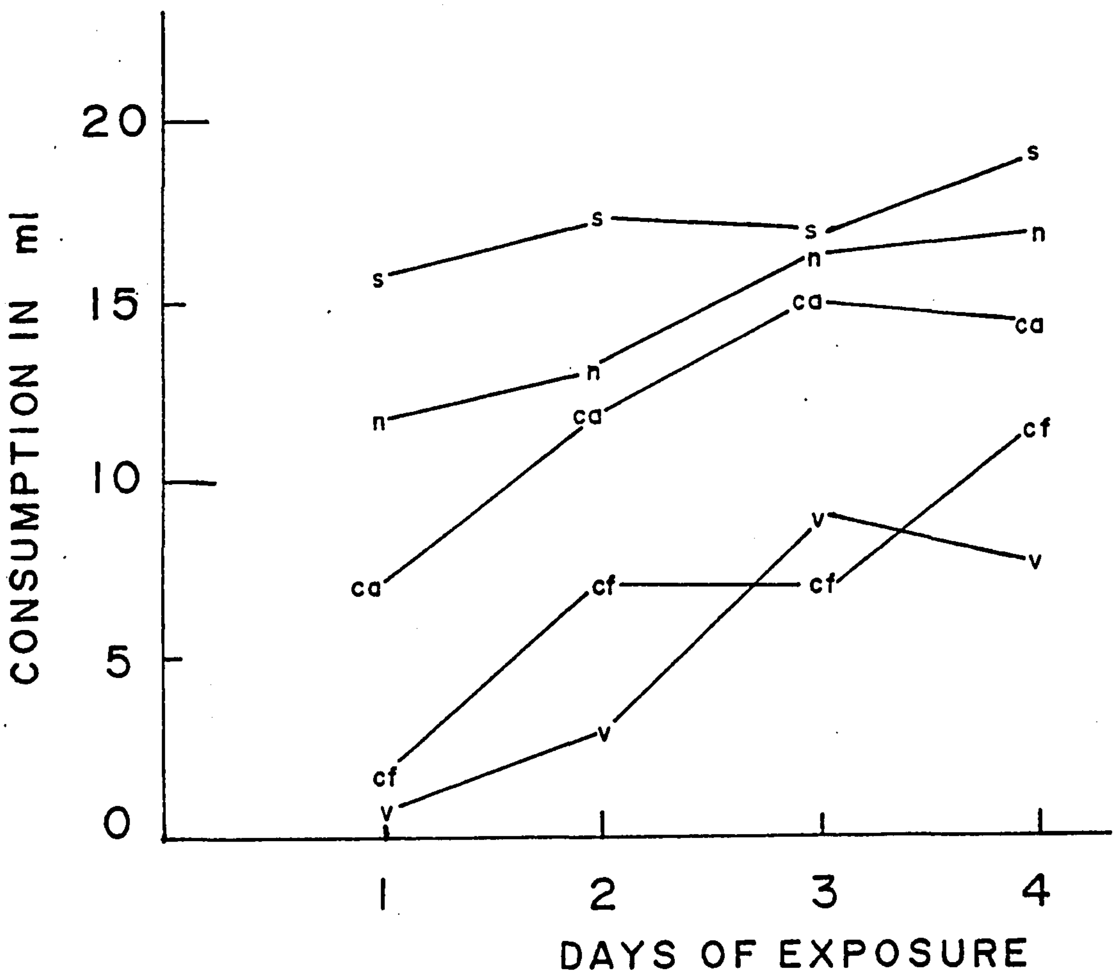


Figure 1

differences were found for both casein and sucrose, $p < .05$, indicating a tendency for consumption to increase during the course of testing. It had originally been intended to use the last two days of the exposure period as the baseline for computing relative change, but due to the continuing increases for casein and sucrose, the baseline selected for all flavors was the mean of the two testing days with 0 ml prewatering and the last day of the exposure period.

Testing. The data from the test sessions, in which consumption was measured after different water preloads, were converted to relative change measures. These data reveal a pattern of decreasing consumption with increasing size of the water preload, $F(2,16)= 40.25$, $p < .01$. There were also differences between the flavors in relative change across all levels of prewatering, $F(4,32)=11.74$, $P<.01$. More importantly for the strength analysis, there was a significant interaction between flavor and level of prewatering, $F(8,64)=5.51$, $p < .01$), indicating that the pattern of decrease was different for the different flavors. Data of individual subjects are shown in Figure 2 for casein, saline, and sucrose solutions. Figure 3. presents mean relative reduction for each of the solutions. Analysis of the simple effects for each flavor showed that consumption of all flavors was significantly affected by prewatering except for sucrose, indicating that

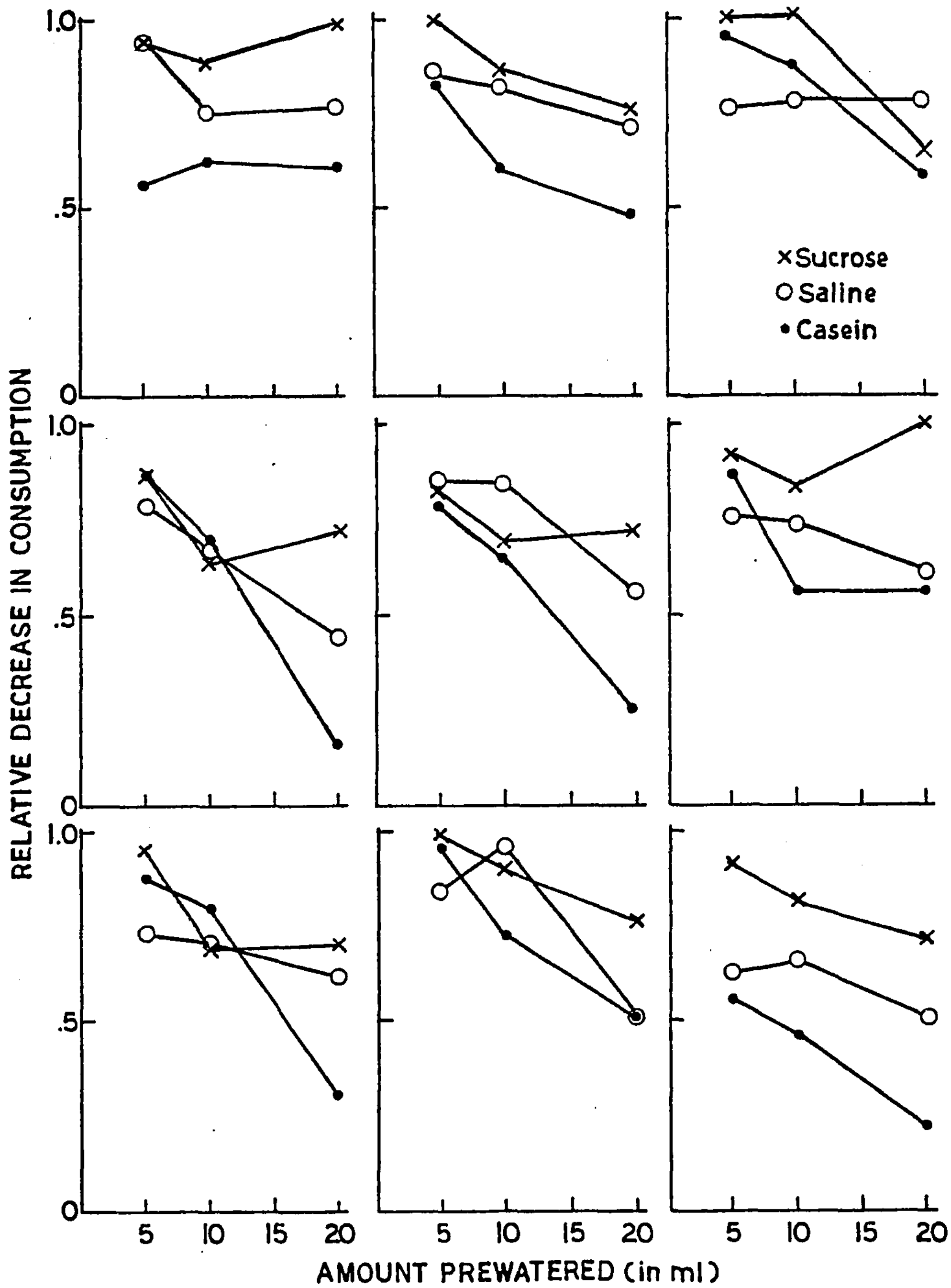
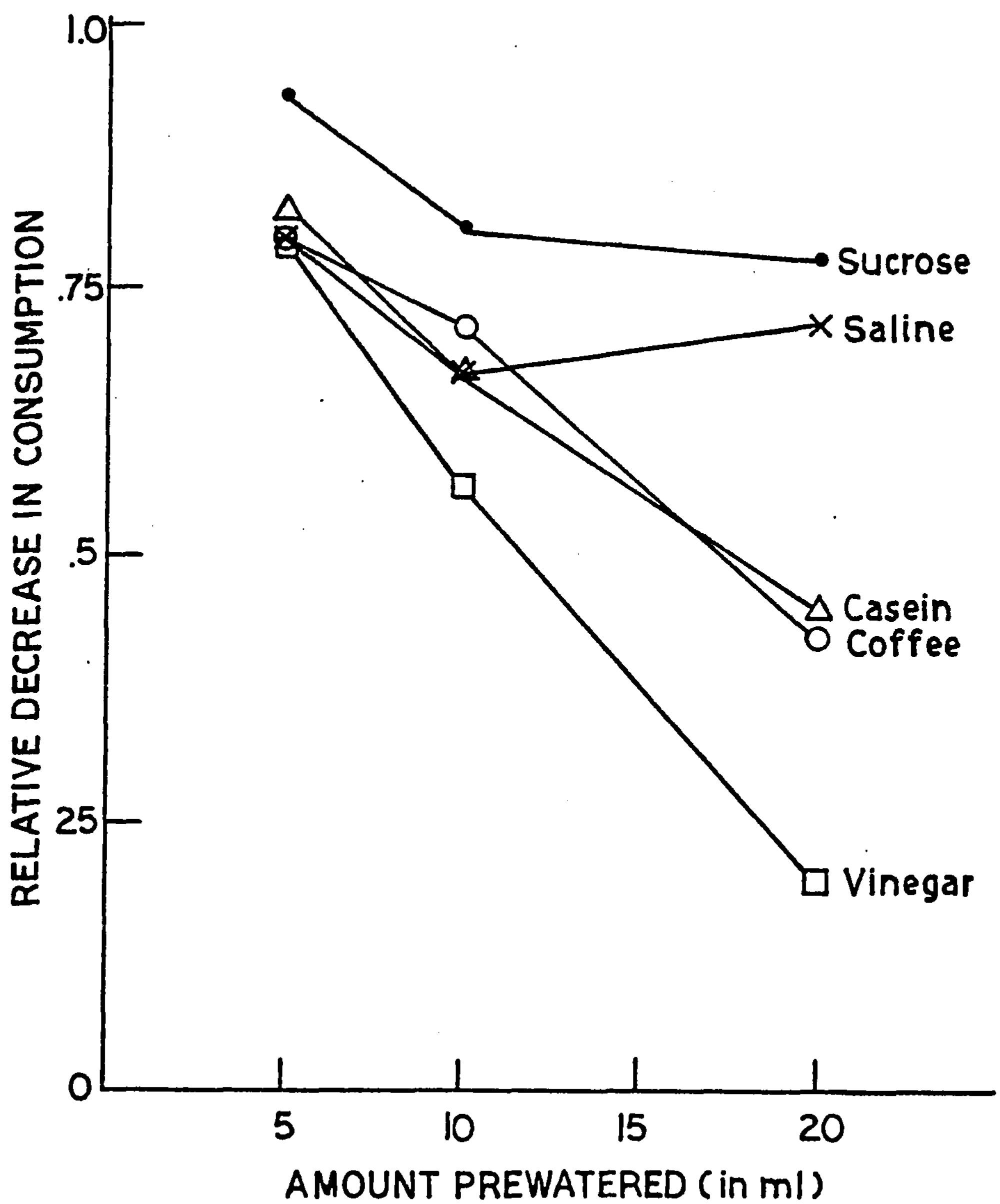

1.0
.5
0
RELATIVE DECREASE IN CONSUMPTION
×Sucrose
○Saline
•Casein
5
10
15
20
AMOUNT PREWATERED (in ml)

Figure 2

Figure 2. Amount of sucrose, saline, and casein consumed by each subject as function of size of water preload. Consumption is expressed relative to the amount consumed in the absence of a water preload.

Figure 3. Grouped means of relative decrease in consumption for each flavor in Experiment 1A as a function of water preload size.



1.0
.75
.5
25
0
RELATIVE DECREASE IN CONSUMPTION
5
10
15
20
AMOUNT PREWATERED (in ml)
Sucrose
Saline
Casein
Coffee
Vinegar

Figure 3

consumption of sucrose was relatively less affected by prewatering than any other solution. This is seen in Figure 3 by the relatively shallower slopes for sucrose consumption as a function of prewatering.

Pairwise comparisons of relative decrease show that it is possible to rank order consummatory responses by resistance to change by prewatering. Table 1 shows the results of the 30 pairwise comparisons that can be made, ten flavor-pair comparisons for three levels of prewatering. The data are presented in Table 1 in a way that emphasizes the consistency of change over individuals. The table entries indicate the number of animals who showed greater relative decrease to the first of the two solutions listed in a given row. Thus an entry of two in the saline-coffee row at 20 ml prewatering indicates that only two of the nine animals tested showed a greater relative decrease to the saline solution while seven showed a greater relative decrease to coffee. A cell in the table marked by an asterisk indicates a statistically significant comparison at the .05 level, Wilcoxon T.

These data show that consumption of sucrose was the least affected by prewatering. In all cases sucrose consumption showed the smallest relative change. After sucrose, saline consumption was the next least disruptable response. Comparison of saline consumption with consumption of vinegar, casein and coffee solution shows that

Table 1

Resistance of Consumption to Change by Prewatering:

Individual Comparisons

Comparisons	Amount Prewatered		
	5	10	20
sucrose-saline	2	4	1*
sucrose-casein	1*	0*	0*
sucrose-coffee	0*	0*	0*
sucrose-vinegar	0*	0*	0*
saline-casein	4	4	0*
saline-coffee	5	5	2*
saline-vinegar	1*	1*	0*
casein-coffee	6	6	4
casein-vinegar	5	2	1*
coffee-vinegar	2	2	0*

Note: Cell entry gives the number of subjects showing greater relative decrease to the second flavor tested. N=9 for all comparisons. Entries marked by an asterisk indicate significant comparisons, $p<.05$ Wilcoxon T.

saline was the least suppressed by 20 ml prewatering. It is also clear that the most readily suppressed response was consumption of vinegar. There is no comparison which vinegar to be less changeable, regardless of the amount of shows prewatering.

Direct comparison of casein and coffee solutions reveals no significant difference. An animal was just as likely to show greater relative decrease in consumption of one as the other. However, other comparisons suggest that coffee was less changeable than casein. The comparison of saline consumption with either coffee or casein consumption, as previously reviewed, indicated that saline was the least disrupted; but inspection of the table shows that this effect was more consistent for the saline-casein comparison than for the saline-coffee comparison. There are a total of 27 comparisons between relative intakes of any two solutions (three tests for each of nine animals). Out of these 27 cases casein consumption was relatively less disrupted than saline in only 8 comparisons, while the corresponding figure for coffee consumption is 12. Additional support comes from the comparison of vinegar with coffee and casein. Of the 27 comparisons for each flavor pair there were eight occassions on which vinegar was less changed than casein, but only four such occassions for coffee. These comparisons indicate that coffee is relatively closer to saline and relatively farther from vinegar than casein. On the basis of these observations it is possible to construct the following ordering of resistance to prewatering, from the least to the most resistant: vinegar < casein < coffee < saline < sucrose. The most questionable ordering is the coffee-casein relation, but no conclusions would be altered if it were to turn out that casein and coffee were equal in resistance to change.

The relation between neophobia and resistance to change by prewatering was examined for casein, sucrose and saline consumption. Correlations between the relative increase in consumption during the exposure phase (day 4 consumption as a percentage of day 1 consumption) for individual subjects with relative decrease at 20 ml prewatering did not approach statistical significance. The largest value of r squared was .13, indicating that this relation could account for little of the variance in decrease of consumption. This was true for correlations for a given flavor or for all flavors considered at once. A consistent relation does emerge when average between-flavor differences are considered. The ordering casein > saline > sucrose describes both the relative increases in consumption during first exposure and the relative decreases produced by prewatering.

Discussion

These results show that consumption of the flavored solutions was systematically reduced by prewatering. This reduction was directly related to the amount of water presented prior to the test. Both the absolute and relative amount of reduction varied as a function of the flavor tested. The major objective of the first experiment was to compare this pattern of reduction with that obtained when consumption is reduced by pairing the flavors with toxicosis. The present data allowed construction of the following hierarchy of susceptibility to change: vinegar > casein > coffee > saline > sucrose. The task now is to evaluate the degree of correspondence between this ranking and that from conditioned taste-aversion studies.

There is no single study that has compared all five flavored solutions in an aversion conditioning procedure. Kalat and Rozin (1970) compared aversion conditioning with solutions of sucrose, casein, and saline in the same concentrations as Experiment 1. Their hierarchy of salience was casein > sucrose > saline, which is not consistent with the present results. If salience corresponds exactly with response strength the ordering should have been casein > saline > sucrose. The reason for the discrepancy is difficult to specify. It could be that salience and response strength refer to different behavioral properties, yielding the obtained partial correspondence between the two rankings. Alternativelv. the discrepancy could be a function of subject or procedural differences. In the interest of the response strength analysis these possibilities are briefly explored.

Evaluation of the discrepancy requires that Kalat and Rozin's (1970) findings be shown to be reliable. The literature contains a few studies which permit comparison of the conditionability of sucrose and saline. These studies tend to agree with the present results and contradict the results of Kalat and Rozin (1970). Earlier work in Rozin's laboratory (Rozin & Ree, 1972) on very long delay conditioning used the same solutions as Kalat and Rozin's (1970) salience study. Rozin and Ree's (1972) results show clearly that casein is the most salient of the three. Conditioned aversion strength was measured by a preference score, and this measure was approximately equal for saline and sucrose. This is the same measure that Kalat and Rozin (1970) used to infer salience differences, and if this measure is given the same interpretation it would mean that sucrose and saline were equally salient. Best, Best, and Lindsley (1976) also concluded that these concentrations of sucrose and saline are equally salient. Two other studies have reported data that show saline to be the more salient. Braun and McIntosh (1973) compared these concentrations of sucrose and saline in an aversion conditioning procedure with rotation as the aversive treatment. Comparison of mean group intake for the sucrose and saline conditioning groups, relative to their respective control groups, yields a greater relative change for the saline group. This is consistent with the claim that saline is more salient than sucrose, or that saline ingestion is a weaker response than sucrose ingestion. Stronger evidence comes from a study by Lorden (1976), who showed sucrose to be less salient than a saline solution over a variety of procedures. The salience difference held for normal animals and animals lacking the gustatory neocortex, for short delay conditioning as well as long delay (6 hr) conditioning. Some caution may be necessary in interpreting Lorden's results as she used slighty different concentrations of saline and sucrose. In sum, of all the studies permitting a sucrose-saline comparison, the Kalat and Rozin (1970) study is the only one which shows sucrose to be more salient than saline; some studies find approximately equal salience while others find saline to be the more salient. Overall, the literature is more consistent with the present results than with the Kalat and Rozin (1970) study.

