du Canada

200

Canadian Theses Division — Division des thèses canadiennes

Ottawa, Canada
K1A 0N4

67450

PERMISSION TO MICROFILM — AUTORISATION DE MICROFILMER

- Please print or type — Écrire en lettres moulées ou dactylographier

Full Name of Author — Nom complet de l'auteur

Larry Otto Stefan

Date of Birth — Date de naissance	Country of Birth — Lieu de naissance
Jan 28. 1956	Canada

Permanent Address — Résidence fixe

9847 - 92 Ave Edmonton
T6E 2V4

Title of Thesis — Titre de la thèse

Facilitated Within-Compound Learning as a Function of US Presentation in Taste-Aversion

University — Université

University of Alberta

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

PhD

Year this degree conferred — Année d'obtention de ce grade	Name of Supervisor — Nom du directeur de thèse
Fall 1983	Dr. C.D. Heth

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

Date	Signature
Sept 30/83	Larry Stefan

THE UNIVERSITY OF ALBERTA

Facilitated Within-Compound Learning as a Function of US Presentation in Taste-Aversion

by

Larry Stefan

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF Doctor of Philosophy

Department of Psychology

EDMONTON, ALBERTA

Fall, 1983

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR Larry Stefan

TITLE OF THESIS Facilitated Within-Compound Learning as a Function of US Presentation in Taste-Aversion

DEGREE FOR WHICH THESIS WAS PRESENTED Doctor of Philosophy

YEAR THIS DEGREE GRANTED Fall, 1983

(SIGNED) Larry Stefan

PERMANENT ADDRESS:

9847 - 92 Ave

Edmonton, Alta.

T6E 2V4

DATED 29 September 1983

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Facilitated Within-Compound Learning as a Function of US Presentation in Taste-Aversion submitted by Larry Stefan in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

....

Supervisor

....

....

....

....

External Examiner

Date 29 September 1983

Dedication

To my partner-in-life, Karen; and to an outstanding supervisor, teacher, and friend, Don.

Abstract

Rescorla & Durlach (1981) reported that a food reinforcer following a visual compound disrupts within-compound Pavlovian learning. In contrast, Experiment 1 of this study demonstrated that a lithium chloride reinforcer following a compound flavor exposure does not interfere with the formation of an association between the flavor components. Instead, the results indicated that a reinforcer in a taste-aversion preparation facilitates within-compound learning. Experiment 2 demonstrated that enhanced within-compound learning was stronger with an immediate reinforcer than a reinforcer delayed for 2 hours. Experiment 3 examined whether this augmentation of within-compound learning was due to the summed effects of associations between each CS element and the US. This model, labeled "double-bonding", was found unacceptable as an explanation for augmented within-compound learning. It was concluded that information-processing models of learning should be revised to recognize the effects of different stimuli on post-CS processing.

Table of Contents

List of Tables

List of Diagrams

I. Introduction

When two or more stimulus elements are presented in very close temporal contiguity, the elements are said to form a compound (Kehoe & Gormezano, 1980). In the last few years increasing attention has been directed toward a phenomenon called within-compound conditioning. In general, this is the association formed between the elements of a compound stimulus. These associations are referred to as within-compound associations (Rescorla & Durlach 1981).

Rescorla and Cunningham (1978) were the first researchers to identify within-compound associations. In one experiment they initially gave rats two separate compounds consisting of two flavors. Then a flavor from one compound was presented alone and followed by lithium chloride (LiCl). During testing with the nonpoisoned element of each compound, strong rejection of the flavor previously paired with the poisoned flavor was found. That is, when one element of a compound was paired with poison, consumption of the other element was also reduced. In a second, converse experiment two flavor-flavor compounds were each followed by poison. Then one element of each compound was extinguished by repeatedly presenting it without poison. A test of the second element of each compound revealed that extinguishing one element reduced the rejection of the other element of that particular compound. Both experiments demonstrated that modifying the associative strength of one element of a compound produces a parallel change in associative status of the other element. Such changes are analogous to sensory preconditioning phenomena (Brogden, 1939) and appear to be dependent upon the joint presentation of the elements of a compound.

Within-compound associations have since been found to occur in other compound stimulus preparations. For example, Speers, Gillan, and Rescorla (1980) have observed such effects in the conditioned inhibition paradigm. Previously reinforced single flavors were paired with another flavor and not reinforced. Following differential conditioning to one element of each compound, the other element was tested. It was found that each test element reflected the conditioning of its associate in a manner that revealed considerable within-compound learning. Speers, et al. (1980) also provided evidence of within-compound associations in blocking and overshadowing procedures. Other investigators have demonstrated within-compound learning between contextual cues and the nominal conditioned stimulus (CS) (Marlin, 1982), between excitatory and inhibitory components of a compound (Cunningham, 1981), in serial compound conditioning (Holland & Ross, 1981), in configural conditioning (Gillette & Bellingham, 1982), and in odor potentiation (Durlach & Rescorla, 1980).

Given the ubiquity of this phenomenon and its importance to other learning processes, it is important to identify the conditions that promote this type of learning. It has been proposed that within-compound conditioning competes or interferes with traditional excitatory conditioning (Rescorla & Durlach, 1981). If this is so, then one important variable would be the presentation of a Pavlovian unconditioned stimulus (US) following a compound presentation. Recently, Rescorla and Durlach (1981) reported that less within-compound conditioning occurred if a reinforcer immediately followed compound stimulus presentation than if the compound was not reinforced. They employed an autoshaping technique in which pigeons were exposed to two types of trials, AB+ and AC- (where + and - refer to Pavlovian reinforcement and nonreinforcement respectively). A was a dot pattern, while B and C were colors projected on different quadrants of a key. Reinforcement consisted of 5 sec access to food. The authors established that less associative learning occurred between A and B than between A and C. It was suggested that within-compound conditioning was disrupted by the reinforcer.

