Biological Psychology 29 (1989) 39–60
North-Holland

AWARENESS OF THE CS–UCS CONTINGENCY AND CLASSICAL CONDITIONING OF SKIN CONDUCTANCE RESPONSES WITH OLFACTORY CSs *

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Accepted for publication 31 March 1989

The possibility of demonstrating acquisition of classically conditioned responses without awareness of the conditioned stimulus–unconditioned stimulus (CS–UCS) contingency using olfactory stimuli with 58 college student subjects was tested. A classical discrimination delay conditioning paradigm was employed, with electric shock as the UCS and two pleasant odors (perfumes) as the conditioned stimuli (CS+ and CS−). Trial-by-trial measures of skin conductance conditioned responses served as dependent variables. A masking task in the form of an olfactory memory task was employed for the purpose of delaying the onset of awareness of the conditioning contingency. Awareness of the conditioning contingency was assessed by a concurrent and a post hoc measure, and subjects who satisfied both criteria were considered aware of the CS–UCS contingency. Conditioning was observed only in the aware subjects, and only after the onset of awareness of the CS+–UCS contingency. Respiratory activity, measured as a check against possible artifacts, had no effect on the SCR measures. It was concluded that the awareness of the CS–UCS contingency is necessary for acquisition of discriminative conditioned responses in humans, regardless of the sensory modality in which CSs are presented. Sex differences in skin conductance measures and performance on the olfactory memory task were observed.

* The authors wish to express thanks to William Troyer for essential help with design and construction of the olfactory stimulus presentation device, and for programming assistance for stimulus control and response recording, and to Dennis VanderWeele for valuable advice on the preparation of this manuscript. We also wish to thank "Saponija" Osijek perfumers of Yugoslavia for providing us with the perfumes used in this study. This research was performed as partial fulfillment of the requirements for the Master's Degree from Occidental College by the first author. Portions of these data were presented at the convention of the Western Psychological Association, May 1988.

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1. Introduction

The premise of equipotentiality, implied in most of the early studies of learning, assumes that the laws of conditioning are equally effective for a variety of conditioned stimuli, reinforcements, and response systems, that regardless of the sensory modality of the conditioned stimulus (CS) and the unconditioned stimulus (UCS) or the nature of the conditioned response (CR), the same basic rules of conditioning apply (Öhman, Fredrikson, Hugdahl, & Rimmö, 1976). However, from research on "belongingness" between the CS and UCS (Seligman, 1970) and taste aversions (Garcia & Koelling, 1966), it has become clear that simple generalization of the laws of conditioning from one type of CS–UCS pairing to another may be unwarranted. This study was designed to explore whether some of the rules of conditioning obtained with visual and auditory stimuli can be generalized to olfactory stimuli as well.

Olfaction is often considered "primitive and elemental", due to its evolutionary primacy, because phylogenetically the sense of smell was developed before either vision or hearing (Stoddart, 1982). The unique role of olfaction is apparent anatomically and physiologically as well as behaviorally. Unlike most sensory cells, the cells of the olfactory epithelium perform both primary reception and conduction functions. That is, they transduce chemical stimulation into neural impulses and at the same time they carry the impulses to the olfactory bulbs via their axons, which form the olfactory nerve. Olfactory central connections also differ from those of other sensory inputs, since projection is directly to the olfactory cortex rather than through the common thalamoneocortical relay. These direct connections between the receptors and the olfactory cortex are unique in that they place the hypothalamus at a distance of just two synapses from the peripheral olfactory input. Other primary sensory systems can only influence the hypothalamus through a far more indirect, hippocampal pathway (Scott & Pfaffman, 1967). Direct connections with the hypothalamus are important because of this structure's control of the autonomic functions of the organism, with direct ramifications for emotional and motivational behavior (Grossman, 1973).

Evidence reviewed by Cain (1974) indicates that the olfactory bulb performs not only sensory functions but also interacts with limbic system structures that mediate motivated and emotional behaviors. Damage to the olfactory bulbs results in altered motivated behavior such as aggression, irritability, and maternal, sexual and social behavior. Close anatomical connections between the olfactory system and limbic structures may be the substrate of the "emotionality" of the olfactory system. Thus, evidence indicates that olfaction as a sensory modality has several unique aspects, and suggests that learning parameters based on auditory and visual stimuli may not be valid for the less-explored olfactory system. Also, rich and direct connections between the olfactory system and central structures responsible for emotional and motivated behavior suggest the possibility of demonstrating "true conditioning" in humans with olfactory CSs.