The lack of consensus on the relative salience of sucrose and saline highlights the problem of the reliability of salience determinations. Research on taste salience seems based on the assumption that salience is a general property of taste stimuli, yet close examination of the literature reveals considerable variability across experiments. The belief in the uniformity of results in taste-aversion conditioning (Garcia, Ervin, & Koelling, 1966; Seligman, 1970) is based on the "prepared" nature of taste-aversion learning. If taste-aversion learning evolved as a special learning ability under heavy selective pressure, individual differences should be minimal. Although the reasoning is convincing, there is little empirical support. Remarkably, there is only one study, in a vast literature, on individual differences, and a handful of studies on the effects of sex- or age-related factors (Elkins, 1973). These studies document that taste-aversion learning is not the uniform process sometimes claimed by advocates of an ethological approach to conditioning.

The operation of subject variables is implicated when studies similar in procedure yield differences in the determination of taste saliences. Inconsistencies are frequent enough to suggest that findings may be seriously affected by subject variables. For instance, most investigators report that coffee is a highly salient stimulus, much more effective than sucrose. Yet Der-Karabetian and Gorry (1973), in a study of interference effects, found that a sucrose aversion could be established where a coffee aversion could not. Vinegar solution is typically reported as more salient than saline, but Revusky, Parker, Coombes, and Coombes (1976) found them to be equally effective taste CSs. Subject variables are implicated in the study, because Revusky et al.'s rats consumed as much vinegar as saline, a result not reported in any published taste preference study. Similar discrepancies have been found with the relative salience of coffee and vinegar (Domjan, 1975; Siegel, 1974). The point of this brief review is that there is a need to attend to sex, age, and strain differences in taste-aversion conditioning.

These considerations may help to resolve the discrepancy between the present results and the findings of Kalat and Rozin (1970). In the Kalat and Rozin study subjects were females aged 50-70 days at the time of testing. For taste-aversion studies these subjects were unusual in both age and sex. Sex differences have been implicated in taste-aversion learning in a number of studies. Green (1969) found that male rats learned an aversion to grape juice more rapidly than females of the same age and strain. Chambers (1976; Chambers & Sengstake, 1976) has demonstrated that female albino rats extinguish taste aversions more rapidly than males, an effect linked to the presence of testosterone. With respect to US effectiveness, Nachman and Hartley (1975) have noted that male rats are less sensitive to a variety of toxic agents. Also implicated in the question of sex differences in conditioning are sex-related differences in taste preferences. Sex-related differences in taste preference have been documented (Zucker, Wade, & Ziegler, 1962), and bear importantly on the present study. From the response-strength perspective these preference differences could be indicators of response-strength differences, and if the argument of the present experiment is accepted, the result would be sex-related salience differences.

The subjects in Kalat and Rozin's (1970) study were also young by comparison with the norm in taste-aversion studies. While there is no doubt about the ability of rats of this age to learn taste aversions, there have been reports of age-dependent learning abilities (Klein, Domato, Hallstead, Stephens, & Milkulka, 1975; Klein, Mikulka, Domato, & Halstead, 1977). These studies have shown that juvenile rats (slightly younger than the rats in Kalat & Rozin, 1970) are slower to acquire a conditioned aversion and less affected by taste preexposure than adult rats.

The present experiment differs from Kalat and Rozin (1970) along a number of subject variables that are known to have an effect on aversion conditioning. No definite source for the discrepancy in results can be identified, but it is interesting to note that of all the studies making a sucrose-saline comparison, only Kalat and Rozin (1970) found sucrose to be more salient, and only Kalat and Rozin used young female rats. Finally the results that corresponded most closely with the present results (Lorden,

1976) were obtained in a study that used male rats of the same strain and the same age as the present study.

The present results display another consistency with taste-aversion findings. Carroll (1975) and Nachman (1977) have reported substantial correlations between neophobia to a flavor and subsequent aversion conditioning with that flavor. Correspondingly, the present study obtained a relation between group measures of neophobia and resistance to prewatering for casein, sucrose, and saline. These relations are expected if salience, neophobia, and resistance to prewatering are all functions of response strength. It is to be noted that the covariation of these measures is not readily explained by any other current formulation of taste-aversion learning.

This experiment has determined the strength relations among a set of five consummatory responses and found these relations to be generally consistent with the findings from taste-aversion conditioning studies. This agreement gives initial plausibility to the response-strength analysis of change during flavor-aversion conditioning. The following studies seek to extend this analysis by obtaining measures of consummatory response change in a variety of situations.

Experiment 1B

The comparisons of Experiment 1A involved consummatory responses to familiar-tasting solutions. Repeated exposure to flavors was required by the repeated testing procedure and the within-subject comparisons. This degree of taste familiarity is not a standard feature of taste-aversion procedures, and it is possible that the relations in Experiment 1A were biased by taste familiarity. To examine the contribution of repeated testing to the results of Experiment 1A, the procedures of that study were repeated in a between-subjects design. Independent groups were tested once with each flavor. One group was always tested following a 10 ml water preload, while the second group was maintained on water deprivation until the time of testing. Because subjects in this experiment were tested only once with each flavor it was not possible to calculate decrease from a pre-testing baseline. In this study relative change was measured by scaling consumption of the flavored solutions from successive test sessions against each other. A consumption ratio of the following form was calculated for each possible comparison: amount of flavor A / (amount of flavor A + amount of flavor B). According to the response strength analysis when the stronger response is in the numerator, prewatering should increase the value of the consumption ratio. This is expected because as the responses decrease the weaker response decreases relatively more. If the two responses are equally strong then the ratio remains unchanged, as both responses change in equal relative amounts.

This experiment compares the strengths of casein, sucrose, and saline ingestion. Given the results of Experiment 1A it is expected that prewatering will increase the consumption ratio for sucrose and saline over casein, and to a smaller degree, the consumption ratio for sucrose over saline.

Method

Subjects.

14 male Long-Evans rats, 150-200 days at the start of testing, were used. Previous taste experience was limited to Purina lab chow and water.

Apparatus.

As in Experiment 1A

Procedure.

Animals were adapted to a 23.5-hr water deprivation cycle. Daily 20-min drinking sessions were conducted until water intake had stabilized - approximately 2 weeks. Animals were then randomly assigned to the prewatered group (PW) or to the non-prewatered (NPW) control group. All testing took place in the home cage and food was removed for the tests. On the 3 test days animals in the NPW group were given one of the 3 flavored solutions in place of water. For animals in the PW group, test days began with 10 ml of water presented in a small ceramic dish. Exactly 1/2 hr after water presentation these animals were presented with one of the flavored solutions for 20 min. Test days were separated by at least 3 days of water alone. All 6 possible presentation orders of the different flavors were used. The presentation order for the seventh subject in each group was randomly selected.

Results

At the end of the adaptation period there was no significant difference between the groups in water intake. The amounts consumed on each test day are presented in Table 2. Analysis of the absolute intakes revealed that consumption of saline and sucrose was not significantly decreased by prewatering, $p>.10$ (all significance values based on t-tests), while the amount of casein ingested was significantly decreased by prewatering, $p<.05$. In both groups between-flavor comparisons indicated that the amount of casein consumed was significantly less than than the amounts of sucrose or saline consumed, $p<.05$ for all comparisons, while saline and sucrose did not differ from each other, $p> .10$. Consumptions ratios for each of the possible two-flavor comparisons were calculated for each animal, and these ratios are presented in Table 3. Between-groups comparisons showed that both the

Table 2

Amount Consumed in 20-min Test: Experiment 1B

Subject	Sucrose	Casein	Saline
	Flavor		
Prewatered			
#1	16.0	2.0	14.5
#2	11.5	7.0	9.0
#3	7.5	2.0	8.5
#4	5.0	.5	6.5
#5	11.5	3.5	7.5
#6	9.0	4.5	9.0
#7	19.5	6.5	17.5
Not Prewatered			
#1	15.5	5.5	17.0
#2	24.0	8.5	14.5
#3	9.0	4.5	12.5
#4	17.5	16.5	13.5
#5	11.0	6.0	15.0
#6	14.5	12.0	8.5
#7	22.0	7.0	11.5

Table 3

Preference Scores as a Function of Prewatering

	Not Prewatered	Prewatered
S/S+C *	.65	.77
N/N+C *	.62	.75
S/S+N	.54	.55

Note: S=Sucrose; N=Saline; C=Casein

* denotes comparison between prewatered and not-prewatered significant at .05 level, one-tailed t test

sucrose/casein ratio and saline/casein ratio significantly increased with prewatering, $p<.05$. The was no measurable change in the sucrose/saline consumption ratio as a function of prewatering.

Discussion

The results of this experiment are consistent with Experiment 1A in showing casein consumption to be a weaker response than consumption of either sucrose or saline. This conclusion is supported by the between-group comparisons of absolute amount consumed with and without prewatering, and the within-group comparisons of relative consumption. But whereas the results of Experiment 1A allowed sucrose to be ranked as stronger than saline consumption, this experiment found saline and sucrose consumption to be equally affected by prewatering. The failure to find any difference is inconsistent with both Kalat and Rozin (1971) and the first experiment. To resolve this discrepancy and to compare the effects of reducing intake by an operation other than prewatering, the next experiment assessed the effects of induced hypothermia on choice responding for sucrose and saline solutions.

Experiment 1C

To resolve the differences between Experiments 1A and 1B the present study examined the relative strengths of saline and sucrose consumption in a more detailed fashion than the earlier studies. Responding was studied in a choice situation with individual licks monitored throughout the session. In addition, another operation to decrease consummatory responding was used. To limit possibilities of interaction between the rate-reducing operation and saline and sucrose consumption, cold-water-induced hypothermia was used. On alternate days of choice testing animals were given a severe cold bath immediately prior to testing. Consumption on these days was then compared to choice responding on days without the induced hypothermia.

Method

Subjects.

Eight male albino rats, bred in the colony at the College of Wooster, served as subjects. Animals were approximately 90 days at the start of testing and had no prior experimental history.

Apparatus.

Choice testing was conducted in a standard rat chamber, the overall dimensions of which were 9"l X 8"w X 6.5"h. This chamber was enclosed within a larger light and sound insulating chamber. Solutions were available from two spigots located to the sides of the chamber, 1.8" from the front wall and 1.8" from the chamber floor. The spouts were recessed behind the side walls and could be reached only by the tongue, insuring that the drinkometer was recording licking. Solutions were delivered through a motor-driven pump system which allowed accurate control of the amount delivered. Illumination was provided from a houselight centered above the chamber. Responding was recorded at 30 sec intervals on print-out counters. Concentrations of saline and sucrose were as in Experiments 1A and 1B.

<u>Procedure.</u>

Animals were adapted to the deprivation schedule and were given their daily ration of water in the testing chamber. Every lick at the spigots resulted in the delivery of .005 ml of water. The animals rapidly adjusted to drinking in the chamber. Responding was initially characterized by side biases, but all animals regularly sampled both sides. Over all subjects there was a small left-side bias. When animals had at least two weeks of drinking in the chamber they received 4 days with vinegar and coffee replacing water. These data are not reported here, but were used to see if preference measures would shift as solutions shifted from side to side. This was in fact the case. Sessions were 20 minutes long throughout the study. After the coffee/vinegar series the animals were returned to a water-only series for three days. Testing consisted of alternating treatment and no-treatment days. On no-treatment days, sessions were conducted as previously, except that saline and sucrose replaced water. On treatment days animals were placed in a plastic restraining harness used for injections, and submerged from the neck down for two minutes in water at approximately +2 C. Immediately after the bath animals were toweled dry and placed in the chamber. There were four no-treatment days and three treatment days. The position of saline and sucrose alternated from left to right every second day.

Results

The cold bath produced a significant overall decrease in total amount of licking, $p<.05$ (all tests based on Wilcoxon T unless otherwise stated). Consumption of saline showed larger relative and absolute decreases. The effects on choice were assessed by calculating the average choice measure for each animal on the day preceding and the day following each treatment session. This ratio was then compared to the treatment days choice ratio. This difference was found to be statistically significant, $p <. 05$. The effect is also apparent from inspection of Table 4, which shows the daily choice ratios. Sucrose preference measures increased on treatment days, for all

Table 4

Relative Preference for Sucrose as a Function of Cold Treatment

	Session				
Subject #	N-T	C-B	N-T	C-B	N-T
#1	.37	.47	.93	.76	.31
#2	.40	.98	.26	.83	.29
#3	.99	1.0	.88	1.0	.77
#4	.58	.98	.99	1.0	.30
#5	.71	.95	.44	.96	.82
#6	.51	.88	.83	.89	.49
#7	.91	.99	.99	1.0	.78
#8	.66	.75	.71	.79	.43
Means	.64	.88	.75	.90	.52

Note: N-T= no treatment days ; C-B= cold-bath days subjects. In addition to these effects on the overall measures of consummatory behavior, the cold water treatment also affected the pattern of responding. On no-treatment days licking always occurred within the first 30 sec of a session. On treatment days there were only four occasions out of 24 in which licking began in the first 30 sec interval. In the average no-treatment session 68% of the total session licks had been emitted by the end of the fifth minute, while the corresponding figure for treatment days is 31%. This indicates that the effect of the cold bath was most strongly felt during the early portion of the session. The pattern of alternation among the solutions was also affected. Animals usually began with a long bout of sucrose licking. The probability was .88 that drinking would begin on the sucrose side on no-treatment days and .92 on treatment days. The cold treatment affected the time to the first saline drinking bout, defined as the first 30 sec interval with more than 10 saline licks. On no-treatment days the median location of this bout was in the second minute, while on treatment days the median interval was in the fifth minute. This reflects a considerable delay in the initiation of saline licking. It is important, therefore, to establish that the reduced saline consumption did not result solely from limited drinking time. If this were the case the present results would be an artifact of session length. To evaluate this possibility consumption during the last five minutes was compared for both saline and sucrose across treatment conditions. If cold treatment merely delayed the initiation of drinking, then there should have been more drinking in the last five minutes of treatment-day sessions than in no-treatment sessions. This was not the case, $p > .10$. On all days there was only sporadic drinking during the last quarter of the session.

Discussion

The results of this experiment support the findings of Experiment 1A in showing saline ingestion to be a weaker response than sucrose consumption. This replication is important in demonstrating that similar results can be obtained with saline and sucrose solutions that are relatively novel, removing the objection that the findings of Experiment 1A were limited to familiar solutions. In addition this replication is useful in demonstrating that the same pattern of change can be obtained with a different procedure for reducing consummatory behavior.

These results are surprising in showing the most pronounced effect during the first portion of the session. The effects of a response-decreasing operation should be seen most clearly in the latter portions of the session. Domjan (1977) reported findings consistent with this expectation. Animals in his study were given consumption tests while experiencing the effects of LiCl illness. Domjan (1977) found no difference between poisoned and unpoisoned groups during the first 10 minutes of the test, but significant differences in each 10 minute period thereafter. The difference between Domjan's (1977) results and the present may lie in the use of a choice procedure, or in the assessment method. Choice tests are commonly regarded as more sensitive tests; this could account for the detection of difference during the first 10 minute period.

III. TASTE FAMILIARITY AND RESPONSE STRENGTH

Experiment 2

It has long been clear that taste salience in aversion conditioning is not merely a function of the qualitative features of a flavor, but reflects as well an animal's familiarity with a taste. Revusky and Bedarf (1967) demonstrated that the salience of taste was reduced by a period of familiarization, a finding which has been replicated many times (Best, 1975; Best & Barker, 1977; Bolles, Riley, & Laskowski, 1973; Carroll, 1975; Domjan, 1972;1977; Elkins, 1973; Farley, McLaurin, Scarborough, & Rawlings, 1964; Fenwick, Mikulka, & Klein, 1975; Kalat & Rozin, 1973; Nachman & Jones, 1974; Siegel, 1974; Wittlin & Brookshire, 1968; Zahorik, Maier, & Pies, 1974). This decrease in taste CS effectiveness can be explained in response strength terms, as outlined earlier. By this account, taste exposure produces an increase in consummatory response strength. The only assumption that needs to be made is that ingestion has reinforcing consequences for consummatory responding. A number of studies have shown that it is possible to reinforce consumption of a "neutral" substance by reinforcement with another consummable substance (Best, 1975; Holman, 1975; Revusky, 1967; 1968b); therefore, it is reasonable to assume that the response of consuming a substance can be reinforced by the direct consequences of that consumption. If this is indeed the case, then the taste preexposure effect follows as a result of the increase in response strength, and no special process need be postulated to explain the effect.

By contrast, current formulations of the preexposure effect appeal to processes that emphasize the uniqueness of taste-aversion learning (Best & Barker, 1977; Best & Gemberling, 1977; Kalat, 1977b). Kalat and Rozin (1973) offered the first theoretical account of the preexposure effect in aversion conditioning. They argued that preexposure retarded susbsequent conditioning by allowing the animal to learn that the exposed substance was safe - i.e., it did not cause any aversive gastric states. In support of their argument, Kalat and Rozin (1973) offered evidence from an ingenious experimental design. They compared taste-aversion conditioning in animals who had a single flavor exposure 1/2 hr prior to lithium chloride injection, and a group that had two exposures - one 4 hr prior to injection and then again 1/2 hr prior to injection. If aversion formation requires only the association of illness with a trace of the taste stimulus, then the two-presentation group, with a stronger taste trace, should form a stronger aversion. On the other hand, if "learned safety" is a factor, then the two-presentation group should develop a weaker aversion because they have had four hours to learn that the solution is safe. The data from Kalat and Rozin (1973) clearly show a learned safety effect, as the various two-exposure groups always developed weaker aversions. Subsequent studies have shown that, within limits, the retardation is a function of the inter-taste interval, as predicted by the learned safety account (Domjan & Bowman, 1974; Best & Barker, 1977; Best & Gemberling, 1977).

The learned safety account has been criticized on logical and theoretical grounds (Best, 1975; Best and Barker, 1977). The theory implies that an animal learns an association between the act of ingestion and the non-occurrence of illness; however, it is not clear how an association is formed to the non-occurrence of an event. A more serious problem for the learned safety formulation comes from a study by Best (1975). Best demonstrated that preexposure retarded aversion conditioning and, unexpectedly, preference conditioning as well. Best first established saccharin as a conditioned aversive stimulus by repeated pairing with poisoning. Following this training saccharin solution was occasionally presented with another previously unpaired flavor. On these occasions animals were never posioned; the second flavor could thus be considered a safety signal. Subsequent preference testing revealed an enhanced preference for the safe flavor relative to a control group. This conditioned preference could not be demonstrated, however, when the safe flavor was exposed prior to its pairing with the aversive saccharin solution. The learned safety account leads to the expectation that preference conditioning should be facilitated or unaffected by preexposure, but not that it should be retarded by exposure. Best (1975) concludes that learned safety is best interpreted as latent inhibition (Lubow, 1973). Kalat (1977a; 1977b) has accepted this reinterpretation, and now refers to the effects of preexposure as learned non-correlation, reflecting a belief that preexposure (even a single exposure) allows the animal to learn that a flavor is uncorrelated with any special (positive or negative) consequences.

Despite the ability of the learned non-correlation account to explain the effects of exposure on aversion or preference conditioning, there is reason for thinking that it is not totally sufficient. The non-correlation position is not able to explain one important associated effect of preexposure - the reduction of neophobia. As Domjan (1977) has noted, it is not clear why animals should consume more of non-correlated, or low salience substances. The attenuation of neophobia does, however, follow from the response-strength account, as stronger responses are, generally, more probable responses.