However, US-interference of within-compound conditioning was not reported by Durlach and Rescorla (1980) in a similar paradigm. These authors had first shown that within-compound associations between odor and taste could account for the phenomenon of odor potentiation. They then investigated whether within-compound learning could have taken place during the nonreinforced preexposures to the compound rather than during the conditioning trials themselves. Durlach and Rescorla hypothesized that a poison US following an odor-taste compound would disrupt the within-compound association and result in little or no potentiation effect. They found, however, that the potentiated CR was the same whether or not nonreinforced pre-exposures to the CS-compound occurred.

Durlach and Rescorla's (1980) results are somewhat surprising. Many investigators have found that a Pavlovian event, such as US, can under some conditions, disrupt learning. For example, Wagner, Rudy, and Whitlow (1973) proposed that post-trial-events (PTE) that were surprising, i.e., demanded rehearsal, would disrupt or redirect processing of an event in short-term memory (STM). Thus learning about a target CS-US episode should decrease. In a test of this proposal, rabbits initially received discrimination training (A+ and B-). In the second phase a new pairing, C+, was followed by a congruous PTE(A+ or B-) or an incongrous PTE(A- or B+). The results clearly showed that incongruous PTEs disrupted the learning of the new CS-US association (i.e., the learning of C+). Other investigators (Cheatle & Rudy, 1978; Terry, 1976; Wagner & Terry, 1975; Wagner, 1976, 1978, 1981) have also shown that surprising events can interfere with ongoing processing.

If a reinforcer is viewed as a surprising event, analogous to Wagner, Rudy, and Whitlow (1973) PTE's, then reinforcement of the compound should result in some diminution of within-compound association. Indeed, Rescorla and Durlach (1981) report such an effect using a food reinforcer. However, the discrepant results of Durlach and

Rescorla (1980) may indicate that a LiCl reinforcement does not diminish within-compound learning. The internal consequences of LiCl (illness) paired with an internal CS (flavored solution) may function differently on within-compound conditioning than external stimuli and reinforcers. According to this view the internal effects of a LiCl reinforcer may not disrupt within-compound conditioning.

This report investigates whether or not a LiCl reinforcer disrupts within-compound conditioning. The first two experiments establish the phenomenon to be investigated and explore some boundary conditions of the basic effect. In a final experiment a model of within-compound conditioning is developed and tested.

II. Experiment 1

The purpose of this experiment was to determine whether poison as a reinforcer disrupts the within-compound learning of a stimulus composed of two ingestive elements. Specifically, the experiment was concerned with comparing the strength of the association between elements of a flavor compound when poisoning treatment follows their presentation and when it does not. To index within-compound strength, a technique used by Fudim (1978) was employed.

In the Fudim procedure one element of a compound is made more attractive by creating a specific hunger for it. This is done by using a subcutaneous injection of 0.6% formalin which induces a strong salt (NaCl) deficiency. Normally subjects prefer water over a salt solution (Wolf & Steinbaum, 1965). However, formalin injected animals exhibit a strong preference for salt solutions as well as any flavors previously associated with NaCl. The degree of preference for the flavor paired with NaCl can then be used as an index of the strength of the within-compound association (see also Rescorla & Freberg, 1978).

Two groups of rats were given exposure to two different compound solutions. To counter-balance the effects of toxicosis, for each group one compound solution was followed by LiCl poisoning and the other solution was not. Then the animals were given a formalin injection to induce a sodium deficiency. The strength of within-compound associations was assessed by measuring the animal's consumption of the flavor paired with NaCl. Because sodium preference had been increased by the injection of formalin, within-compound associative strength is revealed by the amount of consumption of the NaCl paired flavor.

Method

Subjects: The subjects were 32 male Sprague-Dawley rats about 60 days old.

Apparatus: Subjects were housed in individual Wahman wire-mesh cages which were attached to a cage holder with a capacity of 30 cages per side. Each individual cage measured 25 by 18 by 18 cm. Lighting was continuous and temperature a constant 25 C. Water and flavored solutions were available from a 250 ml drinking bottle attached outside the cage with the drinking spout inserted approximately 3 cm into the cage area. The aperature of the water drinking spouts varied between 2 and 4 mm in diameter, but the aperature of the spouts for flavored solutions was always a standard 2 mm in diameter.

Procedure: The animals were initially adapted to a water restricted schedule involving 10 min access of distilled water per day for approximately one week. The design of Experiment 1 is presented in Table 1. On the first training day, Day 1, food was removed for all subjects immediately before compound presentation in order to minimize a possible food-solution interaction. Group NS+ (N=16) was given 15 min access to a compound solution of

0.005M hydrochloric acid (H) and 0.05M sucrose (S). Group NS- (N=16) was given 15 min access to a compound solution of 0.2M NaCl (N) and 0.05M S. One hr later, 10 min access to distilled water was allowed after which food was returned. On Day 2 food was again removed immediately before stimulus exposure for all subjects. Group NS- was given a compound presentation of HS for 15 min, immediately followed by an IP injection of LiCl (0.6M/5 ml/kg). Group NS+ received similar exposure to compound NS solution also followed by a LiCl injection. One hr later, 10 min access to distilled water was given after which food was returned.