Notions about classical conditioning in humans are based almost exclusively on experiments using the visual and auditory sensory modalities. Difficulties in stimulus presentation and control have made the olfactory system inconvenient for use in conditioning experiments, as well as in experiments investigating cognitive processes. Therefore, in order to generalize from vision or audition to the olfactory sensory system, it is necessary to demonstrate commonalities among them. It cannot be taken for granted that conditioned responses to olfactory stimuli are established in the same way as the responses to visual or auditory stimuli, nor that the underlying processes necessarily have the same characteristics, particularly as regards the role of conscious processes.

The basic definition of classical conditioning postulates that it is possible to obtain a CR to a relatively neutral CS solely due to its temporal relation with a significant, response-eliciting UCS. However, it has been demonstrated that with human subjects the classical conditioning paradigm results in at least two processes: acquiring the conditioned response and acquiring conscious awareness of the CS–UCS contingency. Initially, the prevalent attitude was that conditioning does not necessarily involve conscious processes, and that "true" conditioning occurs if such complicating processes are eliminated (Razran, 1955). In order to investigate "true" conditioning in humans, masking tasks were devised whose purpose was to prevent subjects from becoming immediately aware of the CS–UCS relations, while ensuring perception of the relevant stimuli (e.g., Dawson & Grings, 1968; Fuhrer & Baer, 1969). Evidence that the conditioned response cannot be automatically acquired by mere temporal CS–UCS pairing and that only those subjects who could verbalize the CS–UCS contingency acquired conditioned responses was reviewed recently by Dawson and Schell (1985). However, this evidence is entirely limited to studies using visual and auditory CSs.

There is a lack of studies attempting to condition reactions to olfactory stimuli in humans. An extensive search of the literature did not yield any conditioning study employing odors as CSs and measuring autonomic responses to odors. Using non-autonomic measures of conditioning, Kirk-Smith, Van Toller, and Dodd (1983) inconspicuously presented a low level of a neutral odor to subjects during a stressful task. The authors found that if an unfamiliar odor was associated with a stressful situation, then this odor could elicit changes in mood and attitudes at a later time without the conscious recognition of the odor. They concluded that "Both the association and the later elicitation appear to have occurred without overt recognition of the odour" (p. 230).

The evidence discussed above suggests that olfactory stimuli may influence behaviors in ways that are unnoticed by the human subjects. In order to explore the role of awareness of CS–UCS relations in changing behavior when olfactory stimuli are used, a classical conditioning paradigm was employed in the present study and skin conductance responses were monitored as sensitive measures of autonomic conditioning. The study was designed to investigate whether CS–UCS pairings embedded in a masking task are sufficient to produce discrimination conditioning using olfactory stimuli. In other words, are people able to "smell" the danger and react to it even when they are not consciously aware of the signal value of the CS? The study was aimed at answering the following questions:

(1) Is it possible to establish autonomic conditioned responses using as CSs odors in a classical conditioning paradigm?
(2) Does such conditioning occur among subjects unaware of the CS–UCS contingency?
(3) Does the development of the conditioned response coincide with the onset of awareness of CS–UCS contingency?

2. Method

2.1. Subjects

Subjects were 58 undergraduate students – 28 males and 30 females – recruited from introductory psychology classes. They were paid $4 for their participation in the experiment. The data from 39 subjects were used in the final analysis. The data from 19 subjects were discarded from the analyses for the following reasons: poor performance on the task (7); ambiguity about awareness of the CS–UCS contingency, as will be discussed further below (9); habituation to the UCS (2); and equipment malfunction (1). In addition, 33 subjects were used as pilot subjects in preliminary stages of stimulus selection and design of equipment and procedures.

2.2. Design

This experiment employed a classical discrimination delay conditioning paradigm. Electric shock adjusted individually served as the UCS, two odors as the conditioned stimuli (CS+ and CS–) and skin conductance as the measure of the CR. Two between-subjects independent variables were employed: Sex of the subject and Instruction about the CS+–UCS contingency, which was experimentally manipulated using two different degrees of information. A randomly selected half of the subjects were specifically instructed that a contingency existed between one odor and the shock, but they were not told specifically which odor, and the other half were not given any information about the contingency. Trial-by-trial expectancy and post-conditioning interview measures were used to determine whether or not subject had become aware of which CS was associated with the UCS. This 2×2 factorial design yielded four groups: instructed males, uninstructed males (with 9 subjects for whom data were usable in both groups), instructed females (8 subjects), and uninstructed females (13 subjects). An olfactory memory task was employed with the purpose of delaying the onset of awareness of the conditioning contingency.