A second difficulty for associative accounts of the preexposure effect lies in explaining why preexposure occassionally fails to retard conditioning. Kalat (1977b) and Nachman (1977) have shown that if consumption of a preexposed flavor is followed immediately by poisoning there is often no effect of preexposure. Preexposure effects are only reliably demonstrated with CS-US delays of 1/2 hr or longer. Kalat (1977a) has also reported a failure to obtain the preexposure effect when a solution is passed rapidly over the rat's tongue, permitting tasting but preventing swallowing. Domjan and Bowman (1974) have demonstrated that there are stimulus differences in learned safety. They were unable to demonstrate a learned safety effect with the two-presentation procedure of Kalat and Rozin (1973), when the flavored solution was 2% saccharin. It is not clear what kind of associative mechanism could explain these exceptions to the preexposure effect.

The response strength analysis can accommodate these findings in a unified account. Preexposure effects are assumed to be mediated by changes in consummatory response strength. Evidence for changes in response strength with preexposure can be found in a number of learned safety experiments (Domjan & Bowman, 1974; Nachman & Jones, 1974; Siegel, 1974). Domjan and Bowman (1974) replicated Kalat and Rozin's (1973) two-presentation procedure with the addition of a non-poisoned two-presentation control group. They found that the two-presentation control group consumed significantly more than the single-presentation controls, an indication that consummatory response strength had increased in the two-taste group. Nachman and Jones (1974), Parker (1976), and Siegel (1974) found that willingness to consume a "novel" solution on second presentation was an increasing function of time since the first exposure. This is the case whether consumption is measured in a choice procedure or in a single-solution test. Further, the time course of increased consumption following taste exposure mirrors the time course of interference with conditioning. Parker (1976) established six hours as the limit on increased tendency to consume, while Best and Gemberling (1977) found a maximal learned safety effect with a six hour delay. These increases in consumption following exposure are consistent with the idea that taste exposure leads to increases in response strength.

The conditions that fail to produce a preexposure effect are also consistent with expectations from a response strength-analysis. Kalat (1977b) reported no preexposure effect when his animals tasted but did not consume a solution. Part of the reinforcement that produces an increase in consummatory response strength comes from normal post-ingestional consequences. If these consequences are removed, as in Kalat's (1977b) procedure, response strength should not increase, and the preexposure effect should not be detected.

Domjan and Bowman (1974) found no preexposure effect with a 2% saccharin solution. Correspondingly, they failed to find any increase in preference for this saccharin solution in a group given two exposures but not poisoned; although all other concentrations produced both an increase in consumption and a learned safety effect. This correlation indicates that learned safety is only found when taste exposure leads to increases in response strength, suggested by increases in amount consumed. Finally Best (1975) reported that preexposure retarded preference conditioning as well as aversion conditioning. This is consistent with the response-strength interpretation. Strong responses are resistant to change, whether the change be an increase or decrease. Strengthening a response should make that response less modifiable in general, not merely more resistant to decrease.

The plausibility of this analysis would be increased by a demonstration that flavor exposure increases response strength in a test situation specifically designed to assess response strength. This was acomplished in the present study. Animals were given a week of exposure to a casein solution, followed by a series of choice tests. The animals chose between the familiar casein and a novel sucrose or saline solution under different levels of water deprivation. These choices were compared to the choice responses of another group tested in the same way, but not exposed to casein before testing. It was expected that familiar casein would be less resistant to change than novel casein, demonstrating exposure-produced increments in response strength.

Method

Subjects.

The subjects were 28 male Long-Evans hooded rats, 120-150 days old at the start of testing. Previous taste experience was limited to Purina lab chow and water.

Apparatus.

Choice testing was conducted in steel cages identical to the home cages, except for two graduated drinking tubes centered on the front wall. The drinking tubes had rubber stoppers with stainless-steel spouts. The solutions used were identical to the solutions used in the previous studies.

Procedure.

All animals were adapted to a 23.5 hr water-deprivation schedule. This was followed by seven days of familiarization training. Animals in the casein familiar group (N=12) were given 20 ml of casein in a small ceramic dish at the regularly scheduled drinking time. The dish was removed 20 min later, and 1 hr after the introduction of casein, animals were given 20 min of water.

Animals in the casein novel group (N=16) were treated in exactly the same way, except that water, rather than casein, was presented. This week was followed by 3 days of exposure to the choice testing procedure, with water available in the two drinking tubes. The purpose of this period was to familiarize the animals with the test procedure, and to check for side bias. For the purposes of choice testing the groups were divided in four. Each of the four groups (N=3 or 4) received a different amount of water before the choice test, either 0, 5, 10, or 15 ml. Water was presented in the home cages 1/2 hr before the choice test. On the first test day half the animals chose between casein and sucrose, and half between casein and saline. On the second test day the untested alternative was presented with casein. The order of presentation was balanced across groups. The two test days were separated by 4 days of water maintenance.

Results

Analysis of total intake on the two test days showed that casein consumption was significantly greater in the familiar group than in the novel group ($p<.01$, all results based on t-tests), although the total amount of fluid intake did not differ. The increase in casein consumption in the familiar group produced a significant between-groups difference in saline intake, with the familiar group ingesting considerably less saline ($p<.01$). Total sucrose intake did not differ between the two casein conditions. If casein consumption is considered as an interfering operation with respect to saline and sucrose consumption, then these results indicate that sucrose was less disrupted than saline ingestion.

Choice measures, presented in the left panels of Figures 4 and 5, display a complex pattern of interaction with prewatering and type of solution. For the novel group, casein was relatively unpreferred. Choice of casein declined with increases in prewatering, for both the saline and sucrose choice tests. This is the expected pattern if casein is a weaker ingestion response than saline or sucrose consumption. The familiar group displayed a much higher level of preference for casein solution in both choice tests. When familiar casein was tested against novel saline, prewatering increased casein preference, indicating that casein consumption was less affected by prewatering than saline ingestion. When familiar casein was tested against sucrose, prewatering had complex effects. With 5 ml prewatering, preference for casein increased, but with further increases in prewatering, casein preference decreased. The reversal of this function would occur at 10 ml, rather than at 5 ml, if the extreme data from one animal were excluded. Reversal of the

Figure 4. For the casein novel group panel A shows the percentage of casein consumed in a 20-min choice test as a function of size of water preload, with either sucrose or saline as the alternative. Panel B shows the total amount of saline or sucrose consumed during the test.

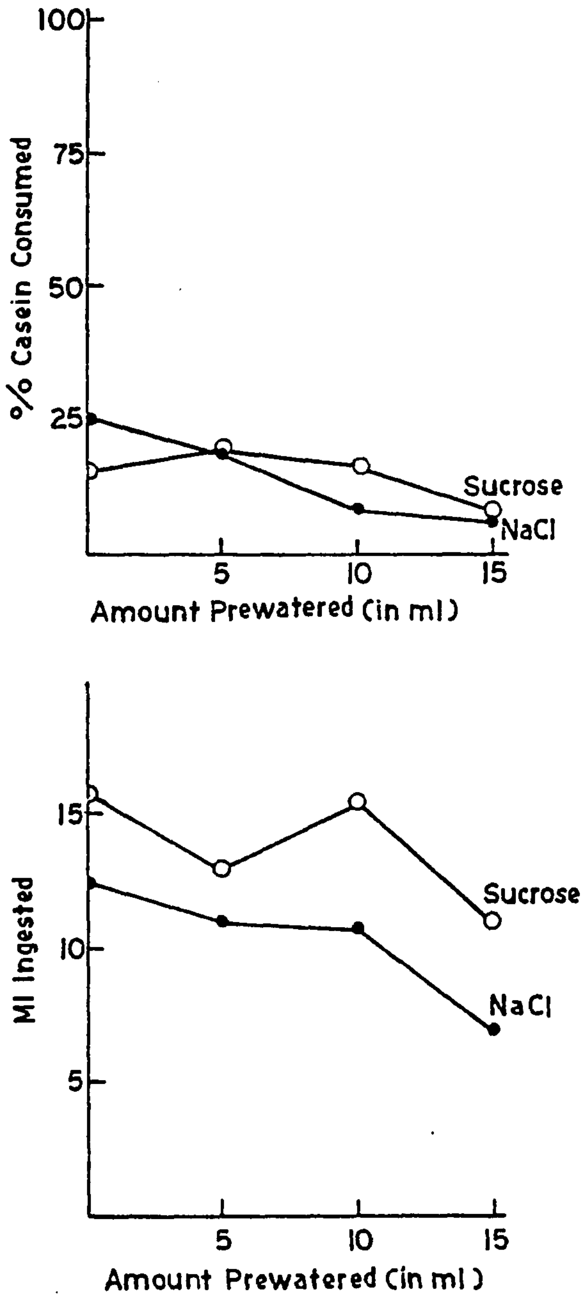

100
75
50
25
% Casein Consumed
Sucrose
NaCl
5
10
15
Amount Prewatered (in ml)
15
10
5
Ml Ingested
Sucrose
NaCl
5
10
15
Amount Prewatered (in ml)

Figure 4

Figure 5. For the casein familiar group panel A shows the percentage of casein consumed in a 20-min choice test as a function of size of water preload, with either sucrose or saline as the alternative. Panel B shows the total amount of saline or sucrose consumed.

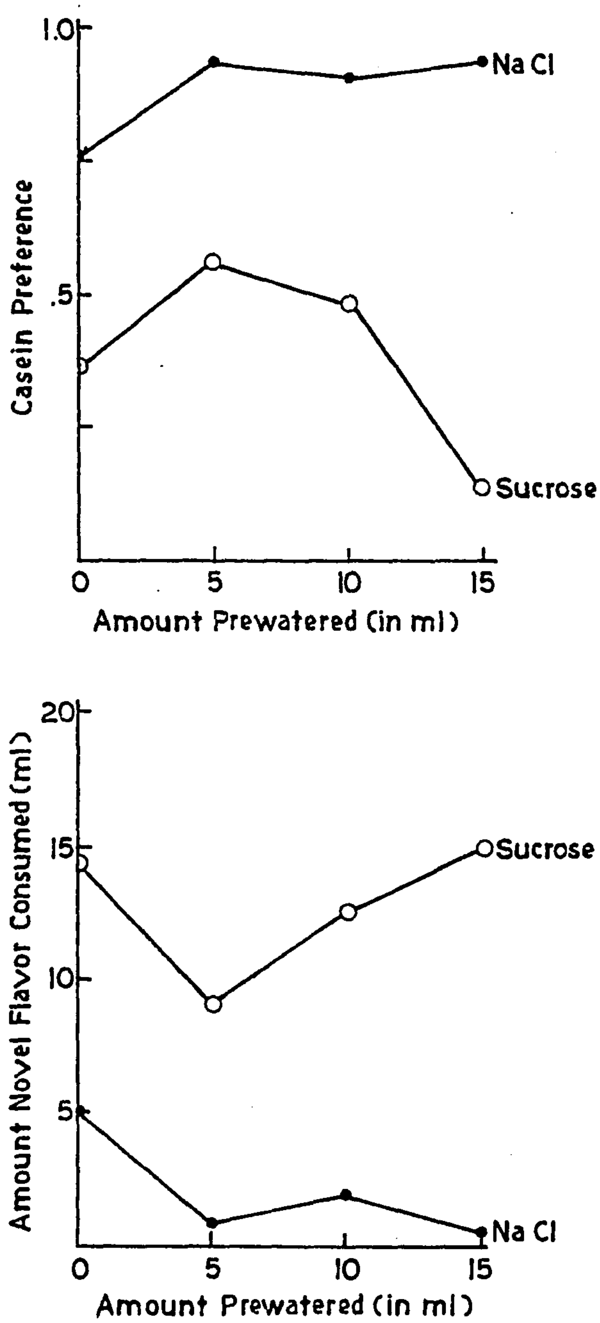

1.0
.5
Casein Preference
Na Cl
Sucrose
0
5
10
15
Amount Prewatered (in ml)
20
15
10
5
Amount Novel Flavor Consumed (ml)
Sucrose
Na Cl
0
5
10
15
Amount Prewatered (in ml)

Figure 5

preference shift is caused by an increase in sucrose consumption as the preload increases in size.

To compare the resistance of casein consumption to prewatering in the two groups, total casein consumption was expressed relative to consumption with 0 ml prewatering. These relative measures, displayed in Figure 6, indicate that consumption of casein in the novel group was more disrupted by prewatering than consumption in the familiar group.

Figure 6. Relative decrease in casein consumption as a function of size of water preload for animals in the casein-familiar group and the casein-novel group.

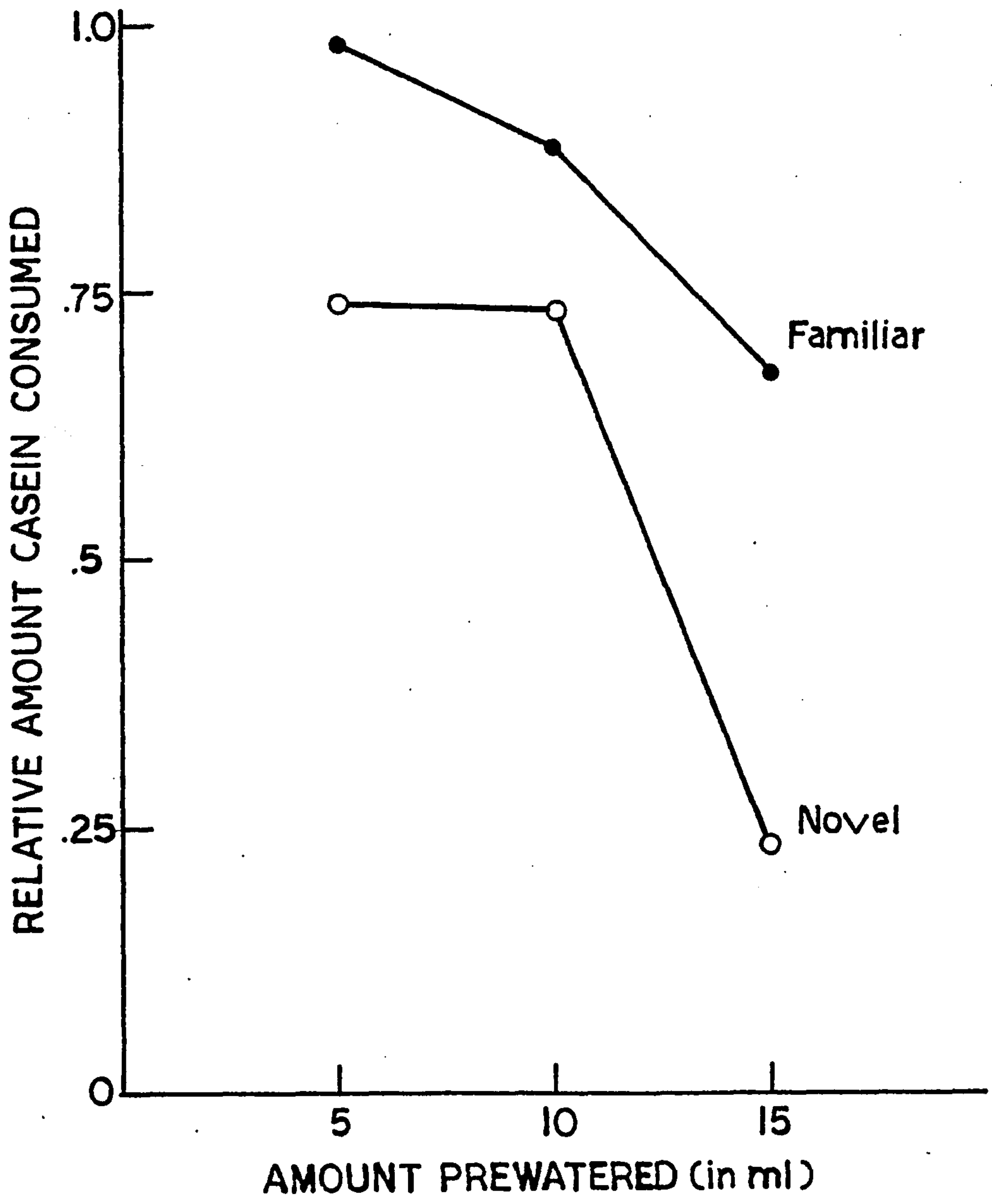

1.0
.75
.5
.25
0
RELATIVE AMOUNT CASEIN CONSUMED
Familiar
Novel
5
10
15
AMOUNT PREWATERED (in ml)

Figure 6

Discussion

These results demonstrate that exposure to relatively unpreferred casein was effective in increasing casein preference and the response strength of casein ingestion. The increase in response strength was revealed by the greater resistance of casein consumption to prewatering in the familiar group, and by the tendency of preference for casein in the familiar group, but not the novel group, to increase with prewatering. This study also supported the results of earlier studies showing saline ingestion to be a weaker response than sucrose ingestion.

The present results lend credibility to the interpretation of flavor preexposure effects given in the introduction to this study. Kalat (1977b) has recently raised objection to a reinforcement interpretation. Because a reinforcement interpretation has not seriously been considered in the taste-aversion literature before, Kalat's criticisms will be taken in turn.

Kalat's (1977b) criticisms stem from a conception of reinforcement that differs significantly from the conception underlying this research. In his first two criticisms, Kalat states that a reinforcement interpretation is discredited by the findings of a preexposure effect under conditions of "no reinforcement". Preexposure effects have been obtained with "non-nutritive" substances such as saline and saccharin (Domjan and Bowman, 1974; Kalat, 1977a). But Kalat uses a concept of reinforcement that does not have wide currency. Kalat identifies nutritive properties as reinforcing, although there is no basis for such an identification. Both saline and saccharin have been shown to be effective reinforcers (see Kling & Schrier, 1971). In a related criticism, Kalat cites findings of preexposure effects in water-satiated animals (Domjan & Bowman, 1974; Seigel, 1974). Here Kalat identifies reinforcing ability with drive-reducing ability, but this identification has been untenable for decades (e.g., Sheffeld, Roby, & Campbell, 1954). Additionally, the fact that the satiated animals willingly ingested a solution is an indication that consumption still retained reinforcing ability.

Kalat contends that if reinforcement is an important part of taste-aversion learning, then we should expect to find an inverse relation between the amount of a solution ingested and conditioned aversion strength (Kalat, 1976). Instead it is found that amount consumed, when duration is held constant, has no relation to aversion strength. There are two replies to this criticism. First, variations in the amount of a reinforcer often do not produce any detectable behavioral effects on instrumental behavior (Kling & Schrier, 1971), but this has not been taken to mean that reinforcement does not affect instrumental behavior. Second, depending on how amount is measured, it be can shown to have powerful effects on taste-aversion learning. If variation in the number of exposures to a solution is taken as a variation in amount, then there is a direct relation between amount of reinforcement and interference with taste-aversion conditioning (Elkins, 1973). Kalat, however, probably means to refer to variation of amount within a single taste exposure. But in this case Kalat's criticism loses some of its force. Kalat's general argument requires that a manipulation that has been shown to affect reinforcement value have no effect when applied in an aversion conditioning procedure. Unfortunately, there are no data that would allow the comparison that Kalat wishes to make. A study is needed that compares the effectiveness of variations in the size of a reinforcer that is presented only once to a subject.

Kalat's final objection to a reinforcement account draws upon data from the two-presentation procedure of Kalat and Rozin (1973). It has been demonstrated that increasing the interval between the two tastes reduces the conditionability of the flavor (Best & Barker, 1977; Kalat, 1977b). A reinforcement account would have to assert that the effectiveness of the reinforcer increases as the temporal interval between presentations is increased. The similarity in the form of the function relating increases in preference with time since testing (e.g., Seigel, 1974), and the decreasing function for conditioned aversion strength with longer taste-illness intervals is consistent with this possibility. In addition, a variety of studies from the massed versus spaced trials literature support the notion that reinforcements spaced in time are more effective than massed reinforcments (Hall, 1966).