On Day 3, 10 min of water was allowed at the usual time (10:00 a.m.). Since water deprived subjects typically eat after watering and since the Fudim procedure requires subsequent removal of food because of its salt content, sufficient time was allowed for the subjects to eat. Food was thus removed three and one-half hr after watering (1:30 p.m.). All subjects were then given a single subcutaneous injection of 2.5 ml of 0.6% formalin on the dorsal side. Distilled water was returned, but food was not returned until after Day 4 testing.

To ensure that subjects would drink, thus avoiding possible floor effects, water was removed 3 hr prior to 10:00 a.m. testing. The test consisted of 10 min simultaneous presentation of distilled water and 0.05M sucrose solution in separate bottles. For half the animals, distilled water was initially on the right and sucrose was on the left. The other half were presented with the two solutions in the opposite order. After 5 min the position of the bottles was reversed to prevent subjects from sampling only one solution. Amount of solution ingested was measured to the nearest 0.1 g by weighing the bottles before and after the test.

The efficacy of the Fudim technique was tested one hr later. All subjects were given 10 min access to two bottles, one containing 0.2M NaCl and the other distilled water. The position of the bottles was reversed after 5 min.

Table 1

Design of Experiment 1

	Day			
Group	1	2	3	4
NS+	HS-	NS+	F	S?
NS-	NS-	HS+	F	S?

Note:

H=0.005M Hydrochloric acid   N=0.2M Sodium

S=0.05M Sucrose   +=0.6M LiCl/5ml/kg

F=Fudim Technique   (Sodium test is not shown.)

Results

Test results are shown in Table 2. A statistical analysis of the results revealed that Group NS+ drank significantly more sucrose than Group NS- (t=3.99, df=30,

$p<.001$)[1], thus indicating Group NS+ had a stronger within-compound association between N and S than Group NS-.

In the test for sodium deficiency, all subjects demonstrated a preference for the NaCl (4.58 g) solution rather than the water (0.84 g). This was found to be significant using a correlated t-test ($t=5.01$, df=31, $p<.001$), clearly indicating that the Fudim technique produced a strong salt need.

Table 2

Mean Consumption of Sucrose (in grams)

On Test Day (Day 4) for Experiment 1

Group	Consumption
NS+	1.96
NS-	0.77

Discussion

Wagner (1976, 1978, 1981) has proposed a model of STM processing in which a memorial representation may be said to be "in" STM to the extent that it is currently active. However, residence in STM does not guarantee sustained processing, i.e., rehearsal. Rehearsal in STM is determined by the degree to which an event is surprising or unexpected. Nonsurprising or expected events do not command rehearsal, whereas surprising events do. Thus occurrence of a

----

[1]All t-tests in this thesis are two-tailed.

surprising events may disrupt learning about other events currently represented in STM.

Consistent with Wagner's model, Rescorla and Durlach (1981) view an immediate and surprising US presentation following a CS compound as disrupting within-compound learning. It appears that in the autoshaping paradigm that pigeons forego within-event learning in favor of between-event learning.

However, the results of Experiment 1 indicate that within-event learning in a taste-aversion paradigm is facilitated by the unexpected LiCl US. This may indicate that between-event learning involving a LiCl reinforcer does not have disruptive effects on processing of the compound stimulus, as noted by Durlach and Rescorla (1980). Instead, a LiCl reinforcer appears to augment within-compound conditioning.

The results of Experiment 1 are inconsistent with predictions derived from current models of information-processing. It therefore seems advisable to examine the boundary conditions of this effect. Experiment 2 was designed to replicate the basic phenomenon and to determine whether it is affected by a delay in the presentation of the reinforcer.

III. Experiment 2

Rescorla and Durlach (1981) found that an immediate reinforcer following compound stimulus presentation interferes with the development of a within-compound association. A plausible account of this effect can be based on current models of animal information-processing (e.g., Wagner, 1981). Rehearsal of the reinforcer in STM could disrupt the processing of the current CS elements. Cheatle and Rudy (1978) report similar reinforcer-induced interference effects on the formation of an association between stimuli presented successively in second-order conditioning. Both sets of investigators also report that delaying the reinforcer improved the learning between CSs. A delayed reinforcer apparently allows more processing time for an association to form between the CS elements.

In Experiment 1, unlike those of Rescorla and Durlach (1981) and Cheatle and Rudy (1978), a reinforcer facilitated within-compound associations. However, we might still expect that the effects of the reinforcer would be reduced if the reinforcer were delayed. In this case, within-compound associations would be weaker using a delayed reinforcer than those established using an immediate reinforcer --exactly the opposite pattern to that observed by Rescorla and Durlach (1981) and Cheatle and Rudy (1978).

In Experiment 2 one group of rats was poisoned immediately after the CS flavor presentation while a second group was poisoned two hours later. To counter-balance the delayed effects of lithium reinforcement, each group was subsequently exposed to a different flavor-compound which was immediately reinforced for the second group but reinforced after a delay for the first group. The Fudim technique was employed to assess within-compound strength. By testing the subjects' aversion to the associative element of NaCl an index of within-compound strength was obtained.

Method

Subjects: Sixteen Sprague-Dawley female rats 85 days of age were used.

Apparatus: The apparatus of Experiment 1 was used.