The Sex variable was considered important and was used as an effect in most of the analyses described below, first because we had found in our pilot work that women were better able to distinguish among the odor stimuli that we used than were men (not surprisingly, since the odor stimuli were perfumes), and since several investigators have reported that men are more electrodermally active than are women (see Schell, Dawson, & Filion, 1988, for a review).

2.3. Procedure

Subjects were told that the purpose of the experiment was to examine the relationship between the accuracy of their olfactory memory and changes in their physiological arousal. In fact, a modified version of a masking task (Dawson, 1970) was employed, with two main purposes: to assure discrimination between the odor stimuli (by checking the accuracy of the performance on a "memory test"); and to delay onset of awareness of the CS–UCS contingency by motivating subjects to attend to the "memory test".

From the subjects' point of view they participated in an olfactory memory test which consisted of a large number of trials. Each trial consisted of four odors presented in a sequence. The subjects were asked to inhale normally through their noses at the onset of every odor, which was indicated by a red light. The first presented odor served as a target odor, and their task was to compare it with three following odors and to try to detect the odor that was the same as the target. At the end of each trial the subjects were asked to report their answer to the experimenter.

After the task had been explained, the subjects were introduced to the physiological variables and the way they were to be measured during the experiment. They were then told that their physiological state would be momentarily altered by administration of an electric shock occasionally during the test in order to determine how this affected their olfactory memory. Finally, they were shown how to use a button box in order to express their expectancy of the shock throughout each trial. The necessity of this was explained to the subjects by telling them that expectancy of the shock as well as the shock itself might affect olfactory memory. At this point half of the subjects, those in the Instructed group, were told that the shock was predictable, that it would usually, but not always, follow one of the four odors, and would come at no other time. The use of this instruction, combined with the masking task, has been found to result in approximately half of the subjects becoming aware of the CS + –UCS contingency, but with awareness delayed long enough into the Acquisition trial series to allow pre-aware and post-aware conditioning to be examined (Biferno & Dawson, 1977; Dawson & Biferno, 1973). To summarize, then, there were two main tasks that subjects were asked to perform: (1) match one of the last three odors of each trial with the "target odor"; and (2) express their expectancy of the shock by using a button box. Shock level was then individually set for each subject at an "uncomfortable but not painful" level.

The experiment proper began with a set of preference ratings.The subject's task was to smell each odor once and express its degree of pleasantness on a scale ranging from 1 ("dislike very much") to 7 ("like very much"). This was followed by four Adaptation trials, two CS + trials and two CS-trials, in order to acquaint the subjects with the task and to assess initial responsiveness to the olfactory stimuli. Each trial consisted of four odors. The first odor (a "target odor") was one of two distractor odors which were never reinforced. The other three odors were: a correct match for the "target odor"; another distractor odor; and a CS + or CS – . These three odors came in a semi-random order so that each of the odors came as the first, second or third in a sequence equally often. Each odor was presented for 8 s, with 5 s between the removal of one odor and the presentation of the next. The intertrial intervals were 25–35 s duration (30 s on average).

Following Adaptation, 24 Acquisition trials were presented. Half of the trials contained a CS + , and half a CS – . CS + and CS – trials were presented in a restricted random order. CS + and CS – trials were paired, with both members of a pair being presented before either trial of the subsequent pair. Which member of each pair was presented first was randomly determined, with the restrictions that CS + and CS – were presented first equally often, no more than six trials of single alternations (CS + , CS – , CS + , CS – , CS + , CS –) could occur in a row, and no more than six trials of double alternations could occur in a row (CS + , CS + , CS – , CS – , CS + , CS +). These restrictions were applied to temporally equate the presentation of CS + and CS – , and to make the occurrence of CS + and CS – as unpredictable as possible for the subject. Each CS + was followed at its offset by a 0.5-s duration UCS. Which of the two CS odors was reinforced was counterbalanced across subjects, so that half the subjects received odor "X" in conjunction with the UCS, while the other half received odor "Y" followed by the UCS. CS + and CS – were counterbalanced for the order of presentation as well.