A plausible basis for the increase in reinforcer effectiveness with increasing temporal separation is to assume that the response-strength increment from a reinforcer is related to the sum of all the post-ingestional consequences of consumption, and that these consequences are extended over a period of time. If a second reinforcer is delivered during this period of summation, it may interfere with the first reinforcer. This speculative account leads to the expectation that there will be a temporal limit on the effectiveness of separation between the two reinforcers. On the other hand, learned safety predicts increasing interference with increasing separation. Data addressed to this point have been collected by Best (Best & Barker, 1977; Best & Gemberling, 1977), and show that the interference effect does not increase with separation of the tastes above four hours. This finding is consistent with the reinforcement interpretation.

IV. GENERAL DISCUSSION EXPERIMENTS 1-2

The first experiments have attempted to demonstrate that taste salience relations can be reduced to differences in consummatory response strength. These experiments have shown that the ordering of taste saliences commonly obtained corresponds to the ordering of response strengths, as assessed by a resistance to prewatering test. It was also shown that repeated exposure to a flavor produces increases in consummatory response strength. A response-strength intrepretation of taste-aversion learning provides a basis for predicting salience relations, accounts for the relation between neophobia and conditioning, and offers a satisfactory account of preexposure effects. All of this is achieved without the introduction of principles unique to food aversion learning.

The response-strength analysis receives additional support from a series of observations by Carroll (1975). Carroll studied the effects of saccharin concentration and taste familiarity on aversion conditioning, extinction, and neophobia. All of her results are consistent with expectations based on the present analysis.

Caroll (1975) reported that increases in saccharin concentration produced increases in conditioned aversions - i.e., stronger saccharin concentrations were more salient.

The more salient concentrations also produced greater neophobia, as would be expected of weaker consummatory responses. Additionally, it follows that if response strength underlies salience, rate of recovery from a conditioned aversion should vary with "salience". This was the case in Carroll's study. Stronger responses, or less salient tastes, displayed more rapid extinction. This difference in extinction rates remained even when adjustments were made for different levels of suppression.

Carroll (1975) also conducted a series of studies on the effects of taste exposure. From the response strength account it is expected that exposure will produce increased resistance to aversion conditioning, and increased consumption. Carroll obtained both effects. The response-strength analysis also leads to the expectation that weaker responses should continue to receive increments in response strength for a greater number of flavor exposures than strong responses. This prediction follows from the observation that strong responses are initially closer to their asymptotic levels of response strength than weaker responses, as indicated by the data on neophobia and response strength (Carroll, 1975). Furthermore, strong consummatory responses are expected to be more powerful reinforcers than weak consummatory responses. Therefore, a long series of flavor exposures should find strong responses at asymptote of response strength early in the series, while weaker responses continue to increase in strength with additional flavor exposures. In taste-aversion conditioning this should be reflected in differences in exposure produced decrements in aversion strength. Within a few sessions maximal exposure-produced interference with conditioning should be reached for strong responses but with weaker responses exposure should continue to produce interference with conditioning for many additional sessions. These predictions are confirmed by the results of Carroll's (1975) third experiment. Comparisons of the consumption of .5%, 1% and 2% saccharin indicated that consumption levels reached asymptote more rapidly for weaker concentrations (stronger responses). In agreement with this measure, repeated taste exposure continued to affect conditioning to the more concentrated solutions for a longer period of time. For the .5% group, exposure beyond the eighth day did not lead to further increases in resistance to conditioning, while resistance to conditioning increased with exposure for 21 days for animals in the 1% and 2% groups.

Finally, Carroll (1975) reported a study on enhanced neophobia. Groups of rats were made ill while drinking water, allowed to recover, and then tested for their willingness to consume different concentrations of saccharin. The enhanced neophobia groups were compared to groups given saccharin-LiCl pairings, and untreated control groups. The present analysis assumes that the pattern of suppression depends only upon the relative strengths of the responses. The pattern of suppression should remain invariant over all operations that affect the responses equally. Consistent with the response strength account, Carroll's enhanced neophobia groups displayed a pattern of suppression identical to saccharin-LiCl groups. Enhanced neophobia was greater to more concentrated solutions, the same solutions that supported stronger conditioned aversions. Not only was the pattern of suppression identical between the enhanced neophobia group and the conditioned aversion groups, but quantitatively the effects were similar. For the most concentrated solution the learned aversion could not be distinguished from the enhanced neophobic reaction.

The correspondence between salience and the ordering of enhanced neophobia effects raises a serious question about the utility of the taste salience concept. As originally introduced, the concept was defined as ".. the tendency of a solution to be associated with subsequent poisoning"(Kalat & Rozin, 1970). But Caroll's (1975) findings show that the same pattern of suppression is obtained whether a solution is paired with poisoning or unpaired with poisoning. This suggests that some property besides salience underlies the relation.

The utility of the salience concept is further questioned by results of Domjan (1977). Domjan investigated the primary suppressive effects of LiCl-induced illness. Animals were injected with LiCl and 30 min later given a consumption test, with concentrations of saccharin similar to those used by Carroll (1975). Domjan (1977) found that illness produced greater suppression of consumption with stronger concentrations, the same solutions that have been shown to be more "salient" (Carroll, 1975; Garcia et al., 1977), and the same concentrations that have been shown to be more susceptible to enhanced neophobia. In support of the present interpretation of taste exposure, Domjan (1977) reported that illness-mediated suppression was reduced by taste preexposure. This is to be expected if taste exposure produces increases in response strength.

From these studies the following pattern emerges. Consumption of saccharin can be suppressed by pairing saccharin with LiCl, by injecting LiCl while animals are consuming another edible, or by injecting LiCl shortly before the consumption period. The concept of salience applies only to the first case above. But the same pattern of suppression in consumption is found with all these operations. The notion of taste salience cannot explain this correspondence. There is no readily apparent reason why associable tastes should show greater enhanced neophobia, or be more suppressed illness, or be more disrupted by prewatering. All of these changes are, however, consistent with the response strength account.

One of the major issues in taste-aversion learning has centered around the "belongingness" phenomenon (Garcia & Koelling, 1966). Belongingness refers to differential stimulus control which results when drinking is suppressed by induced illness or by electric shock. When electric shock is the aversive agent, rats learn to avoid a food source on the basis of visual or auditory cues, while following illness avoidance is guided by taste. The full pattern of results is not consistent with the response strength account of stimulus effectiveness. The observation that poisoned rats avoid the taste of a solution is, by itself, consistent with the present account. Taste-mediated avoidance is the observation that rats who have been made ill will subsequently drink more "bright-noisy" water than saccharin solution. This shows that water consumption is a stronger response than saccharin consumption, consistent with studies that show the difficulty of establishing a water aversion (Revusky & Garcia, 1971). Also, Domjan (1977) has found that animals tested during the period of LiCl illness display greater suppressrion of saccharin drinking than water drinking. Extending the response-strength account to the case of consumption suppressed by electric shock leads to an incorrect prediction, however. The response-strength account predicts the same pattern of results, regardless of the nature of the aversive event. This finding places a limit on the generality of the response-strength account of stimulus effectiveness in taste-aversion conditioning.

At some point in the future it may be possible to extend the response-strength account to the analysis of belongingness. The response strength analysis might be usefully integrated with the analysis of punishment and response type interactions. A number of studies have demonstrated that different responses are differentially sensitive to different punishers (Bertsch, 1972; Bolles & Seelbach, 1964; Shettleworth, 1978; Walters & Herring, 1978). If illness causes more suppression of ingestion than electric shock, and if electric shock causes more suppression of approach or search behavior, then the interaction known as belongingness could be explained in response-strength terms. Such an account, while recognizing species differences, would make no assumptions about the uniqueness of food aversion learning. But for the present this account remains speculative.

V. CONSUMMATORY AND INSTRUMENTAL MEASURES OF RESISTANCE TO CHANGE

Experiment 3

The first experiments have presented an account of taste-aversion learning that emphasizes the motivational properties of the tastes used as conditioned stimuli. The experimental strategy has been to show that relations obtained in taste-aversion studies are also obtained when prewatering replaces illness as the consumption-reducing operation. These relations were interpreted in terms of the concept of response strength. The analysis thus far has not included a direct comparison between change produced by an aversion conditioning procedure and the change produced by an independent rate suppressing operation; this is accomplished in the present experiment. Changes in responding produced by three operations - aversion conditioning, prewatering, and presentation of a conditioned aversive stimulus - are compared over a variety of response measures. Data are obtained on the change in consummatory responding, and the instrumental behaviors that provide access to the consummatory behaviors. Additionally, the change is measured when only one response is available, and when choice between two responses is available.

The procedures used to measure response strength replicate the procedures used by Nevin (1974, 1979) to measure the strengths of operant responses. Determinations of strength are made within a single session, and all comparisons are within-subject comparisons. The procedural changes move the analysis closer to traditional taste-aversion studies, and closer to the response-strength procedures previously shown to be reliable.

The present experiment examines the effects of pairing coffee and vinegar solutions with LiCl injection on a number of response dimensions. This contrasts with the standard aversion conditioning procedure, where conditioning is measured only by a change in consumption. The addition of response measures has relevance to evaluation of the special status of taste-aversion learning. It has been argued that taste-aversion learning is an adaptation linked to feeding and drinking behaviors (Garcia et al.,1974; Rozin & Kalat, 1971; Seligman, 1970). The relation between taste-aversion learning and feeding regulation may constrain the behaviors that can be modified by pairing with illness. Garcia, Kovner, and Green (1970) provided evidence for such constraints. In their study rats learned to choose saccharin over saline in a T-maze. When differential responding was established saccharin in the home cage was paired with poisoning. The animals readily learned to suppress consumption of saccharin, but they continued to run to the saccharin arm. The aversion conditioning procedure modified consummatory behavior, but had no measurable effect on instrumental behavior. Additional evidence suggesting a constraint on illness-motivated learning was provided by Morrison and Collyer (1974, Experiment 2). In their study, rats failed to decrease rate of bar pressing in the presence of a cue associated with a conditioned aversive taste, although consummatory behavior was strongly affected. Even more striking evidence of constraints on the behavior modified by taste-aversion learning has been presented by Reicher and Holman (1977). Rats were given amphetamine injections following choice of one arm of a T-maze, where they also consumed a distinctively flavored solution. The injections reinforced choice in the T-maze, even though the animals were simultaneously developing a taste aversion to the flavored solution. On the basis of such observation Garcia et al. (1974) have argued that natural selection has promoted an associative mechanism for feeding behavior that selectively modifies consummatory behavior. The corresponding proposition is that instrumental behavior will be less sensitive to gastric consequences than consummatory responses.

The insensitivity of instrumental responses to aversion conditioning manipulations would not be expected on the basis of findings with chained schedules of reinforcement (Kelleher, 1966). Studies of chained performances are consistent in showing that performance in the early portions of a response sequence is weaker than performance nearer the reinforcing event (Nevin, 1979). But the earlier portions of the chain of responses in the studies cited above all involved instrumental behaviors. If instrumental behaviors were in fact weaker behaviors, they should have been more disrupted by pairing with illness than the consummatory responses. The greater sensitivity of consummatory behavior in the taste-aversion studies cited above is also surprising in light of demonstrations that show little variation in consummatory responding with variations in motivation. Corbit and Luschei (1966) found that rats' rate of drinking remains invariant over changes in solution quality and length of deprivation. Miller, Bailey, and Stevenson (1950) demonstrated that amount consumed by food-deprived rats was a less sensitive measure of "hunger" than rate of lever pressing. Similarly, in lesion-induced obesity, consumption measures generally indicate increased hunger, while a variety of non-consummatory measures indicate that food motivation is actually reduced (Teitelbaum, 1966).

The present experiment provides an opportunity to examine this question in greater detail by obtaining response measures that vary in form (bar press vs.

licking), in context (one vs. two responses available), and in function (instrumental vs. consummatory).

Method

Subjects.

Eight male Long-Evans hooded rats, 100-120 days, served as subjects. The animals had no prior experimental history, and taste experience had been limited to water and lab chow.

Apparatus.

A standard operant chamber, as described in Experiment 2, was used. Two retractable response levers were centered on the front wall, with jewel lamps located 2.5 cm above each lever. On the side wall by each lever was a slot, and behind this slot was the spout that delivered reinforcement. The chamber was enclosed in a larger light and sound insulating box. Electro-mechanical control equipment was located in an adjoining room.

Procedure.

Animals were first trained to drink water in the chamber. Drinking from the two spouts was brought under control of the jewel lamps by providing reinforcement for licking only when the appropriate side lamp was on. In the next phase the retractable levers were inserted into the chamber and a single bar press was required to turn on the side lamp, making water available at the corresponding spout. When bar pressing was well established reinforcement duration was set at 2.5 sec, where it remained for the course of the experiment. The final step before introduction of the full set of conditions was to reinforce responding on a 20 sec variable interval (VI) schedule (arithmetic progression).

Each session contained 20 periods of lever pressing. During these 80-sec periods only one lever was available, and reinforcement was delivered on a VI 20 sec schedule. Periods of left-bar and right-bar availability alternated regularly. At the completion of a period the houselights were turned off for 10 sec. Interposed between every bar press period was a choice trial. On choice trials both levers were inserted in the chamber, and the first response on a lever produced reinforcement on that side, terminating the choice trial, and initiating a 10-sec blackout. After 20 lever pressing periods and choice trials the levers were retracted, while the houselights and cue lights were turned on for a three-minute period. During this period licks at either spout were reinforced on the same VI schedules used for lever pressing. Animals had at least 30 days exposure to this full set of conditions.

Aversion training: There was one day of taste aversion conditioning. On this day coffee and vinegar replaced water as the reinforcer. There was no other change in conditions. Position of vinegar and coffee was balanced across groups. Immediately following completion of the session the animals were removed from the chamber and given an injection (10 ml/kg bodyweight) of either isotonic saline or .15M lithium chloride. The animals were then returned to their home cages, with food and water removed for 1.5 hr. On the succeeding 10 days animals were tested with vinegar and coffee in the experimental chamber.

Satiation testing: In the next phase of the experiment the pattern of change in responding produced by satiation was examined. To equate exposure to the two solutions and extinguish any lingering aversions, the animals were given a week of exposure to vinegar and coffee in their home cages. On alternate days coffee or vinegar was freely available, in addition to a daily 10-min water period. Animals were then returned to the experimental chamber for testing. Over the next 10 sessions animals were given four irregularly spaced test sessions. On test days animals were given 20 ml of water in the home cage, 1/2 hr before the start of the session. In all other respects sessions were run as before.

Conditioned suppression: Following the satiation test series animals were given four days of conditioned suppression, or conditioned emotional response (CER), training in a separate chamber. On each of these days animals received 5 pairings of an 80 sec tone and a 1 sec footshock (.3 mA), delivered at the offset of the tone.

The effects of pairing were assessed by presenting the tone during bar pressing periods and during the final 3-min licking period. There were two days of testing, with five tone presentations per session, four during lever pressing and one during the final concurrent licking period. The tone was presented for 80 sec at the start of the selected bar-press period. For concurrent licking testing the tone was presented for 80 sec, beginning 80 sec after the start of the period.

Results

Aversion training. On the conditioning day, the first day of exposure to the flavored solutions, responding on the vinegar side was more disrupted than responding on the coffee side. The ratio of bar pressing on the conditioning day to bar pressing on the last day of water reinforcement was .94 on the coffee-reinforced side, but only .64 on the vinegar-reinforced bar.This difference, which was statistically significant ($p<.01$, Wilcoxon T), held for 7 of the 8 subjects. Concurrent licking was also affected by introduction of the flavored solutions. Side-preference scores (licking to one side/ total of all licking) became more extreme; that is, choice measures diverged more from .5 on the first flavor day than on previous water-only days. However, there was no systematic shift of responding to one side or to one flavor. Lever press choice responses showed only a small shift away from the vinegar side, and the shift was seen only in three animals. Even less change was detectable in the rate of licking during reinforcement (hereafter referred to as drinking rate).

Responding during the 10 post-conditioning sessions revealed an acquired aversion to the vinegar solution, but no measurable aversion to coffee. Evidence supporting this conclusion comes primarily from analysis of rates of concurrent licking and VI-reinforced lever pressing. Rates of lever pressing for the course of testing and the last five days of water baseline for each subject are presented in Figures 7 and 8. These figures show that for animals in both groups introduction of vinegar occassioned a drop in response rate relative to the water-reinforced baseline. It was also the case for animals in both groups, with the exception of #4 in the NaCl group, that vinegar supported lower rates of responding than coffee. The distinction between the LiCl group and the NaCl group is found in the magnitude of difference between coffee-reinforced and vinegar-reinforced responding. The differentiation in rates of lever pressing is greater for subjects in the LiCl group than for NaCl-injected subjects. Rate differentiation in the LiCl group was greatest early in the post-conditioning period, and gradually decreased over the 10-day test period. This pattern is clearest in subjects #1 and #2, but is also characteristic of #8. This

Figure 7. Rate of lever pressing over the last five sessions of water reinforcement and the first ten sessions after conditioning for animals injected with LiCl. Responding on the vinegar side is indicated by closed symbols; responding on the coffee side is indicated by open symbols.