Procedures: The design for Experiment 2 is presented in Table 3. Subjects were divided into two equal groups and restricted to distilled water for 15 min a day for 7 days. On the next two days, Days 1 and 2, food was removed immediately before compound presentation and returned approximately 1 hour later. On Day 1 Group IM received 15 min access to a compound sodium (0.2M) and hydrochloric acid (0.005M) solution (NH) followed by an immediate IP injection of LiCl (0.1M/5 ml/Kg). Group DE received 15 min access to the same solution, but the LiCl injection was delayed for 2 hr. One hr after receiving the poison treatment both groups were given 15 min access to distilled water and food was returned. On Day 2 both groups received 15 min access to a compound sucrose (0.05M) and hydrochloric acid (0.005M) solution (SH). Group DE received an immediate LiCl injection and Group IM was injected 2 hr later. Distilled water was given for both groups 1 hr after the delayed LiCl injection of Group IM. Food was then returned. On Day 3 all subjects were given 15 min access to water at the usual time (10:00 a.m.) and 3 hr later received the Fudim treatment designed to induce a sodium deficit. Since the female rats were quite light in weight (200-230 g) the usual dosage of 2.5 ml formalin was reduced. The scale used was 1.0 ml of 0.6% formalin for 200 g of body weight plus 0.01 ml for each additional gram of weight. Thus no rat received more than 1.3 ml of formalin. The formalin was injected subcutaneously on the dorsal side. Distilled water was available ad lib until 3 hr before (7:00 a.m.) testing on the next day (Day 4). Food, because of its salt content, was removed immediately before the formalin injections and was returned after the Day 4 10:00 a.m. testing. During testing all subjects were allowed 15 min access to 0.005M H.

In Experiment 1 a two-bottle test consisting of a salt solution and water was used to test the effectiveness of the Fudim procedure. It was found that all subjects consumed less than 1 gm of water. Since the subjects consumed so little water a one-bottle test within each group was used in Experiment 2. Thus 1 hr after testing half the subjects in each group were given 15 min access to 0.2M NaCl and the other half 15 min access to distilled water.

Table 3

Design of Experiment 2

Group	Day 1	2	3	4
IM	NH-im	SH-de	F	H?
DE	NH-de	SH-im	F	H?

Note:

H=0.005M Hydrochloric acid

S=0.05M Sucrose

N=0.2M Sodium

im=immediate IP injection of 0.1M LiCl/5ml/Kg

de=2 hr delayed IP injection of 0.1M LiCl/5ml/Kg

F=Eudim Technique

(The sodium test is not shown.)

Results

The results are presented in Table 4. Group IM drank significantly more than Group DE (t=2.27, df=14, p<0.04).

There was also a significant difference between the amounts of sodium and water consumed indicating a sodium deficiency had been induced. Subjects given access to sodium consumed an average of 11.93 g while the subjects drinking distilled water consumed an average of 1.54 g (t=9.46, df=14, p<0.001).

Table 4

Mean Consumption (in grams) of HCl on Test Day (Day 4) For Experiment 2

Group	Consumption
IM	2.05
DE	1.15

Discussion

The results of this experiment further support the hypothesis that a LiCl reinforcer in taste-aversion learning promotes the formation of within-compound associations. Specifically, when the reinforcer is delayed, the strength of the within-compound association is weaker than when the reinforcer is immediate.

One plausible interpretation of reinforcer-facilitated within-compound learning may be that multiple associations are formed between the compound elements and the US. Such "double-bonds" would produce the pattern of results obtained in Experiments 1 and 2.

Evidence suggesting that multiple associations are formed in compound conditioning can be found in several studies of compound odor-taste conditioning by Rescorla and Durlach (Durlach and Rescorla, 1980; Rescorla and Durlach, 1981). When odor is conditioned in compound with taste, subsequent rejection of the odor is greater than if the odor had been conditioned by itself; a phenomenon called potentiation. When the aversive response to taste is later extinguished the odor aversion is also reduced. Rescorla and Durlach suggest that odor potentiation can be attributed to the formation of multiple associations during compound odor-taste conditioning. One association is formed between odor and the US and a second between taste and the US as a result of normal conditioning. During the compound presentation, an additional association is established between odor and taste. Thus the odor stimulus has two associations with the US. One association is direct (odor-US) and the other is indirect (odor-taste-US). These two sources of aversion combine to produce greater avoidance of an odor conditioned in compound than of an odor conditioned alone.

Similarly, it can be argued that if the compound CS and US are presented closely together, an aggregate three-element compound may result. In other words, within-compound associations are established between all stimuli. This is based on evidence suggesting that the concurrent presentation of stimuli is the cause of within-compound learning (cf. Lavin, 1976; Rescorla, 1980; Rescorla and Durlach, 1981). Consequently, each stimulus (including the US) would have two associations with every other stimulus.

When tastes are conditioned, the CS(s) and US may be sufficiently close in time to permit within-compound associations between all components. Although the flavors are often presented before the poison, one might argue that they are present internally at the onset of toxicosis (see Logue, 1979; Garcia, Ervin, & Koelling, 1966). The US then becomes part of the within-compound aggregate with the CS components. The outcome is an augmented CR to each flavor.

The double-bond model can account for the results of Experiment 1 by assuming that a single symmetrical bond is formed between the compound elements and between each element and the US. Thus for the two groups in Experiment 1 the following conceptualization of bonding would occur after conditioning Days 1 and 2. See Diagram 1 below.