After all trials were presented, the experimenter administered a two-question recall questionnaire, asking subjects whether there was any way to predict the shock and whether the shock was associated with a particular odor or odors. This was followed by a short recognition questionnaire which consisted of a presentation of all the odors used in the experiment and a rating by the subject of the relationship, if any, between each odor and the UCS. The preference ratings of all the odors were then repeated.

2.4. Stimulus materials and apparatus

Stimulus materials consisted of four pleasant odors, all perfumes, that were presented in a concentration of eau de parfum. (Eau de parfum contains 12–18% of fragrance in an alcohol base, in contrast to perfume, which contains 20–30% of fragrance.) Two odors served as CS + and CS − and two served as targets/distractors employed in the masking task. Odors used in this experiment were selected on the basis of their evaluation in a pilot study as being easily distinguishable from each other during a series of paired comparisons. They were rated equally on scales of preference and familiarity. Approximately 20 drops of each fragrance were placed on a small ball of cotton in a glass vial.

Four vials containing odors were enclosed in a box placed on a tray in front of the subject's nose. Fig. 1 presents a simple diagram of the box, which housed four solenoids which were energized by an IBM PC computer-controlled external power source. [1] A clip attached to the end of each solenoid held a 6-cm glass vial with an odorant. The solenoids were mounted on the arc of a circle, so that when one was energized its vial was moved forward into position under a hole in the top cover of the box. The box was positioned so

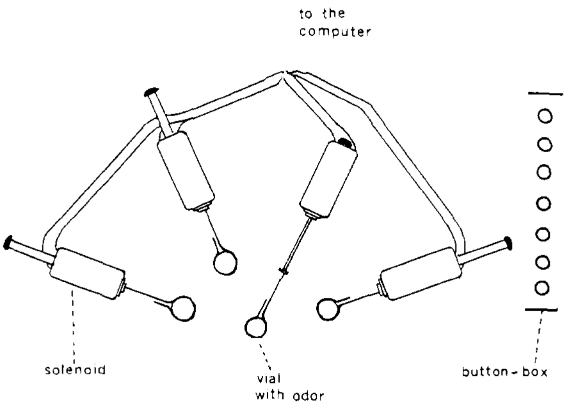

Fig. 1. Odor presentation box.

[1] Any reader seriously considering the construction of a similar device for presenting olfactory stimuli may obtain more detailed information on the construction of this one (circuit diagrams, etc.) by contacting Anne Schell at the address for reprints.

that the hole in the top cover was just below the subject's nose. A red light mounted in front of the subject indicated the presentation of an odor and signaled the subject to inhale and to attend to the odor.

The electric shock UCSs were delivered from a Grass S-9 stimulator and administered to the subject's right leg through a pair of 1.6-cm diameter silver electrodes coated with K-Y jelly (Johnson & Johnson).

Skin conductance responses (SCRs) were recorded from Beckman silver–silver chloride electrodes filled with K-Y jelly placed with adhesive collars (1 cm in diameter) on the volar surface of the first and third fingertips of the left hand. SCRs were recorded on a Narco-Bio DMP 4 Physiograph through a constant 0.5-V bridge circuit. Respiration was recorded from a Narco-Bio Thermistor Respiration Transducer attached above the hole on the top cover of the odor presentation box.

Time parameters for all the stimuli and intervals were controlled by the IBM PC computer. These included: stimulus duration for the odors (8 s); the light (1 s); intervals between the onsets of odor stimuli (13 s) within a trial; interval between CS+ and UCS stimuli (8 s); and the intertrial intervals (25–35 s). Duration of the electric shock that served as UCS (0.5 s) was controlled by both the IBM PC and a Hunter timer. The SCR data were recorded on the physiograph and, in addition, stored in a floppy disk file.

The button box that subjects used to indicate their expectancy of the shock on a trial-by-trial basis has been previously utilized as a valid concurrent measure of the development of contingency learning (Dawson & Biferno, 1973; Dawson, Schell, & Banis, 1986; Furedy & Schiffmann, 1973). The box displayed 7 buttons representing a 7-point scale. The buttons were labeled: "no shock – absolutely certain"; "no shock – very certain"; "no shock – fairly certain"; "completely uncertain"; "shock – fairly certain"; "shock – very certain"; "shock – absolutely certain". The button box was attached to the right side of the odor presentation box, allowing the subject to use his or her right hand for pressing the buttons.