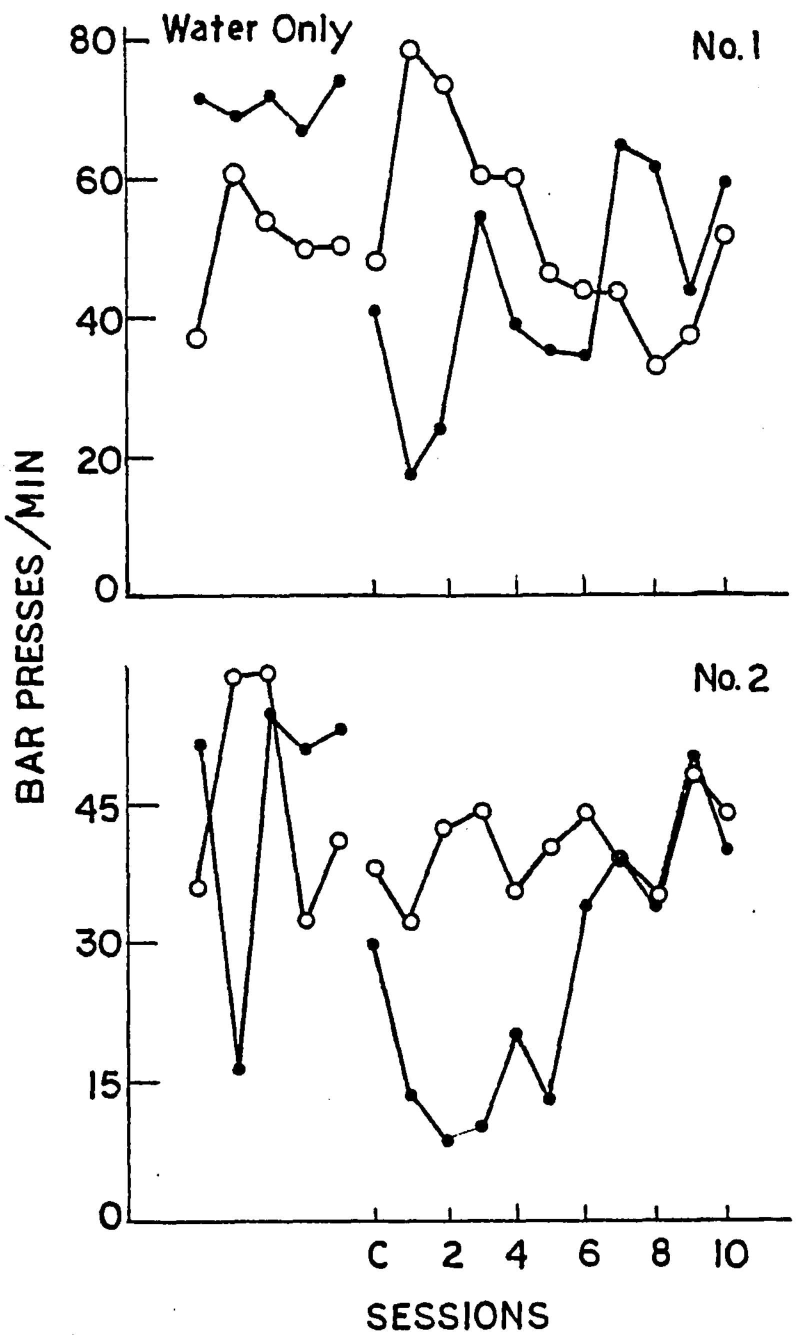

Water Only
No. 1
No. 2
80
60
40
20
0
45
30
15
0
BAR PRESSES/MIN
C
2
4
6
8
10
SESSIONS

Figure 7

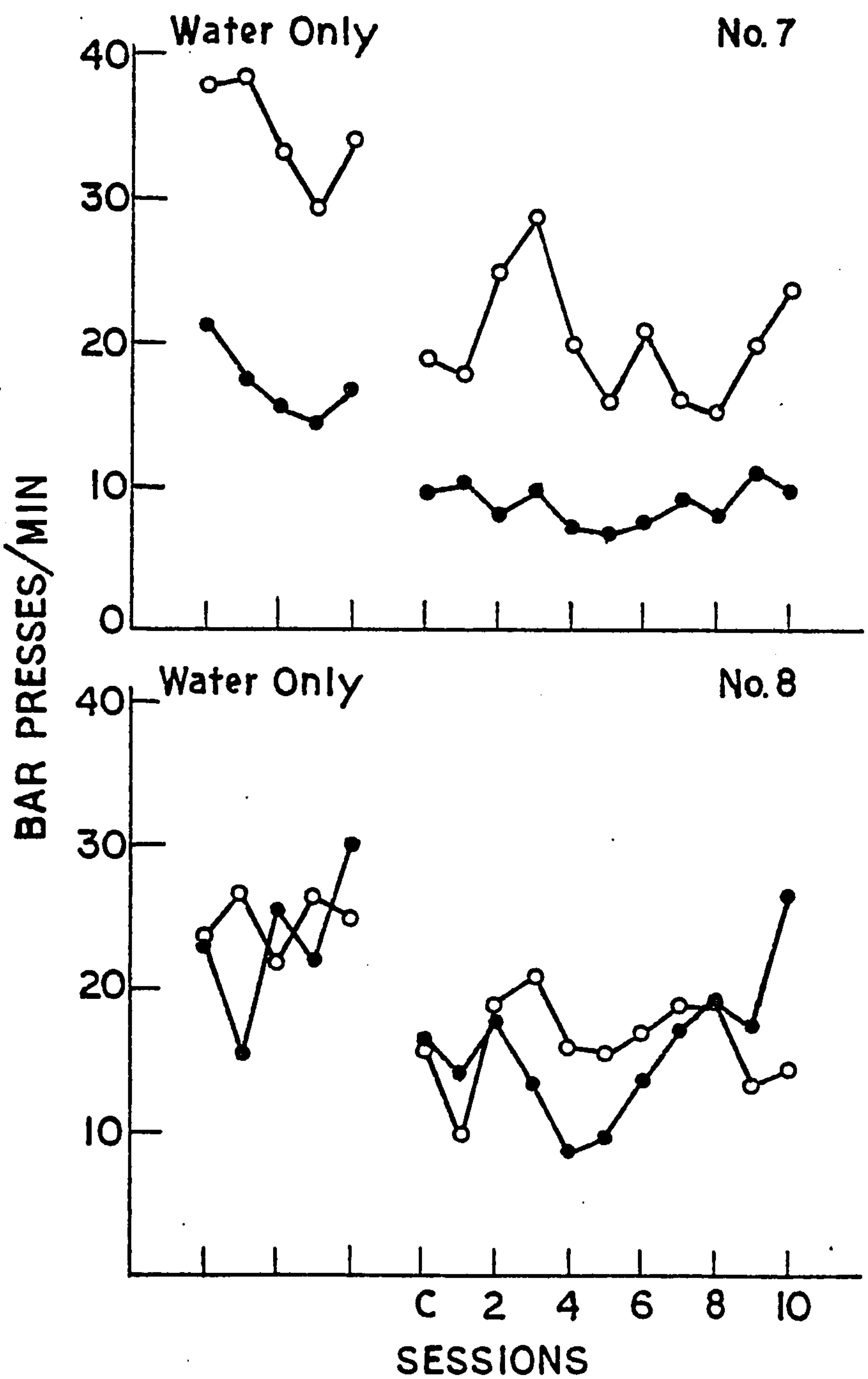
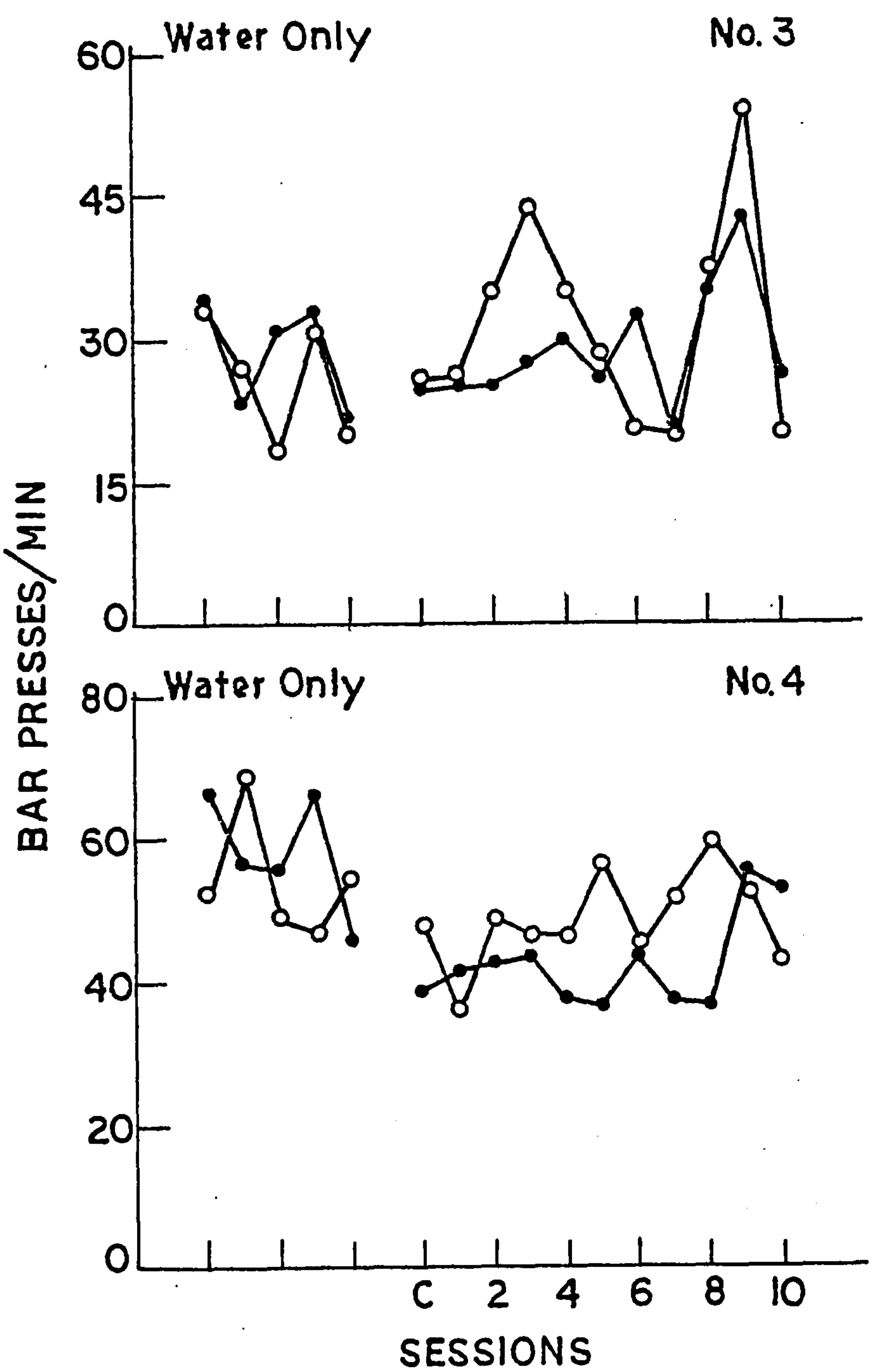


Figure 7 (cont.)

Figure 8. Rate of lever pressing over the last five sessions of water reinforcement and the first ten sessions after conditioning for animals injected with NaCl. Vinegar side= closed symbols; coffee side= open symbols.



Water Only
No. 3
60
45
30
15
0
Water Only
No. 4
80
60
40
20
0
BAR PRESSES/MIN
C
2
4
6
8
10
SESSIONS

Figure 8

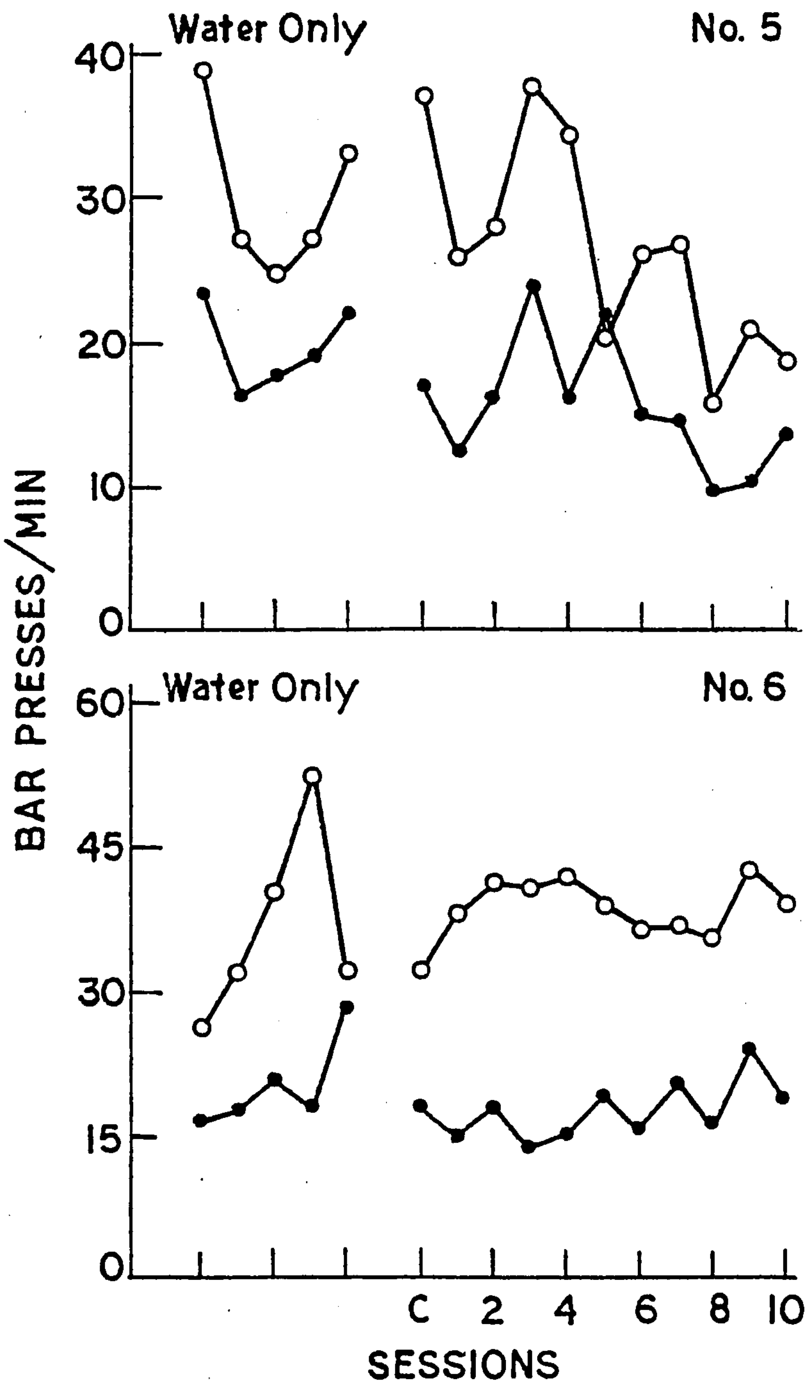


Figure 8 (cont.)

contrasts with the pattern of differences in the NaCl group. In that group the subjects who show the clearest differentiation between coffee and vinegar responding, #5 and #6, maintained a constant difference over the course of testing. Lever pressing for coffee in the LiCl group increased during the early portion of testing, and declined to its initial level over the test period. The increase in rate of responding for coffee generally occurred during the sessions when responding for vinegar was most suppressed. Figures 7 and 8 emphasize the transition from water-reinforced responding to the conditioning phase. For the purposes of a strength analysis it is useful to consider relative rates. In the analysis to follow relative rates were calculated by expressing responding during the 10-day test period in ratio to a baseline determined after the testing period. When animals had completed aversion testing they were given a week of flavor exposure in their home cages, and then returned to experimental sessions as before. For all subjects the means of performance on the first four days of post-exposure testing served as the baseline for relative rates. The relative rates of bar pressing are presented in Figures 9 and 10. The effects of pairing consumption with LiCl are more clearly revealed in these figures. For all animals in the LiCl group there is a sharp difference in relative rates of responding for coffee and vinegar.

Figure 9. Rate of lever pressing of animals in the LiCl group for the ten post-conditioning days, expressed relative to the mean post-exposure rate of responding. Vinegar responding= closed symbols; coffee responding= open symbols.

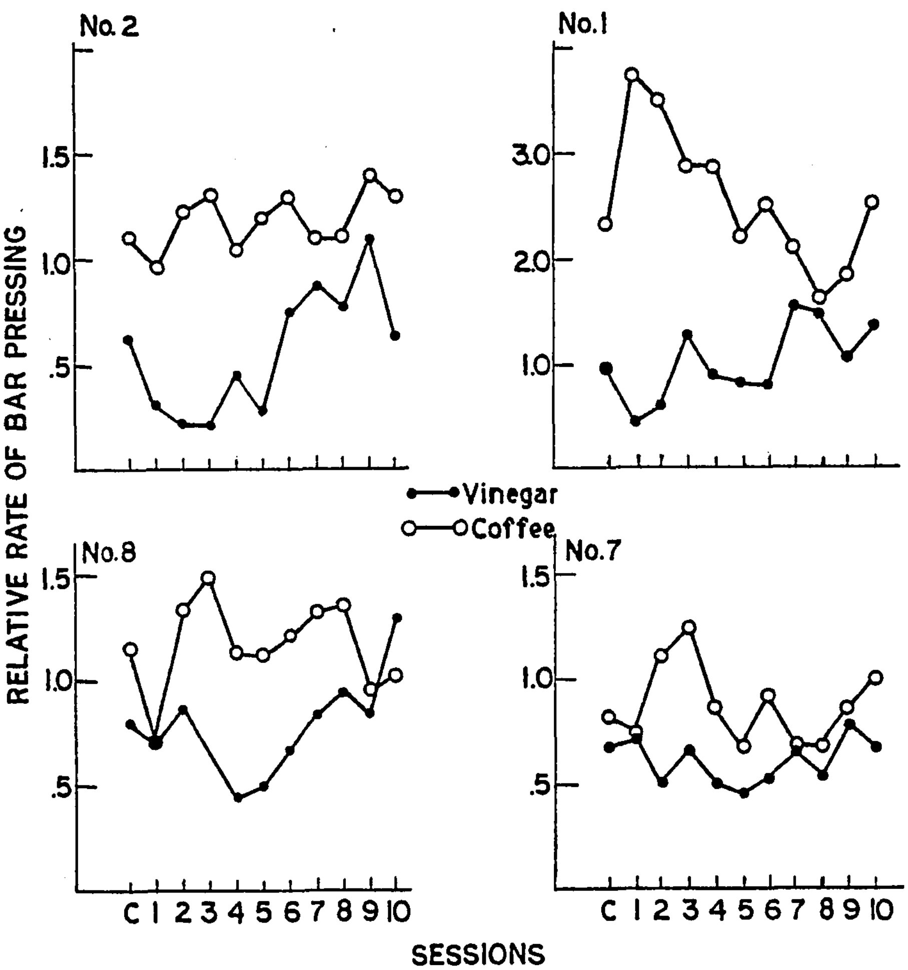

No. 2
No. 1
No. 8
No. 7
1.5
1.0
.5
3.0
2.0
1.0
RELATIVE RATE OF BAR PRESSING
Vinegar
Coffee
C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 9

Figure 10. Rate of lever pressing of animals in the NaCl group for the ten post-conditioning days, expressed relative to the mean post-exposure rate of responding. Vinegar responding= closed symbols; coffee responding= open symbols.

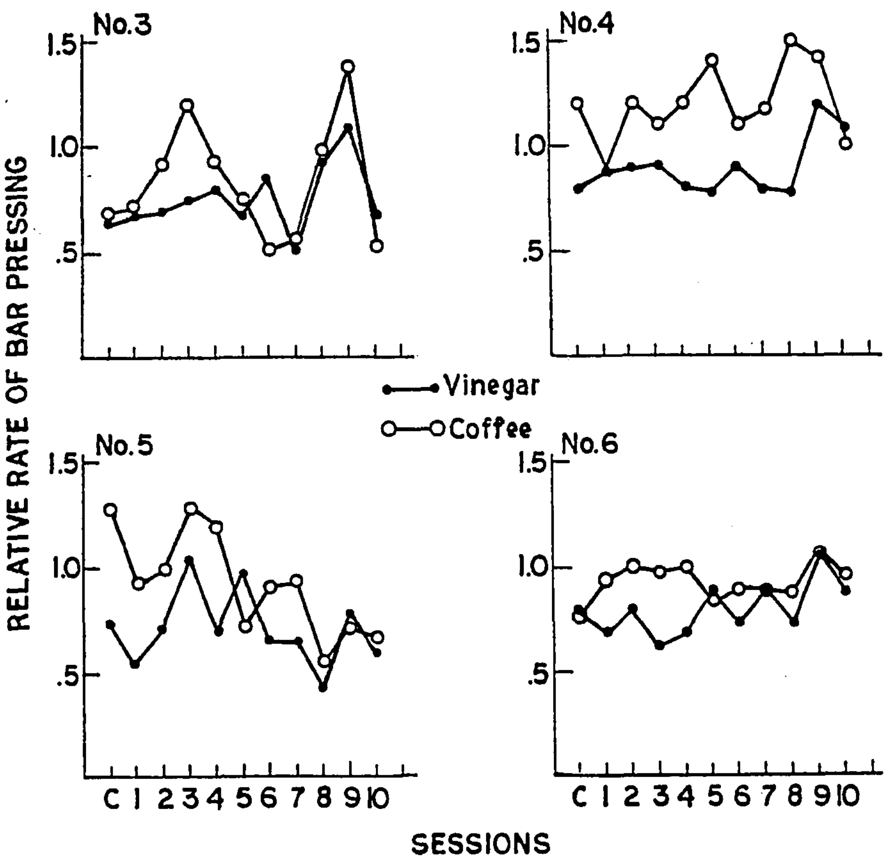

No.3
No.4
No.5
No.6
1.5
1.0
.5
RELATIVE RATE OF BAR PRESSING
Vinegar
Coffee
C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 10

Figure 11. Grouped relative rates of bar pressing for each post-conditioning session. Each point represents the group median relative rate. Vinegar reinforced responding is displayed in Panel A, coffee-reinforced responding in Panel B.