Diagram 1

Conceptualization of Double-Bonding

For Experiment 1

Group

NS+ NS-

Note: H=Hydrochloric acid N=Sodium

US=Lithium Chloride S=Sucrose

Of central importance is that in Group NS- the element N has only one bond to element S (N-S), whereas in Group NS+

element S has two bonds to N (N-S and N-US-S). After the Fudim procedure on Day 3 all subjects have an enhanced preference for N, but NS+ subjects will consume more S on Day 4 because of the double-bonding between S and N. Group NS- will have only one bond between N and S, and their S consumption should be less than Group NS+ on Day 4. Thus the double-bonding model is able to account for facilitated within-compound learning by proposing that a double-bond between compound elements results in stronger within-compound conditioning than a single bond.

The double-bond model can account for the results of Experiment 2 by assuming that those subjects receiving a delayed US have little or no bonding between the elements and the US. Thus when the US is delayed evidence of facilitated within-compound learning is weak because little double-bonding has occurred between the CS elements and the US. In other words, with an immediately reinforced compound the within-compound associations are stronger between the elements because each element has an additional bond to its partner element via the US. This would account for the stronger preference for HCl in Group IM than Group DE.

Two assumptions are required in order to make the double-bond model theoretically tenable. First, since no empirical data can be brought to bear on a possible difference in strength between a direct and an indirect association in within-compound learning, it will be assumed that both associations are of equal strength. Second, to prevent a reverberating system, it is necessary to assume that once an element of a compound is activated it can no longer reactivate itself.

As mentioned above, one way to detect an association between components of a compound is to modify the response to one of them and observe whether the response to the other is changed (Rescorla and Cunningham, 1978). It follows then that a similar method can be employed to see if the US has formed within-compound associations with the CS components. That is, changing the response to the US after compound conditioning should produce a corresponding response change to the components of the CS. The resultant change would indicate that double-bonds had been formed between all three stimulus elements during conditioning.

Pre- and post-conditioning manipulations of the US have been successful in modifying the conditioned response to a single-element CS. These procedures have involved training designed to inflate or habituate the US. For example, in a conditioned suppression procedure, Rescorla (1974) found that exposure to a more severe shock before or after conditioning elevated the conditioned response established by a moderate shock. Rescorla (1973) also found that habituation to the US either before or after conditioning successfully attenuated the subsequent CR. Similar US-inflation and US-habituation effects have been reported in fear conditioning studies (Marlin, 1982; Randich & Rescorla, 1981; Sherman, 1978) and in taste-aversion studies

(Colby & Smith, 1977; Mikulka, Leard, & Klein, 1977; Westbrook, Provost, & Nagley, 1982). However, other investigators (Brookshire & Brackbill, 1976; Holman, 1976; Riley, Jacobs, & LoLordo, 1976) found no attenuation of a previously conditioned flavor aversion following US-illness habituation. Also, Ayres and Bendict (1973) did not find US-habituation in a fear conditioning procedure. It is unclear why some experimenters have been unable to demonstrate a US-habituation effect.

It is predicted that if double-bonds are formed during compound conditioning, post-conditioning manipulations of the US should affect behavior to one of the tastes. In Experiment 3 both habituation and inflation of a LiCl reinforcer were attempted. US-inflation procedures should augment the US component of the memorial representation, thus making the flavor components more aversive. US-habituation training should diminish the US representation, resulting in less aversiveness to the flavor components. Positive results in both cases would support a double-bond intepretation in facilitated within-compound conditioning.

IV. Experiment 3

The present experiment was conducted to determine whether double bonds are formed between all stimuli in a taste-aversion preparation. The presence of double-bonding was assessed by following compound conditioning with additional exposure to a US that was either stronger than the orginal US (inflation) or more prolonged than the orginal US (habituation). The present experiment also has implications for the generality of post-inflated or post-habituated US exposure effects since conflicting findings exist from different conditioning paradigms involving these manipulations.

To test whether experience with a stronger US after compound CS-US training would affect the subsequent response to the components of the CS, two groups of rats were given a mild LiCl reinforcer after ingestion of a sodium-sucrose compound (NS). The following day, one group received a substantially more toxic injection of LiCl, without NS exposure. The other group did not receive the NS solution or LiCl. It was anticipated that the administration of a strong poison would result in strengthening of the US representation, resulting in a greater avoidance of the associated CS components.

To determine if US habituation training after compound conditioning changes the response to the components, another two groups of rats were given compound NS solution immediately followed by a poison injection. Then one group received poison habituation training while the other group was given no further exposure to either the flavored solution or the poison. It was anticipated that repeated presentation of the US would attenuate the aversion to the CS-flavor. If the US-inflation and US-habituation training affect subsequent conditioned responding, then evidence would be obtained in favor of a double-bond mechanism operating between the elements of the compound elements and the US.

Method

Subjects: Thirty-two male Sprague-Dawley rats approximately 110 days old were used.

Apparatus: The apparatus of Experiment 1 was used.

Procedure: The design of Experiment 3 is presented in Table 5. Subjects were divided into four equal groups and restricted to distilled water for 10 min a day for 1 week. The next day, Day 1, all subjects had food removed and were immediately given 10 min access to a solution of NaCl (0.2M) and sucrose (0.05M) (NS). This was followed by an immediate injection of 0.1M LiCl (5 ml/Kg). One hr later 10 min of distilled water was allowed and food was returned.

Immediately following food removal for all subjects on Day 2, Group INF (inflation) was given a single injection of 0.3M LiCl (5 ml/Kg). Group HAB (habituation) received an injection of 0.1M LiCl on this day and on the subsequent three days. Two control groups, Group INF-C and Group HAB-C, although left untreated in home cages on Day 2 and Days 2-5 respectively, did have food removed with the other subjects and were allowed 10 min access to distilled water 1 hr later followed by food. On Day 3, after food removal for all subjects, Group INF and Group INF-C were given 10 min access to NS to test for conditioning. Following food removal on Days 6 and 7, Group HAB and Group HAB-C were also given access to NS for testing. (One subject in Group INF died on the fifth day of the water deprivation.)