2.5. Dependent variables

2.5.1. Skin conductance

Since a long (8-s) CS–UCS interval was employed, it was possible for either or both of two different electrodermal conditioned responses to occur on any trial, the First Interval Response (FIR–SCR), beginning 1–4 s after CS onset, and the Second Interval Response (SIR–SCR), beginning 4–9 s after CS onset. FIR and SIR magnitude were measured by taking the difference in conductance between response onset and response peak (Lockhart, 1966). All SCR measures were expressed as square root of skin conductance change in microsiemens.

2.5.2. Respiration

Since the perception of odors involves an active respiratory participation by the subject, it was necessary to monitor respiratory activity as a check against possible artifacts in skin conductance caused by breathing irregularities. The measure of the respiratory activity that was taken in this study was the magnitude of the largest respiratory cycle observed during each odor presentation.

2.5.3. Expectancies of the UCS

Also recorded on a trial-by-trial basis was a measure of expectancy of the UCS. These expectancies were measured by means of the buttons depressed during each trial as a concurrent measure of awareness of the conditioning contingency. If a subject depressed more than one button during one stimulus presentation, the expectancy for that stimulus was expressed as an average value of the buttons depressed.

2.5.4. Other measures taken

Other measures obtained during the experiment were the post-conditioning measure of awareness of the CS + –UCS contingency, obtained from a recognition questionnaire, and preference ratings of all the odors used during the experiment, obtained twice, before and after conditioning. Subjects' performance on the olfactory memory task was monitored to ensure that accurate perception of the odors occurred.

3. Results

In this section the following analyses will be discussed: (1) measures taken to assess awareness of the CS + –UCS contingency and classify subjects as aware or unaware; (2) analysis of olfactory memory task performance; (3) determination of whether or not conditioning of the FIR–SCR and SIR–SCR occurred in aware and unaware groups; (4) determination of whether or not pre-aware conditioning occurred among aware subjects; (5) analysis of respiration response data, including examination of the correlation between respiration and FIR–SCR responses; (6) analysis of preference scale ratings.

3.1. Assessment of awareness of the CS + –UCS contingency

Subjects were divided into "aware" and "unaware" groups (with 18 and 21 subjects, respectively) based on the trial-by-trial button expectancy using a "dual contingency' criterion of awareness (Biferno & Dawson, 1977), which has been shown to be a sensitive concurrent measure of awareness. According to this criterion, a subject is categorized as aware of the contingency if he or she expresses both a positive expectancy of the UCS during CS + (fairly, very, or absolutely certain that shock is about to come) and a negative expectancy of the UCS during CS − (fairly, very, or absolutely certain that shock is *not* about to come), for three consecutive pairs of trials by means of the buttons. The first pair of the three indicates the actual onset of awareness. Besides this concurrent measure, a post hoc measure of awareness was taken from the recognition questionnaire: ability to correctly identify the CS + and only the CS + as having been followed by the shock. Only subjects who satisfied both criteria were considered aware. Similarly, "unaware" subjects were those who failed to satisfy the "dual contingency" criterion, and did not rate the CS + as having been followed by the shock during the post-conditioning recognition questionnaire. Subjects who indicated contingency awareness only on one measure of awareness, and therefore failed to satisfy both criteria, were considered "ambiguous" regarding their awareness of the conditioning contingency. According to this criterion, 9 subjects were considered "ambiguous".

(The results of the recognition questionnaire were highly consistent with those of the recall questionnaire. Of 18 subjects who correctly recognized the CS + and only the CS + as having been followed by the shock, 17 indicated on the preceding recall questionnaire that they had been able to predict the UCS because it followed one odor that they could identify. One subject stated on the recall questionnaire that he was uncertain if he could identify the UCS-associated odor, but he was able to do so on the recognition questionnaire. Of the 21 subjects who were classified as unaware on the recognition measure, 18 were unaware on the recall measure. The remaining 3 stated on the recall measure that one odor had been associated with the UCS and that they could identify it, but they were unable to do so correctly on the recognition measure.)

A χ^2 test revealed that the instructions were successful in that a significantly larger number of subjects given contingency instructions became aware of the correct contingency as compared to the non-instructed subjects, χ^2 (1) = 15.89, d.f. = 1, $p < .001$. In the group of 17 instructed subjects (9 males and 8 females), 14 became aware of the CS–UCS contingency (7 males and 7 females), while 3 (2 males and 1 female) did not. In the group of 22 uninstructed subjects (9 males and 13 females), only 4 became aware of the contingency (2 males and 2 females), while 18 (7 males and 11 females) did not. Since the instructed and non-instructed groups overlapped so greatly with the aware and unaware groups, only the awareness variable was used in further analysis. This variable was selected instead of the instruction variable because it was evident that the instructions affected conditioning only if they affected awareness for a given subject. Unaware instructed subjects behaved like unaware uninstructed subjects, and aware uninstructed subjects behaved like aware instructed subjects. Thus, for the purposes of further data analysis, our four groups of subjects consisted of 9 aware males, 9 unaware males, 9 aware females, and 12 unaware females.