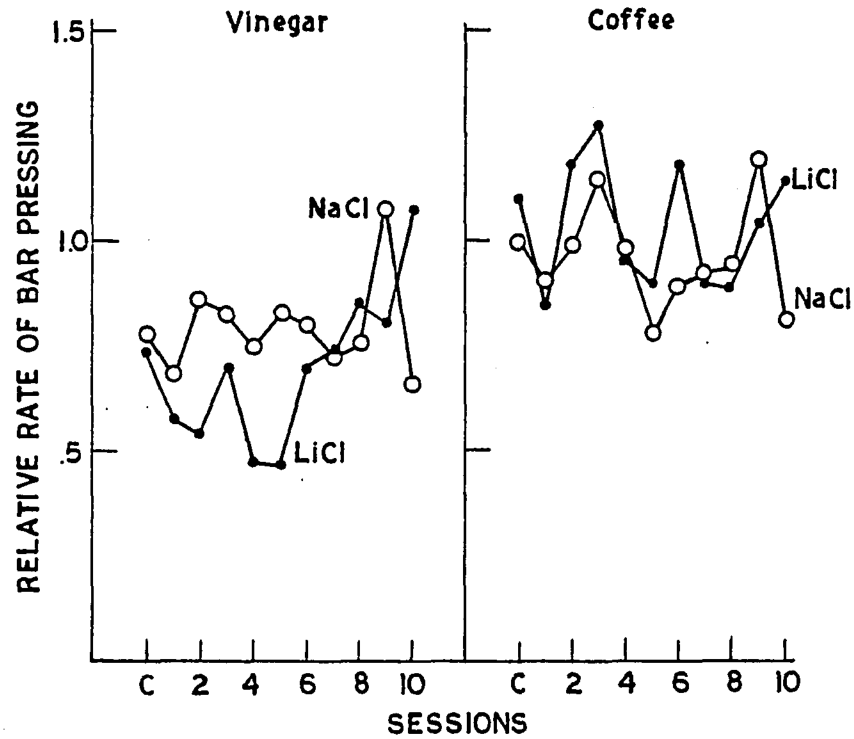
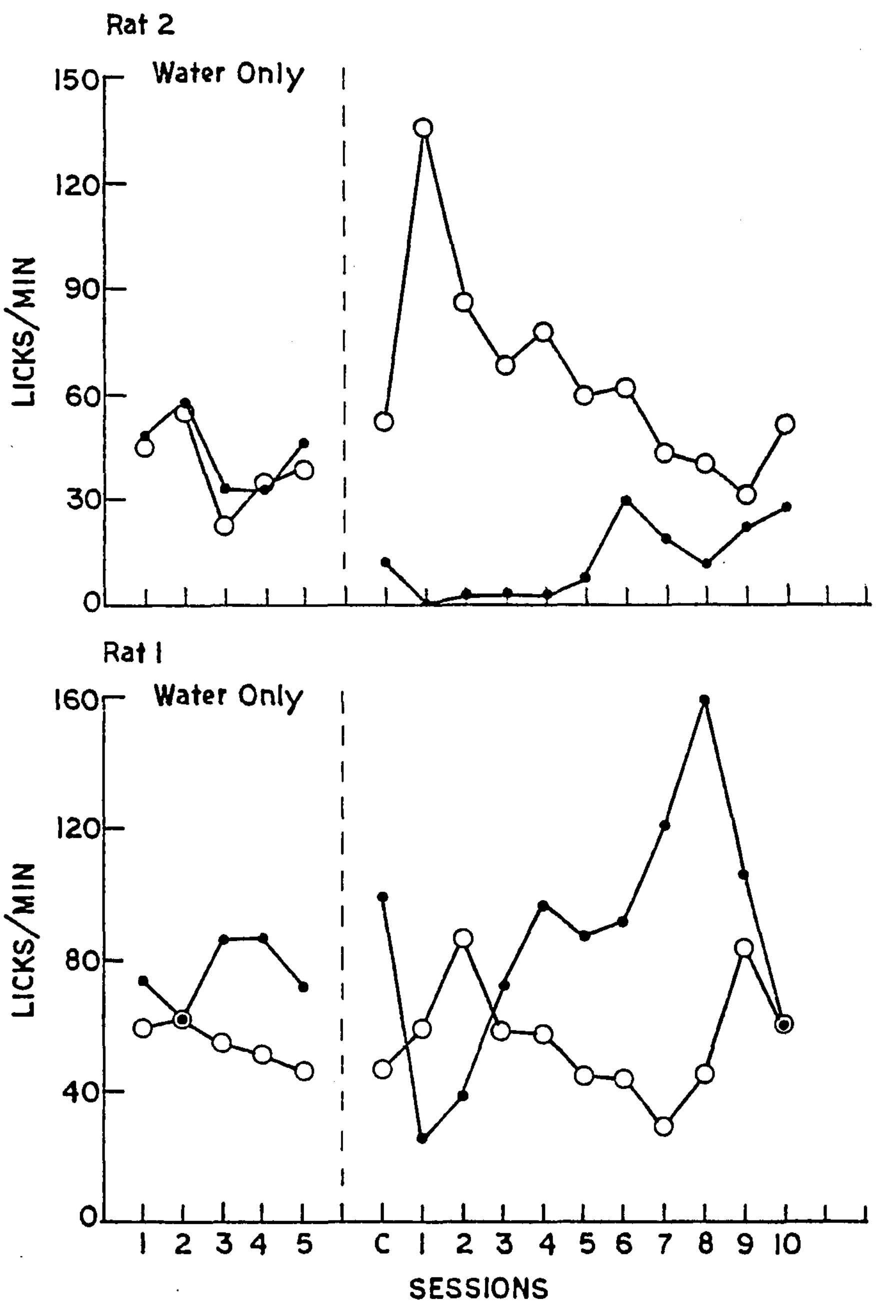

Vinegar
Coffee
1.5
1.0
.5
RELATIVE RATE OF BAR PRESSING
NaCl
LiCl
LiCl
NaCl
C 2 4 6 8 10
C 2 4 6 8 10
SESSIONS

Figure 11

Figure 9 also shows that coffee responding, relative to the post-exposure baseline, was greatly enhanced. The same degree of separation in rates of responding is not seen for the NaCl group. These individual plots are summarized in Figure 11, which shows group medians for the 10 days of testing. The group comparison reveals that there was a between-group difference for vinegar-reinforced responding, but not for coffee-reinforced responding.

The difference between coffee and vinegar responding is largest when concurrent licking is considered. Rates of licking for vinegar and coffee during the course of testing are shown in Figures 12 and 13. For the animals in the LiCl group, the effects of lithium are seen in the first testing session as a sharp decrease in responding for vinegar. For three of the subjects in this group vinegar responding was completely suppressed on at least two occasions. The exception to this, #1, shows a decrease in the first session which is followed by a rapid recovery of responding. The other three animals showed only a partial recovery of responding on the vinegar side, and then only after a number of sessions. Subject #6 in the NaCl group showed a suppression of responding more characteristic of the LiCl animals; this suggests that part of the decrease seen in the LiCl group was an unconditioned response to vinegar.

Figure 12. Rate of coffee- and vinegar-reinforced concurrent licking for the last five sessions of water reinforcement and the ten days after conditioning for animals in the LiCl group. Vinegar responding= closed symbols; coffee responding= open symbols.



Rat 2
Water Only
LICKS/MIN
150
120
90
60
30
0
Rat 1
Water Only
LICKS/MIN
160
120
80
40
0
1 2 3 4 5
C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 12

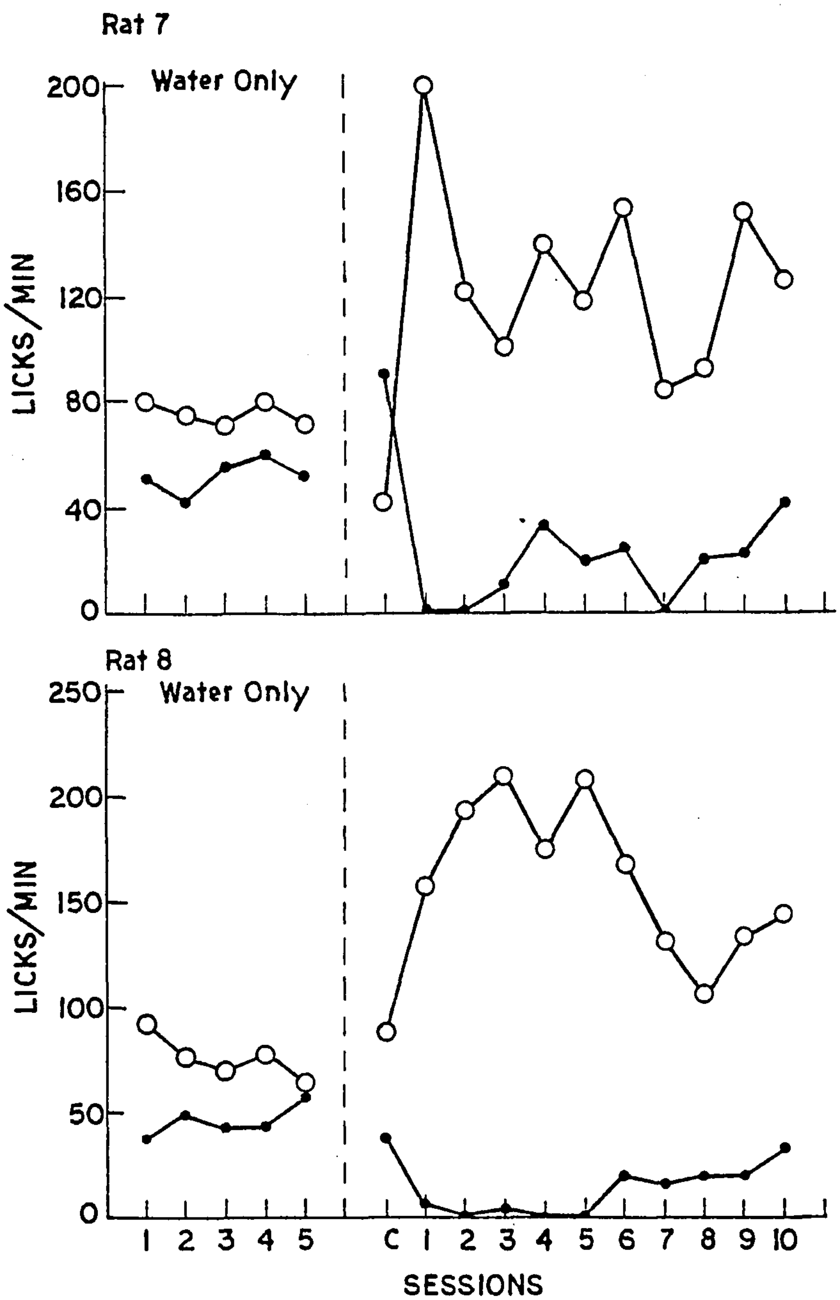


Figure 12 (cont.)

Figure 13. Rate of coffee- and vinegar-reinforced concurrent licking for the last five sessions of water reinforcement and the ten days after conditioning for animals in the NaCl group. Vinegar responding= closed symbols; coffee responding= open symbols.

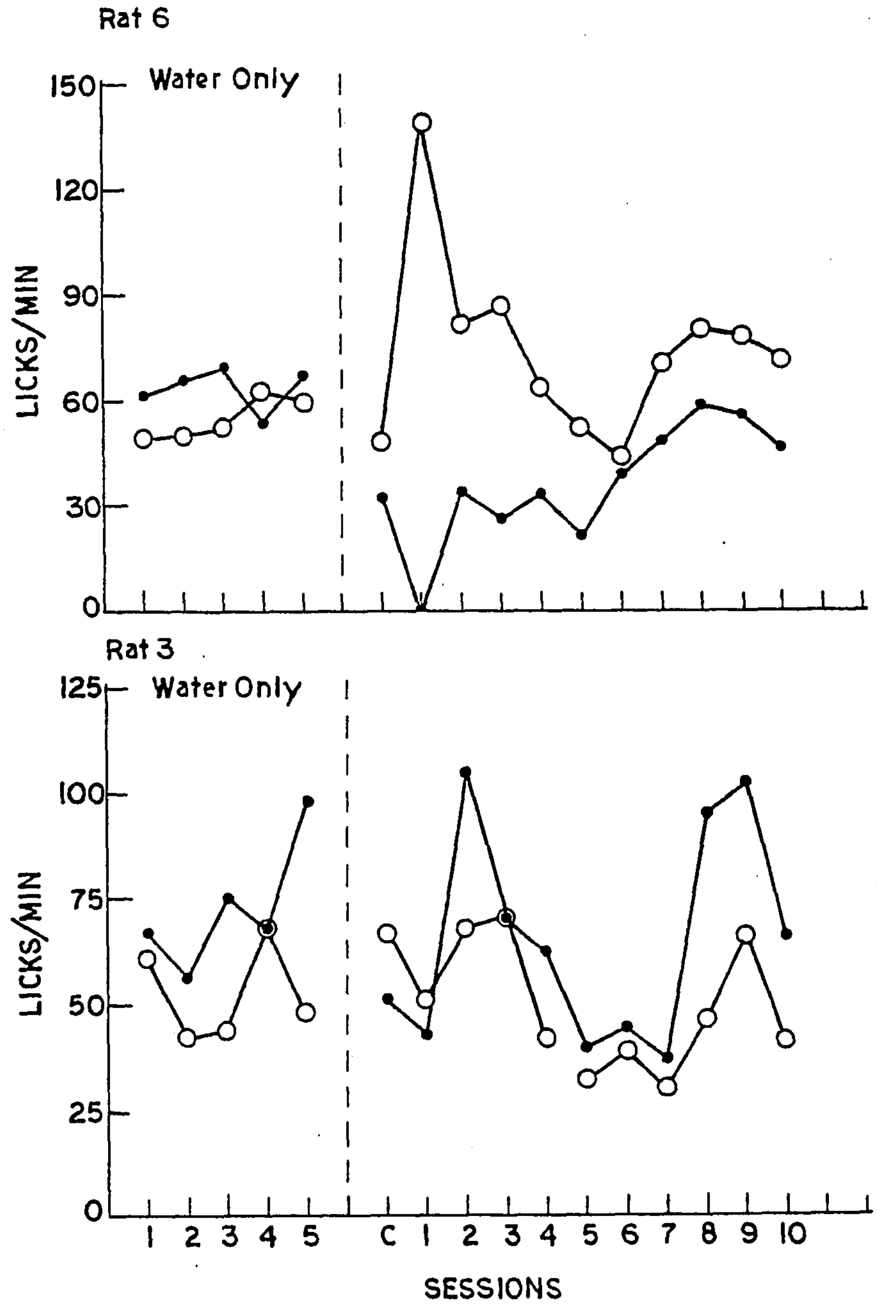

Rat 6
Water Only
150
120
90
60
30
0
LICKS/MIN
Rat 3
Water Only
125
100
75
50
25
0
LICKS/MIN
1 2 3 4 5 C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 13

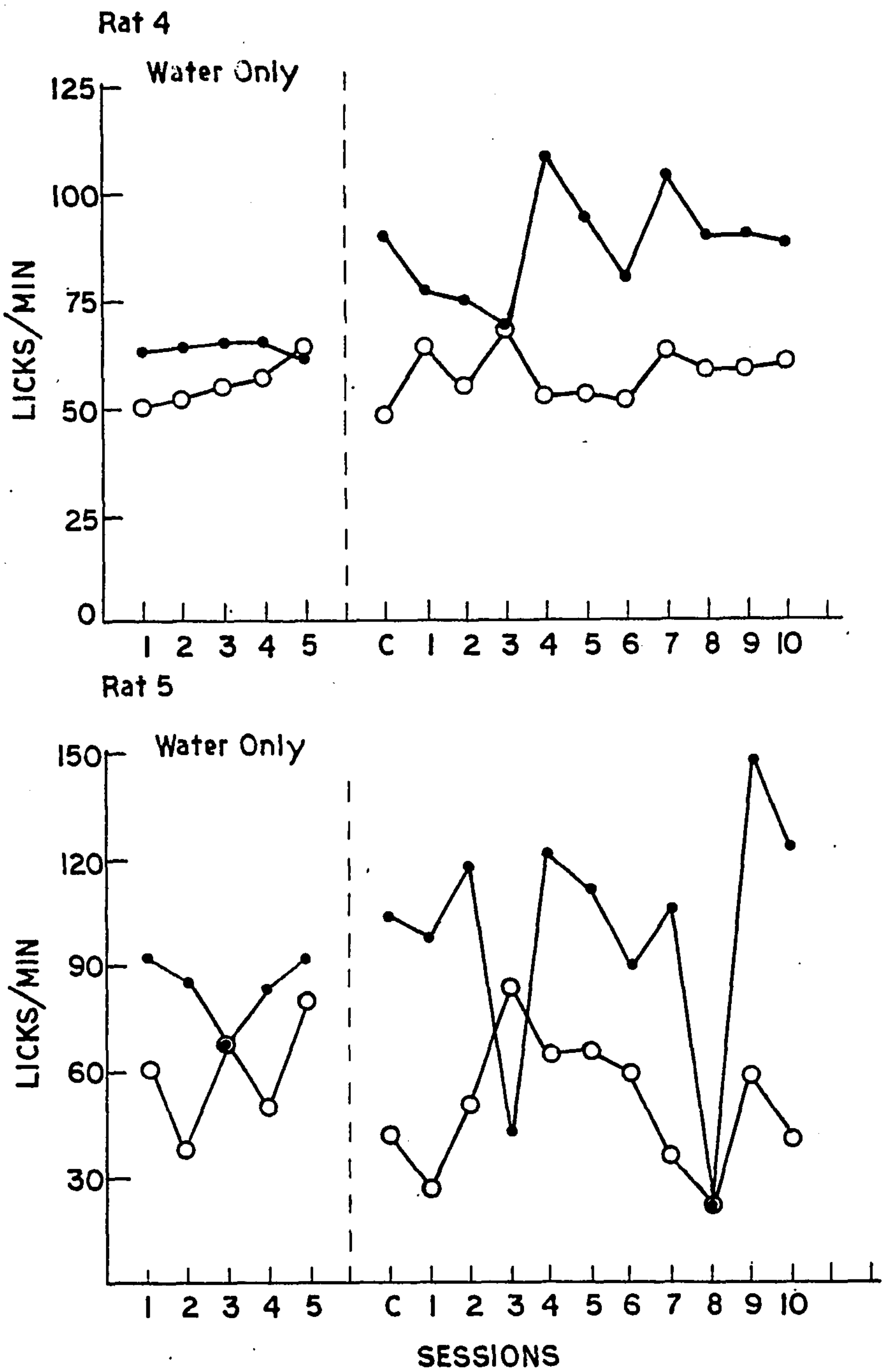


Figure 13 (cont.)

The decrease in licking for vinegar was accompanied by increases in coffee licking. This is similar to the increase seen in bar pressing, but the magnitude of the effect is far greater here. The increase occurs for subjects in both groups, but is considerably larger in the LiCl group; two animals in the LiCl group show over a four-fold increase above their water-reinforced baseline. This increase mirrors the pattern of decrease in vinegar licking. In general, the increases are greatest during the early portion of testing, when the aversion to vinegar is greatest - the same pattern observed with bar pressing. This may be seen in Figure 14, which displays the group medians for both coffee licking and vinegar licking.

Differentiation of vinegar and coffee responding was maintained over more sessions for concurrent licking than bar pressing. This difference may be due to differences in relative rates of reinforcement. The proportion of total reinforcers for bar pressing delivered on the vinegar lever never fell below .43 for any LiCl animal in any session. The proportions for concurrent licking occasionally fell to zero, and for the most part were maintained below .4 .