Table 5

Design of Experiment 3

	Day				
Group	1	2	3	4-5	6-7
INF	NS+	++	NS?		
INF-C	NS+	-	NS?		
HAB	NS+	+	+	+	NS?
HAB-C	NS+	-	-	-	NS?

Note:

N=0.2M Sodium ++=0.3M LiCl/5ml/kg

S=0.05M Sucrose +=0.1M LiCl/5ml/kg

Results

The results of Experiment 3 are presented in Table 6. No difference was found in the consumption of NS during testing between Groups INF and INF-C (t=0.71, df=13,

$p<0.489$). These results do not provide support for the double-bond model.

No significant difference was found in the consumption of NS on either Day 6 ($t=0.58$, $df=14$, $p<0.569$) or Day 7 ($t=0.37$, $df=14$, $p<0.714$) between Group HAB and HAB-C. An additional t-test was conducted to compare NS consumption across test Days 6 and 7. Overall, subjects consumed an average of 13.97 g of NS on Day 6 and 24.14 g of NS on Day 7. This difference was significant ($t=8.20$, $df=30$, $p<0.001$). The larger intake of NS on Day 7 indicates that subjects did form an aversion to NS which quickly extinguished for all subjects after a single exposure. Because of asymptotic NS consumption on Day 7 no additional NS tests were conducted.

Table 6

Consumption of NS (in grams) on Test Day(s)

Group	Consumption	
INF	11.71 (Day 3)	
INF-C	10.05 (Day 3)	
HAB	13.40 (Day 6)	23.84 (Day 7)
HAB-C	14.55 (Day 6)	24.44 (Day 7)

Discussion

No support was found for the double-bond model in Experiment 3. The findings that US-inflation (Groups INF vs. INF-C) or US-habituation (Groups HAB vs. HAB-C) trials failed to affect NS aversion suggest that the double-bond mechanism cannot serve as an explanation for enhanced within-compound learning in a taste-aversion preparation.

It is not known why the present experiment failed to replicate US-habituation effects using a taste-aversion paradigm (Colby & Smith, 1978; Mikulka et al., 1977). One possible reason Colby and Smith (1977) were able to demonstrate a US-habituation effect may be their use of tap water instead of distilled water. Tap water can contain impurities that potentially can be tasted. It is possible that US-habituation trials resulted in an aversion to tastes in the tap water that followed the US presentations. Thus in the subsequent two-bottle test of tap water and the CS-flavor, subjects may have consumed more of the flavor-solution because it was less aversive than the tap water rather than because the CS-flavor aversion had been attenuated. Since Colby and Smith do not report the amount of tap water consumed during the testing periods the results of their study must be viewed as inconclusive.

Mikulka et al. (1977) do not indicate whether distilled or tap water was used. However, because they employed a one-bottle test to assess the subsequent aversion to the flavored solution, a confounding aversion to tap water is less critical. The mixed results suggest that the exact conditioning procedures needed to demonstrate US-habituation or US-inflation have not been adequately investigated. Nevertheless, the results of Experiment 3 indicate that the double-bond model is not a viable explanation for the findings of Experiments 1 and 2.

IV. General Discussion

This research has demonstrated that a lithium reinforcer can enhance within-compound flavor associations (Experiment 1) and that an immediate reinforcer is more effective in facilitating within-compound learning than a delayed reinforcer (Experiment 2). Before discussing the implication of these findings some discussion of the double-bond model is warranted.

Experiment 3 discounted the double-bond model as an explanation for facilitated within-compound learning. Durlach and Rescorla (1980) have suggested that, during compound conditioning, one association is formed between the elements themselves and other associations are formed between each element and the US. Then each element presented separately may evoke a stronger response because it has two associations to the US, one direct and one indirect. Such a result could be misinterpreted as a stronger within-compound association.

Experiment 3 attempted to identify the existence of a double-bond between the components of a flavor compound and a poison by administering US-inflation and US-habituation training after compound conditioning. Both training procedures failed to modify the conditioned aversive response. Thus no support was found for a double-bond mechanism in taste-aversion. Inflation and habituation effects have sometimes been reported in taste-aversion learning (e.g., Westbrook et al., 1982) and sometimes not (e.g., Holman, 1976). The reasons for this discrepancy are not yet clear. Regardless, double-bonding does not seem to be a viable model in the present setting.

Lack of support for the double-bond model may indicate a need for reconceptualization of Rescorla and Durlach's (1981) memorial account of within-compound learning. They proposed that elements of a compound form a single memorial representation so that presentation of one element of the compound activates the whole memorial unit. Such an approach can readily account for many of the within-compound findings. Although elements of a compound-CS may be integrated into a single memorial representation, the present research suggests that CS components and the US do not form a single memorial unit. It may be possible that the CS and US have such dissimilar characteristics that a single [illegible]al representation is prevented. In other words, [illegible]r elements in the nominal compound stimulus may [illegible]ase within-compound associative strength.

The results of Experiments 1 and 2 conflict with [illegible]evious findings of post-CS processing investigations. A [illegible]mmon tenet of many information-processing models (e.g., [illegible]e Wagner, 1976, 1978, 1981) is that learning is dependent [illegible]n rehearsal of stimuli in STM. However, STM is assumed to [illegible]ve a limited processing capacity. Wagner (1981), for example, proposes that only two or three items can be rehearsed simultaneously. In addition, the current contents of STM are assumed to be potentially affected by surprising events (e.g., stimuli with which the organism has no previous experience with) that demand rehearsal. Many investigators (e.g., Cheatle & Rudy, 1978; Terry, 1976; Terry & Wagner, 1975; Wagner, 1978, 1981; Wagner, Terry, & Whitlow, 1973) have shown that surprising events can interfere with ongoing processing, resulting in little conditioning accruing to the current contents of STM.

However, the results of Experiments 1 and 2 indicate that reinforcers can facilitate processing of the contents of STM. Experiment 1 demonstrated that a poisonous reinforcer facilitated within-compound learning in comparison to no reinforcer. In Experiment 2 it was shown that these facilitating effects were stronger following an immediate reinforcer than a delayed reinforcer. Thus, two basic findings on the effects of a LiCl reinforcer require explanation: lack of within-compound disruption and facilitated within-compound learning.

The fact that a LiCl reinforcer did not disrupt within-compound learning of taste could have occurred for several reasons. First, an ingestive CS is a proximal stimulus. A proximal cue may provide a longer source of stimulation than a distal cue and thus be less likely disrupted by a surprising event. In other words, a flavor cue may remain longer in STM memory in spite of the effects of reinforcement. Also, a characteristic of a LiCl reinforcer is its gradual onset in intensity. Its "surprisingness" may therefore be less than that of a reinforcer such as shock or food. The LiCl reinforcer would still evoke rehearsal of the contents of STM but be less likely to disrupt the rehearsal of the CS-compound.

Since a LiCl reinforcer may not disrupt STM, the results of Durlach and Rescorla (1980) are understandable. Recall that they found that an unexpected LiCl reinforcer did not attenuate potentiation. Based on the results of Experiment 1, it is proposed that an unexpected LiCl reinforcer does not disrupt processing in STM. Thus the processing of the odor and taste elements would continue undisrupted in STM resulting in unattenuated potentiation. In other words, within-compound learning between odor and taste occurs in spite of reinforcement because the reinforcer does not disrupt STM processing of the compound stimulus.

Rescorla and Durlach (1981) claim that US disruption of within-compound learning is consistent with current information-processing models. The presentation of an unexpected US is conceptualized as a "surprising" event which demands immediate STM processing. Such processing supposedly disrupts ongoing processing of previous stimulus events and results in inferior learning about these stimuli. Analysis of the results of Experiments 1 and 2 of the present study suggest that a LiCl reinforcer does not disrupt STM in this way. It is important to note that there are quantitative differences between Rescorla and Durlach's (1981) autoshaping paradigm and the taste-aversion paradigm used in the present study. The most salient difference between the two paradigms is with respect to the temporal effects of US stimuli. In autoshaping, a food reinforcer presented for several seconds may have different effects on learning or utilize a different processing mechanism by the organism than a reinforcer such as illness, which typically lasts for a much longer period of time. It would appear that current information-processing models are in need of revision to recognize specific characteristics and effects of different types of reinforcers.

Some suggestions can be made concerning how a LiCl reinforcer improves within-compound conditioning. First, it could be argued that since the effects of a LiCl reinforcer are long-lasting and nondisruptive, the CS-compound could remain active in STM and be rehearsed during the temporal duration of the US effects. In this case there is no unique processing state induced by LiCl. Facilitated within-compound conditioning merely results from normal, but extended, processing of the CS-compound. In other words, the subject learns both the within-event and between-event associations successfully. Alternatively, perhaps LiCl induces a "super" processing state in STM. In this instance, facilitated within-compound learning is the result of heightened processing in STM, possibly caused by the chemical effects of LiCl on the brain. Finally, it could be that a LiCl reinforcer does displace the contents of STM, but because of a rat's unique ability to associate flavor and illness (Seligman, 1970) the flavor CSs are constantly "retrieved" back into STM for additional processing, thus ensuring that the animal learns the presumed cause of its illness. No experiments exist today to provide any choice among these alternatives.

In conclusion, it is proposed that facilitated within-compound learning is due to the unique characteristics of the stimuli used in a taste-aversion preparation. Specifically, it is suggested that the processing in STM of a flavor-flavor CS-compound is not disrupted by a poison reinforcer but instead the compound is rehearsed along with the reinforcer. In contrast, distal CSs may be easily disrupted by a reinforcer resulting in disrupted within-compound conditioning. Finally, it is proposed that current models of information-processing should be revised to recognize the effects of different stimuli on STM processing.

References

Ayres, J.B., & Benedict, J.O. US-alone presentations as an extinction procedure. *Animal Learning and Behavior*, 1973, *1*, 5-8.

Brookshire, K.H., & Brackbill, R.M. Formation and retention of a conditioned taste aversions and UCS habituation. *Bulletin of the Psychonomic Society*, 1976, *7*, 125-128.

Brogden, W.J. Sensory pre-conditioning. *Journal of Experimental Psychology*, 1939, *25*, 323-332.

Cheatle, M.P., & Rudy, J.W. Analysis of second-order odor-aversion conditioning in neonatal rats: implications for Kamin's blocking effect. *Journal of Experimental Psychology: Animal Behavior Processes*, 1978, *4*, 237-249.

Colby, J.J., & Smith, N.P. The effect of three procedures for eliminating a conditioned taste aversion in the rat. *Learning and Motivation*, 1977, *8*, 404-413.