The sensitivity of concurrent licking contrasts with the results from lever press choice trials. These data, shown in Figures 15 and 16, reveal only weak trends in choice away from the vinegar side. Animal #2 came to prefer coffee after an initial preference for the vinegar

Figure 14. Grouped relative rates of concurrent licking. Each point is a group median of rates expressed relative to the post-exposure baseline. Vinegar responding= closed symbols; coffee responding= open symbols.

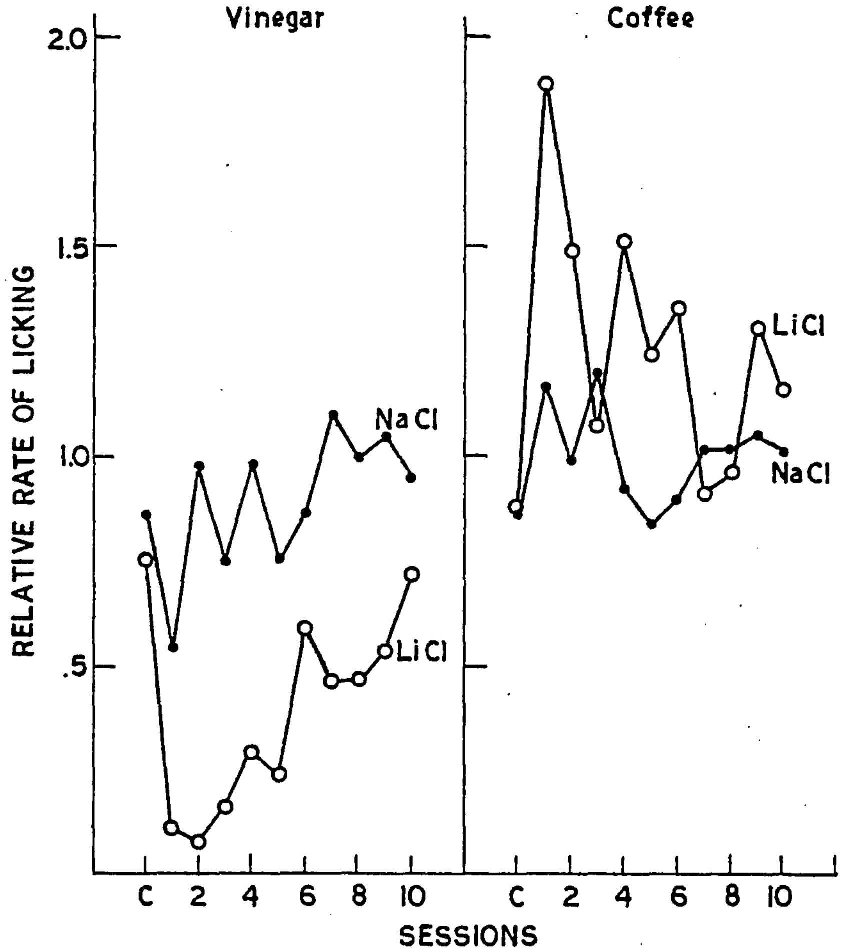

Vinegar
Coffee
2.0
1.5
1.0
.5
RELATIVE RATE OF LICKING
NaCl
LiCl
LiCl
NaCl
C 2 4 6 8 10
C 2 4 6 8 10
SESSIONS

Figure 14

Figure 15. Proportion of discrete-trial lever-press responses to the vinegar side over the last five days of water reinforcement and the ten post-conditioning sessions for animals in the LiCl group.

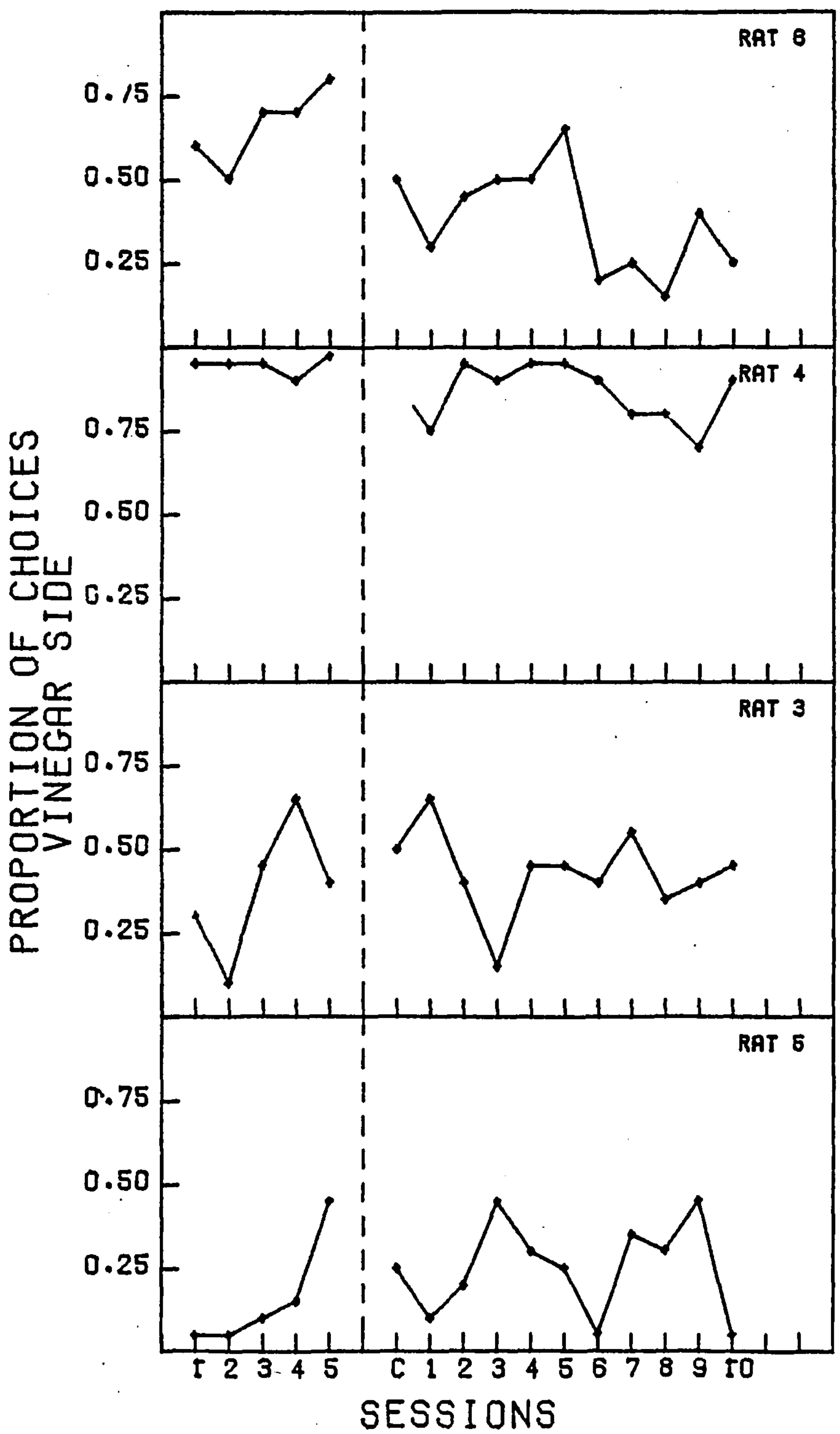

RAT 8
RAT 4
RAT 3
RAT 5
PROPORTION OF CHOICES
VINEGAR SIDE
0.25
0.50
0.75
1 2 3 4 5
C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 15

Figure 16. Proportion of discrete-trial lever-press responses to the vinegar side over the last five days of water reinforcement and the ten post-conditioning sessions for animals in the NaCl group.

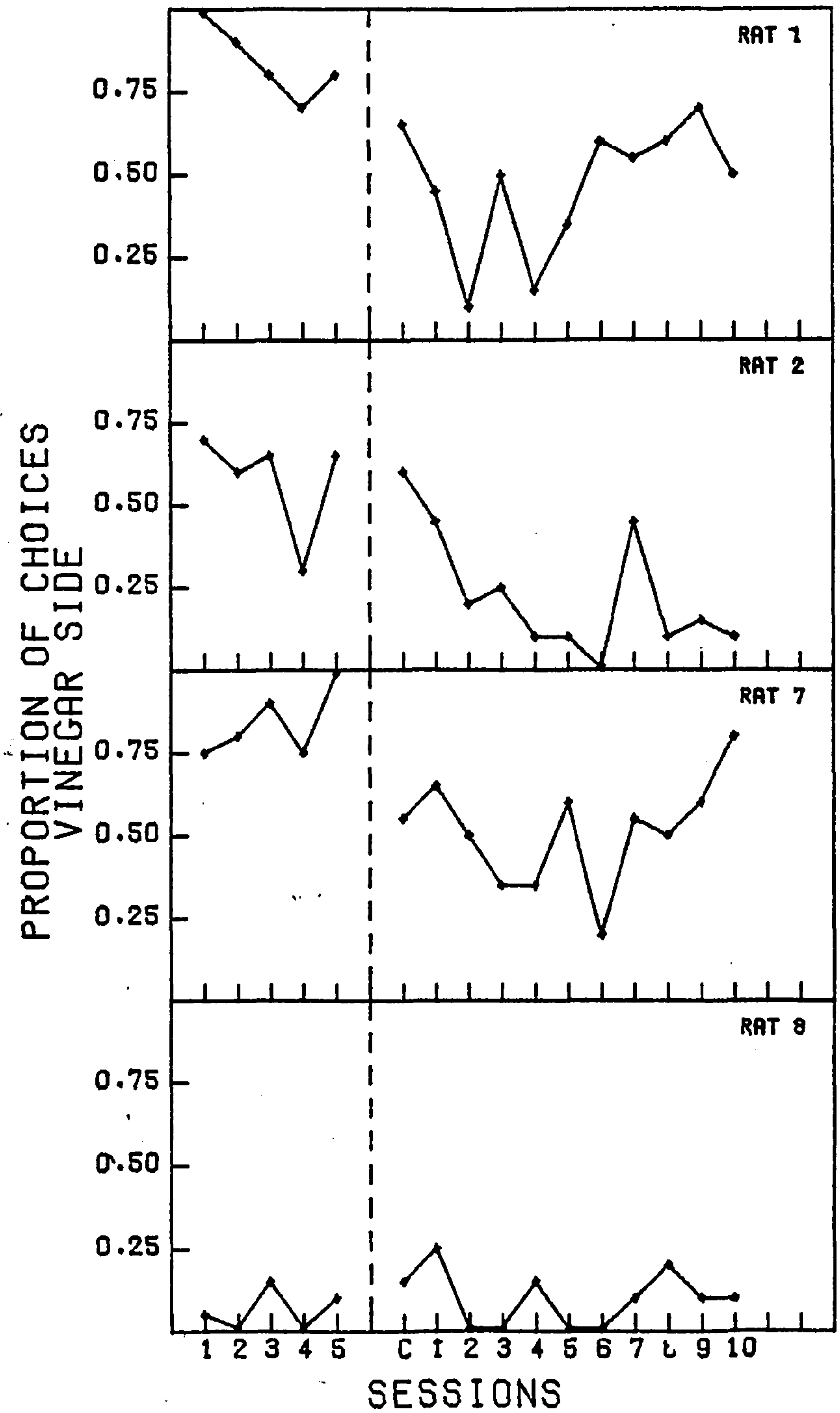

RAT 1
RAT 2
RAT 7
RAT 8
0.75
0.50
0.25
PROPORTION OF CHOICES
VINEGAR SIDE
1 2 3 4 5
C 1 2 3 4 5 6 7 8 9 10
SESSIONS

Figure 16

side, but this is the only animal to show a clear shift. These results suggest that the sensitivity of concurrent licking was not due merely to the availability of two responses.

Rate of drinking during the reinforcement periods was sensitive to the LiCl treatment. Rate of ingestion of vinegar, relative to a post-exposure baseline, was significantly decreased on the first two post-conditioning days; consumption of coffee was not significantly affected. Grouped data are presented in Figure 17. This figure reveals that the difference between groups in consumption of vinegar was eliminated by the fourth post-conditioning day. This stands in contrast to the measures of conditioning based on instrumental responding, which continued to show signs of suppression well past the fourth session. Drinking rates showed the most rapid recovery of any measure. Drinking rates to coffee, unlike bar-pressing or concurrent licking reinforced by coffee, did not increase during the period of suppression of vinegar drinking.

The 10-day post-conditioning period was followed by a home-cage exposure period to the flavored solutions. When the animals returned to experimental sessions lever pressing and licking for vinegar increased, while coffee responding remained essentially unchanged. The increase seen for the unpoisoned group gives a measure of flavor

Figure 17. Drinking rate for coffee - right panel - and for vinegar - left panel - expressed relative to post-exposure baseline. Each point represents a group median.

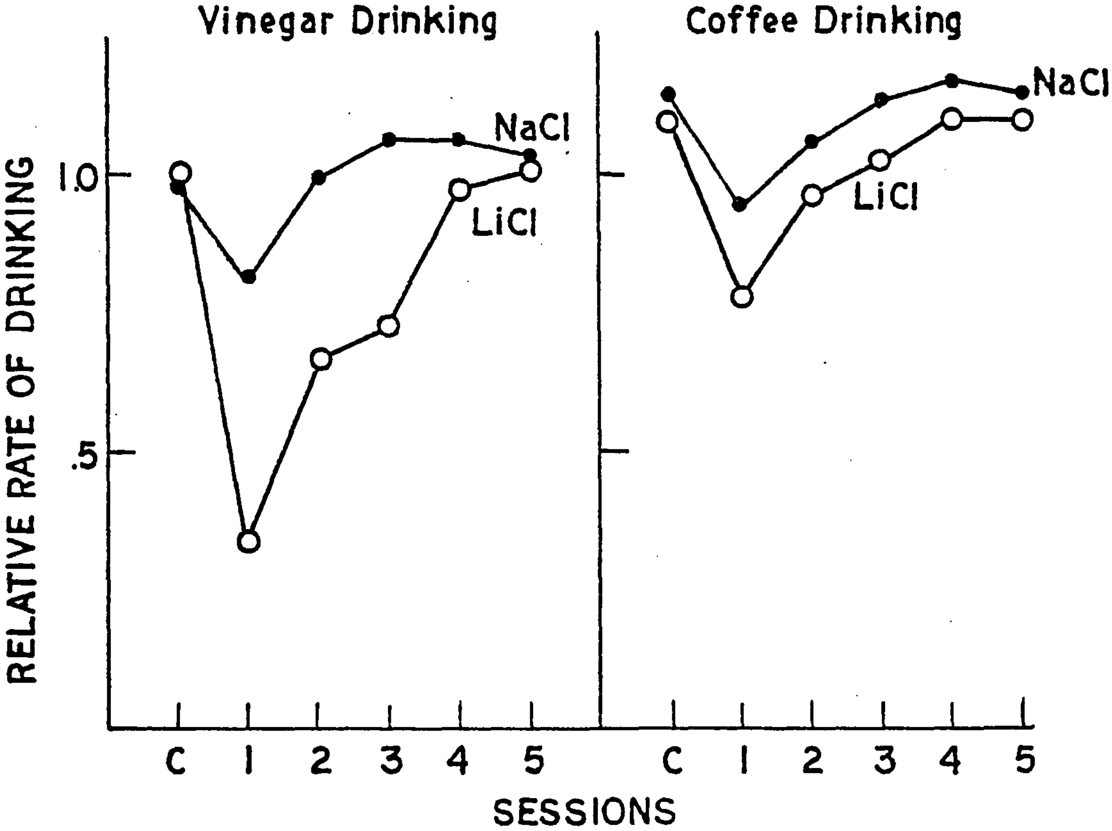

Vinegar Drinking
Coffee Drinking
NaCl
LiCl
NaCl
LiCl
1.0
.5
RELATIVE RATE OF DRINKING
C 1 2 3 4 5
C 1 2 3 4 5
SESSIONS

Figure 17

neophobia. This measure indicates greater neophobia to vinegar than to coffee. It is interesting to note that neophobia is reflected here in an instrumental response measure.

Satiation testing. After five post-exposure sessions to re-establish a baseline of performance, animals were tested as before, with sessions preceded by 20 ml of water in the home cage. Four sessions were conducted, and the results here are based on totals for those four sessions. For each test session responses were expressed relative to the mean of the preceding and succeeding session without water preloads. These relative rates were then averaged over the four sessions. These averages, shown in Tables 5 and 6, indicate vinegar responding was more suppressed by prewatering than coffee responding. For lever pressing this was true for 3 of the 4 animals in the LiCl group, and for 2 of the 4 in the NaCl group. By comparison with the change in instrumental responding produced by pairing with LiCl during the first four testing days, prewatering produced small and inconsistent effects. This is also true when prewatering change is assessed on concurrent licking, which had been the most sensitive index of change. Six of the eight subjects showed a greater relative decrease in responding for vinegar, but the difference was often very small and out of proportion to the decreases produced by LiCl. This occurred despite the fact that prewatering

Table 5

Relative Change In Responding Across the Different Rate-Reducing Operations (LiCl group)

Subject	Operation	Bar Pressing V	Bar Pressing C	Licking V	Licking C	Drinking V	Drinking C
#1	LiCl	.80	3.27	.71	1.07	.95	.98
	Prewater	.59	.68	.42	.91	.44	.66
	CER	.70	.34	.70	.56		
#2	LiCl	.30	1.13	.04	1.69	.48	1.00
	Prewater	.26	.40	.38	.56	.26	.39
	CER	.37	.58	.76	.90		
#7	LiCl	.59	.98	.22	1.63	.63	.87
	Prewater	.59	.39	.52	.43	.20	.24
	CER	.46	.53	.42	.45		
#8	LiCl	.61	1.26	.10	1.70	1.09	1.00
	Prewater	.39	.46	.60	.83	.31	.60
	CER	.27	.87	.33	.91		

Table 6

Relative Change In Responding Across the Different Rate-Reducing Operations (NaCl group)

	Operation	Response					
		Bar Pressing		Licking		Drinking	
Subject		V	C	V	C	V	C
#3	NaCl	.73	.93	.73	1.43	.84	1.31
	Prewater	.59	.86	.64	.67	.32	.43
	CER	.12	.35	.83	.89		
#4	NaCl	.87	1.10	.90	1.10	1.05	1.00
	Prewater	.64	.78	.71	.74	1.10	.26
	CER	.61	.48	.68	.49		
#5	NaCl	.75	1.10	1.40	.76	.97	1.20
	Prewater	.50	.40	.18	.23	.29	.30
	CER	.76	.30	.33	.53		
#6	NaCl	.70	.98	.70	.97	.95	.94
	Prewater	.67	.43	.69	.42	.20	.24
	CER	.53	.43	.34	.46		

produced greater overall suppression of licking. Although there was clear suppression of drinking there was little differentiation in relative suppression. Even though all eight subjects did show a greater decrease in vinegar drinking, the size of the difference was small. Examination of suppression on the individual test sessions shows that the effect was not consistent over separate tests for animals in the NaCl group, but did hold for three of the LiCl animals. This may indicate a lingering aversion not completely extinguished by the exposure period. Lever press choice responding showed no systematic change with level of prewatering.

Table 5 also allows a comparison between the pattern of change produced by satiation and the change produced by aversion conditioning. Unlike the LiCl-induced decrease, the effect of prewatering was not always most pronounced on rates of concurrent licking. Rates of concurrent licking did generally show greater coffee-vinegar differentiation , but the size of this comparison was out of proportion to the difference in differentiation produced by aversion conditioning. This is due in part to the absence of an increase in coffee-reinforced responding with prewatering as the disrupting operation.

Conditioned suppression testing. In two sessions responding was measured in the presence of the tone that had been previously paired with electric shock.