Cunningham, C.L. Associations between the elements of a bivalent compound stimulus. *Journal of Experimental Psychology: Animal Behavior Processes*, 1981, *7*, 425-436.

Durlach, P.J., & Rescorla, R.A. Potentiation rather than overshadowing in flavor-aversion learning: an analysis in terms of within-compound associations. *Journal of Experimental Psychology: Animal Behavior Processes*, 1980, *6*, 175-187.

Fudim, O.K. Sensory preconditioning of flavors with a formalin-induced need. *Journal of Experimental*

Psychology: Animal Behavior Processes, 1978, *4*, 276-285.

Garcia, J., Ervin, F.R., & Koelling, R.A. Learning with prolonged delay of reinforcement. *Psychonomic Science*, 1966, *5*, 121-122.

Gillette, K., & Bellingham, W.P. Loss of within-compound associations: configural preconditioning. *Experimental Animal Behavior*, 1982, *1*, 1-17.

Holland, R.C., & Ross, R.T. Within-compound associations in serial compound conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1981, *7*, 228-241.

Holman, E.W. The effect of drug habituation before and after taste aversion learning in rats. *Animal Learning and Behavior*, 1977, *4*, 329-332.

Kehoe, E.J., & Gormezano, I. Configuration and combination laws in conditioning with compound stimuli. *Psychological Bulletin*, 1980, *87*(2), 351-378.

Lavin, M.J. The establishment of flavor-flavor associations using a sensory preconditioning training procedure. *Learning and Motivation*, 1976, *7*, 173-183.

Logue, A.W. Taste-aversion and the generality of the laws of learning. *Psychological Bulletin*, 1979, *86*, 276-296.

Marlin, N.A. Within-compound associations between the context and the conditioned stimulus. *Learning and Motivation*, 1982, *13*, 526-541.

Mikulka, P.J., Leard, B., & Klein, S. Illness-alone exposures as a source of interference with the acquistion and retention of a taste aversion. *Journal of*

Experimental Psychology: Animal Behavior Processes, 1977, *3*, 189-201.

Randich, A., & Rescorla, R.A. The effects of separate presentations of the US on conditioned suppression. *Animal Learning and Behavior*, 1981, *9*, 56-64.

Rescorla, R.A. Effects of US habituation following conditioning. *Journal of Comparative and Physiological Psychology*, 1973, *82*, 137-143.

Rescorla, R.A. Effect of inflation on the unconditioned stimulus following conditioning. *Journal of Comparative and Physiological Psychology*, 1974, *86*, 101-106.

Rescorla, R.A. Simultaneous and successive association in senory preconditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1980, *6*, 207-216.

Rescorla, R.A., & Cunningham, C.L. Within-compound flavor associations. *Journal of Experimental Psychology: Animal Behavior Processes*, 1978, *4*, 267-275.

Rescorla, R.A., & Durlach, P.J. Within-event learning in Pavlovian conditioning. In N.E. Spear & R.R. Miller (Eds.), *Information Processing in Animals: Memory Mechanisms*. Lawrence Erlbaum Ass., N.J., 1981.

Rescorla, R.A., & Freberg, L. The extinction of within-compound flavor associations. *Learning and Motivation*, 1978, *9*, 411-427.

Riley, A.L., Jacobs, W.J., & LoLordo, V.M. Drug exposure and the acquisition and retention of a conditioned taste aversion. *Journal of Comparative and Physiological*

Psychology, 1976, *90*, 799-807.

Sherman, J.E. US inflation with trace and simultaneous fear conditioning. *Animal Learning and Behavior*, 1978, *6*, 463-468.

Speers, M.J., Gillan, D.J., & Rescorla, R.A. Within-compound associations in a variety of compound conditioning procedures. *Learning and Motivation*, 1980, *11*, 135-149.

Terry, W.S. The effects of priming US representation on short-term memory on Pavlovian conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1976, *2*, 354-370.

Terry, W.S., & Wagner, A.R. Short-term memory for "surprising" versus "expected" US in Pavlovian conditioning, *Journal of Experimental Psychology: Animal Behavior Processes*, 1975, *1*, 122-133.

Wagner, A.R. Priming in STM: an information-processing mechanism for self-generated or retrieval-generated depression in performance. In T.J. Tighe & R.N. Leaton (Eds.), *Habituation: Perspectives From Child Development, Animal Behavior, and Neurophysiology*. Hillsdale, N.J.: Erlbaum, 1976.

Wagner, A.R. SOP: A model of automatic memory processing in animal behavior. In N.E. Spear & R.R. Miller, *Information-processing in animals: memory mechanisms*. Lawrence Erlbaum Associates, Inc. Hillsdale, New Jersey, 1981.

Wagner, A.R., Rudy, J.W., & Whitlow, J.W. Rehearsal in animal conditioning. *Journal of Experimental Psychology*, 1973, *97*, 407-426.

Wagner, A.R., & Terry, W.S. Backwards conditioning to a CS following an expected versus a surprising UCS. *Animal Learning and Behavior*, 1975, *3*, 370-374.

Westbrook, R.F., Provost, S.C., & Nagley, M. Lithium exposures interfere with a previously established taste aversion in the rat. *Australian Journal of Psychology*, 1982, *34*, 139-149.

Wolf, G., & Steinbaum, E. A. Sodium appetite elicited by subcutaneous formalin: Mechanism of action. *Journal of Comparative and Physiological Psychology*, 1965, *59*, 335-339.