Presentation of the tone produced suppression on each occassion. Suppression scores were calculated as the ratio of responding in the presence of the tone to responding in the appropriate preceding period. For concurrent licking the ratio was determined by using the first 80 sec of the concurrent period as the baseline. As these ratios are calculated, a value of 1.0 indicates no suppression, while a value of 0.0 indicates complete suppression. Individual suppression ratios covered a wide range, from 0.0 to over 1.0 in the two days of testing. Comparisons revealed differences between subjects who had been in the different conditioning groups. In the NaCl group only #3 showed more suppression in vinegar-reinforced responding, while among animals in the LiCl group only #1 failed to show greater suppression to vinegar. Suppression ratios for all subjects are given in Tables 5 and 6. These tables show that there is greater agreement in direction of change for lever-pressing than forlicking. Six of the eight animals showed greater suppression of vinegar-reinforced lever pressing, while for licking only four animals displayed greater vinegar suppression.

Finally, the consistency of the operations used to reduce responding is summarized in Table 7. This table gives the number of comparisons in which coffee responding was found to be less changed in ratio to the total number of comparisons with that treatment. The table points out

Table 7

Consistency of Response Change Over Different Operations

Operation	Response Bar Pressing	Licking	Drinking
Neophobia	7/8	5/8	6/8
Aversion Conditioning	4/4	4/4	4/4
Prewatering	6/8	6/8	8/8
CER	6/8	4/8	

Note: Cell entry gives the number of comparison that showed coffee responding to be less disrupted than vinegar responding.

that later treatments were less consistent in their effects on responding. This could be due to the nature of the treatments, some interaction between the order and the treatments, or to increases in response strength over the course of extended exposure to coffee and vinegar. Support for the latter possibility comes from noting (see Tables 5 & 6) that once an animal showed no difference in vinegar and coffee responding, or greater change in coffee responding, that pattern was maintained for all subsequent tests.

Discussion

Experiment 1 indicated that vinegar consummatory responding was weaker than coffee consummatory responding. Consistent with that determination, this experiment has shown that vinegar is more salient than coffee in a taste-aversion conditioning procedure. This holds true whether aversion conditioning is measured by instrumental bar-pressing, instrumental licking, or consummatory licking. The demonstration of the high salience of vinegar was also consistent with the pattern of change produced by prewatering. This supports the conclusion that the salience relation corresponds to the strength relation.

The difference in aversion conditioning to vinegar and coffee cannot be attributed to differential exposure on the conditioning day. The multiple schedule insured roughly equal rates of reinforcement, and choice proportions were not extreme enough to cause significant deviation from equality. Two animals in the LiCl had ratios of vinegar drinking to total drinking of .52 and .53 , while two animals consumed slightly more coffee than vinegar (drinking ratios of .42 and .43). These values are not changed if number of reinforcement periods, rather than number of licks, is used to calculate the ratios.

The present experiment also obtained clear evidence for the sensitivity of instrumental responses to the effects of LiCl. For all the animals in the LiCl group there was a significant and sustained differentiation of responding for coffee and vinegar. The instrumental response suppression recorded here contrasts with the failures of Garcia et al. (1970) and Morrison and Collyer (1974, Experiment 2). In those studies instrumental responding was not suppressed, despite the near total suppression of consumption. Two studies have reported suppression of lever pressing when the reinforcer was paired with toxicosis (Best, Best, & Ahlers, 1971; Treadway, 1975), but the effects were small in comparison to the change in consumption. Treadway (1975) reported a suppression of lever pressing, reinforced on a fixed-ratio schedule, on the first post-conditioning day; thereafter responding in the poisoned group was not different from either of the two control groups. Treadway also collected consumption measures in daily home cage tests. These tests gave evidence of a conditioned aversion persisting over many days, in contrast to the one day of difference for lever pressing. The present study obtained a pattern of results not reported in these earlier investigations. In the present study instrumental measures gave evidence of an effect maintained over five or more sessions. For three of the poisoned animals, bar-pressing rate, relative to the post-exposure baseline, was less than .5 at the end of the sixth session, whereas in the NaCl group only one daily session (out of 40) was ever as low as .5 . The difference between this study, showing a considerable effect on instrumental behavior, and the studies cited above is possibly a function of two procedural differences. Inspection of the relative rates of lever pressing reveals that responding never reached a minimum in the first session. The effects of pairing with LiCl were more likely to be observed from the second testing session onward. The grouped data, presented in Figure 10, show a maximum separation between groups on the fifth and sixth testing days. Conducting testing in one session (e.g., Best et al., 1971) would, if the present data are representative of other procedures, reduce the probability of detecting an effect. The size and durability of the effect on lever pressing seen in Figure 10 is also a function of the use of relative rate measures based on individual baselines.

These results provide an interesting reversal of the pattern obtained by Garcia et al. (1970). By the sixth day of testing the animals in this study were still displaying suppression on instrumental lever pressing and instrumental licking for vinegar, while no sign of suppression in consumption could be seen after the second session. Over the first four days of testing, relative drinking rates (vinegar/ coffee) in the LiCl group ranged from .46 to .51 , and from .48 to .53 in the NaCl group. The instrumental measures continued to reflect the differential aversion conditioning sessions after the difference had failed to be detectable based on consummatory measures.

Although it was expected that instrumental responses would prove more sensitive than consummatory responses, it was not expected that licking would be more sensitive than bar pressing. On the basis of response strength considerations, licking was expected to be more resistant to change than bar pressing. First, reinforcement for licking is immediate, whereas reinforcement for bar pressing is delayed while the animal moves to the drinking spout. Second, the similarity of the instrumental and consummatory lick may lead to response induction. These factors should have made licking less changeable; instead licking was considerably more sensitive than lever pressing. Therefore, if the reasoning about the relative strengths of licking and bar pressing is correct, some factor in addition to response strength must be involved. One possibility, in keeping with the suggestion of Garcia et al. (1970; 1974), is that sensitivity may be a joint function of form and function. Both the contingencies of reinforcement for a response, and the relation to natural food-getting behaviors may be important factors in the sensitivity of a response to LiCl induced change. This possibility is consistent with the present pattern of results.

The present data also revealed a contrast effect (Catania, 1968) in lever pressing and licking. Coffee-reinforced lever pressing and licking increased, while vinegar-reinforced responding decreased. In many cases the size of the effect was considerable. Rate of concurrent licking was observed to increase over fourfold for two animals, and lever pressing was consistently increased to over twice the post-exposure baseline. At the same time, there was no contrast effect in consummatory responding. Domjan and Gillan (1977) reported a series of studies showing a similar effect, when the consummatory response measure was total consumed, rather than rate of drinking. Rats were presented with a solution that had previously been paired with LiCl. Fifteen minutes after this presentation animals had the opportunity to drink a neutral solution. Exposure to the conditioned aversive taste resulted in a significant increase in consumption of the second solution. The increase apparently depended on the conditioned aversiveness of the first solution. The increase was not found if the first solution was a flavor explicitly unpaired with LiCl, or if the aversion to the first solution had been extinguished.

The increase in consumption following exposure to a conditioned-aversive flavor reported by Domjan and Gillan (1977) is consistent with the present results. In addition the present experiment extends findings on this effect in the following ways. First, the enhancement of responding occurs with instrumental responses as well as consummatory responses. Second, the effect is obtained when availability of the solutions alternates over a short period of time (90 sec), or when the solutions are simultaneously available. Finally, the effect persists for a number of sessions. Domjan and Gillan (1977) only tested their animals once, but the present results show there is a definite time course. The present data also contain a suggestion that the effect may not depend on the conditioned aversiveness of the alternated solution, but simply on the aversiveness of the alternate solution. Animal #6 (NaCl) had one day of suppression of vinegar-reinforced licking. On that day he exhibited a significant increase in the rate of coffee licking. This fits the pattern obtained with the LiCl-injected animals.

Domjan and Gillan (1977) were mainly concerned with the theoretical significance of this effect, but it also has a important methodological implication. If the effect shown by Domjan and Gillan to operate over a 15 min interval also operates when the solutions are simultaneously available, as the present results indicate, then two-solution tests are subject to an unappreciated source of bias. This experiment has shown that the enhancement effect is larger for licking than for lever pressing. This makes it reasonable to assume that the enhancement effect may depend upon the response strength of the alternate solution. If this is the case, measures of aversion strength or taste salience will be strongly biased by context. Single-solution tests are regarded as less sensitive tests of aversion strength; nevertheless, there may be reason to prefer these less sensitive, but also less complicated, tests.

VI. FINAL DISCUSSION

The preceding experiments have considered the implications of regarding consummatory response strength as a factor in taste-aversion learning. The response-strength perspective offers an integrated view of taste salience, flavor neophobia, preexposure effects, enhanced neophobia, and deprivation effects. This concluding review briefly considers the evidence in support of the response-strength analysis.

The basic assumption underlying the present set of experiments is that consummatory responses can be analyzed as discriminated operant, as previously suggested by Skinner (1938). One direct implication of this assumption is that satiation will lead to increased food selectivity. Only strong responses will occur under consumption-reducing effects of satiation. Without support for this basic assumption there would be no reason for extending the analysis. The assumption of greater finickiness in the satiated, although supported by common sense, has been challenged by Jacobs (1968; Jacobs & Sharma, 1969), in studies that showed hungry dogs to be more "taste reactive" than satiated dogs. Jacob's work lacked some desirable controls, and a more thorough follow-up study by Booth (1972) shows that satiated rats are indeed more selective of foods than hungry rats. Booth measured amounts and rates of consumption on preferred, neutral, or unpreferred diets, at three levels of food deprivation. The results from Booth's (1972) between-group comparison are presented in Figure 18. This figure displays the relative decrease in rate of consumption within a meal as function of the amount already consumed. The unpreferred diet shows the greatest relative suppression, consistent with the idea that it represents the weakest ingestion response. Likewise, the effects of diet are greater in satiated rats than in hungry rats. Booth's data provide support for the approach to ingestion responses taken in the present analysis.

The finding that satiation produces differential response suppression of foods was extended to liquids in the first set of experiments. Prewatering was found to produce considerable suppression of some responses (vinegar, casein), and only marginal suppression of others (sucrose, saline). This pattern of change was assumed to be identical to the ordering of ingestion response strengths. As such, it was expected that the ordering would also correspond to the ordering of conditionability in taste aversion procedures. The literature reviewed in Experiment 1 indicated that this was the case.

A strong prediction of the response strength analysis is that the pattern of suppression should remain invariant across changes in the rate-reducing procedure, provided the

Figure 18. Data from Booth (1972) on the relative decline in rate of consumption as a function of the amount already consumed. Lines are the least squares fit. The numeral by each line gives the number of hours since the last meal. P= Plain diet; Q= Quinine adulterated; S= Sucrose added

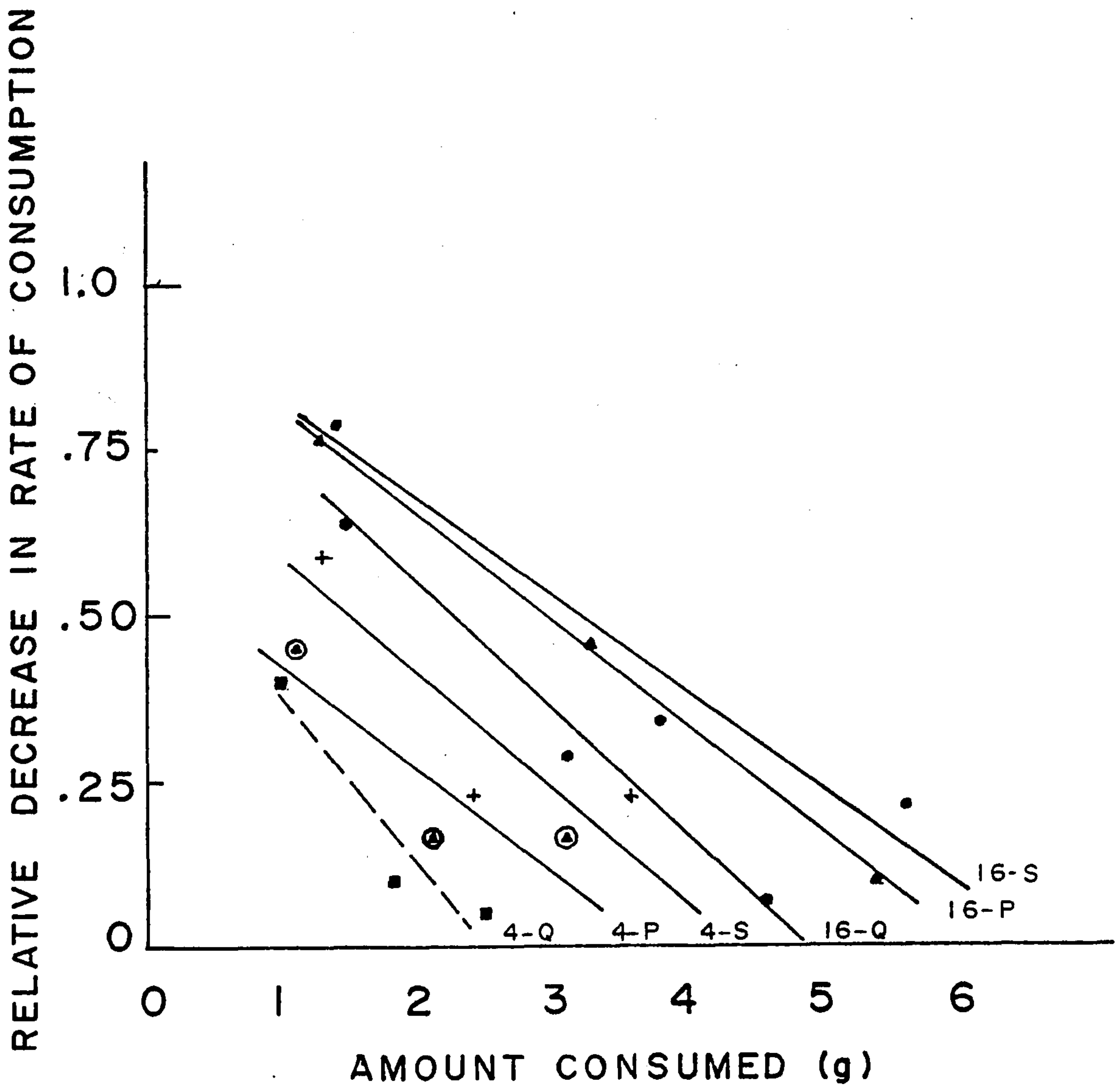

RELATIVE DECREASE IN RATE OF CONSUMPTION
1.0
.75
.50
.25
0
0
1
2
3
4
5
6
AMOUNT CONSUMED (g)
4-Q
4-P
4-S
16-Q
16-P
16-S

Figure 18

procedure can be applied equally to all responses. The available data support this prediction. There is a perfect correspondence among measures of taste salience, neophobia, enhanced neophobia , and illness-mediated suppression for different concentrations of saccharin (Carroll, 1975; Domjan, 1977).

The response strength analysis provides a natural explanation for neophobia and its relation to flavor-aversion conditioning. The increase in consumption of novel foods is taken as an indication of an increase in the strength of consummatory responses. From this increase, the retardation of conditioning produced by taste exposure follows. The response strength account of neophobia can be distinguished from other accounts that emphasize the effects of taste exposure on associability of the taste with illness (Best & Barker, 1977; Carroll, 1975). The present account predicts that flavor preexposure will diminish the effect of illness-mediated suppresion, and the expression of enhanced neophobia. Both expectations are confirmed by recent findings (Best and Batson, 1977; Carroll, 1975; Domjan, 1975, 1977; Mitchell, Scott, & Mitchell, 1976). An associative account cannot explain the consistency of the effect of taste familiarity across these different consumption-reducing operations without introducing additional theoretical notions.

The relation between neophobia and aversion conditioning is maintained even when neophobic tendencies are modified by physiological intervention. Rats with lesions of the ventromedial hypothalamus (VMH) become finicky eaters. Their food selection pattern resembles the pattern of satiated animals; they consume only highly palatable, familiar foods (Teitelbaum, 1955; Teitelbaum & Campbell, 1958). The food selection pattern of VMH-lesioned animals suggests that the strength of all ingestion responses has decreased. This may seem paradoxical given that VMH-lesioned animals become obese, but measures of motivation based on instrumental behavior indicate decreased hunger in these animals (Miller et al., 1950). With lower strength ingestion responses VMH-lesioned animals should form stronger conditioned taste aversions. Confirming observations have been reported by Peters and Reich (1973), by Thomas and Smith (1975), and by Weisman, Hamilton, and Carlton (1972).

In contrast to the facilitation of conditioning associated with the increased neophobia of VMH-lesioned animals, interference of conditioning is associated with the surgical elimination of neophobic tendencies. In a response-strength interpretation, the reduction of neophobia indicates a strengthing of consummatory responding. The generalized increase in strength should interfere with the formation of conditioned taste aversions. Supporting results have been obtained by Kiefer and Braun (1977), by Krane, Sinnamon, and Thomas (1976), and by Rolls and Rolls (1973). The consistency of the relation between neophobia and taste-aversion conditioning, even when neohpobia is altered by surgery, implies that there is a very basic relation between initial-ingestion tendency and aversion conditioning. The simplest account of this relation is to assume that both measures are determined by the strength of consummatory behavior.

Research on taste aversions has only infrequently been concerned with the strength of consummatory responding. Increases in deprivation should strengthen consummatory responding and lead to weaker aversions. Increased deprivation has been found to facilitate extinction of a conditioned aversion in several studies (Balagura & Smith, 1970; Grote & Brown, 1973; Peck & Ader, 1976). Conditions of high need have been reported to block the development of conditioned taste aversions. Weisinger, Parker, and Skorupski (1974) attempted to conditioned aversions to sucrose or saline using insulin or formalin injections as the aversive treatment. Insulin was an adequate US when the taste CS was saline, but not when the CS was sucrose. Similarly, formalin as the US produced a conditioned aversion to sucrose, but not when saline was the CS. These results are in agreement with a response-strenth account. The formalin injections produced depletion of sodium, strengthening sodium-reinforced responding. Likewise, insulin injections produced a glucose need state. These injections have a strengthening and weakening effect; when the CS solution is unrelated to the need state produced by the injection only the weakening effect is seen; when the CS is the object of the need state the conditioning process is obscured. Recently, Domjan and Levy (1977) reported a failure to replicate Weisinger et al. (1974), but convincing evidence for the role of response strength in conditioned aversions is found in the results of Frumkin (1971, 1975). Frumkin (1975) removed the adrenal glands or the parathyroid gland from rats prior to taste-aversion conditioning. The operations produce specific hungers for sodium or calcium, as seen in the greatly increased consumption levels of solutions containing these nutrients. This indication of increased consummatory response strength corresponds to the failure of the animals to learn aversions to the object of their specific hunger. Frumkin (1975) has also shown that this effect requires the maintenance of a sodium or calcium deficit, also consistent with the response-strength account.

Extinction of taste aversions should vary as a function of response strength. Stronger responses should recover pre-conditioning levels more rapidly than weaker responses. Although no studies have directly examined the effect of "flavor" on extinction, Carroll's (1975) data show that aversions to weak saccharin concentrations -i.e., strong responses - extinguish more rapidly.

In review, the response-strength account offers a basis for integrating a variety of data on conditioned taste aversions. Stimulus salience, flavor preexposure, flavor neophobia, enhanced neophobia, extinction differences, and deprivation effects are related in a simple framework. This account is representative of a general-process approach, but it does not affirm or deny the the continuity of flavor-aversion learning with other forms of learning. The more modest goal has been to show that a general-process approach is a useful starting point for the analysis of consummatory responding and aversion learning. By exploring the limits of a general-process approach we may reach a better position for evaluating the distinctiveness of flavor-aversion learning and its implications for learning theory.

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