3.2. Olfactory memory task performance

One purpose of the masking task was to ensure that all the relevant stimuli were discriminated. Ability to discriminate between the stimuli was of great concern, especially since odors – not easily controllable stimuli – were used. It is of vital importance in this kind of paradigm to ensure that the unaware subjects did not fail to become aware simply because of their poor ability to discriminate between the odors. For this reason subjects' performance on the "olfactory memory test" was monitored. Data of all the unaware subjects (7) who failed to find the correct match for a target odor on more than 10 trials in the Acquisition phase were discarded.

When the data of all the subjects (including those eliminated because of their poor performance on the olfactory memory test) were included in the analysis of performance errors, the Sex effect reached significance, $F(1, 42) = 4.50$, $p < .04$. Females performed better on the olfactory memory task, making significantly fewer errors than males (means were 7.27 for females and 9.50 for males).

3.3. Skin conductance

3.3.1. Adaptation

Means and standard deviations for the FIR–SCR and the SIR–SCR during Adaptation and Acquisition for the four groups are given in table 1.

The data collected during the two pairs of Adaptation trials were analyzed for both SCR measures. For each variable a four-way analysis of variance

Table 1
Mean FIR–SCR and SIR–SCR values during Adaptation and Acquisition, in square roots of microsiemens (standard deviations in parentheses)

Group	Adaptation				Acquisition			
	FIR		SIR		FIR		SIR	
	CS+	CS−	CS+	CS−	CS+	CS−	CS+	CS−
Aware males	0.71	0.66	0.45	0.32	1.01	0.62	0.61	0.30
($N = 9$)	(0.38)	(0.28)	(0.37)	(0.32)	(0.47)	(0.30)	(0.45)	(0.21)
Unaware males	0.67	0.77	0.39	0.37	0.62	0.52	0.27	0.29
($N = 9$)	(0.47)	(0.38)	(0.35)	(0.36)	(0.38)	(0.29)	(0.23)	(0.16)
Aware females	0.66	0.47	0.31	0.24	0.63	0.38	0.33	0.28
($N = 9$)	(0.44)	(0.36)	(0.41)	(0.27)	(0.54)	(0.29)	(0.32)	(0.22)
Unaware females	0.80	0.72	0.29	0.25	0.29	0.34	0.16	0.15
($N = 12$)	(0.46)	(0.34)	(0.31)	(0.38)	(0.33)	(0.32)	(0.16)	(0.17)

(Awareness × Sex × Conditioning [CS + vs. CS −] × Trials) was performed in order to check for initial differential responses across groups or to CS + and CS − . No such differences were found. The only main effect or interaction found to be significant was the Trials effect for the FIR–SCR, $F(1, 35) = 8.86$, $p < .01$; response magnitude declined over the two pairs of Adaptation trials.

3.3.2. Acquisition

The data obtained during the Acquisition period were analyzed in four blocks of three pairs of trials. A four-way (Awareness × Sex × Conditioning [CS + vs. CS −] × Blocks) analysis of variance was carried out on the FIR–SCR and the SIR–SCR data in order to determine whether conditioning had occurred and, if so, whether it was affected by the Awareness variable.

First interval response. Results of the analysis of variance for the FIR revealed a significant Conditioning effect ($F(1, 35) = 15.15$, $p < .01$), with subjects responding significantly more to the CS + than to CS − . This provides an affirmative answer to the first experimental question of whether classical discrimination conditioning could be successfully demonstrated using these olfactory stimuli. The FIR–SCR appears to be an excellent indicator of conditioning when using odors as CSs.

The FIR–SCR analysis also showed a significant Conditioning × Awareness interaction, $F(1, 35) = 10.99$, $p < .01$, and a Conditioning × Block interaction, $F(3, 105) = 3.97$, $p < .05$. From inspection of fig. 2, it is obvious that larger responses occured on CS + trials than on CS − trials only in the aware group; the unaware subjects did not show differential responding to the two CSs. Also, while responses to CS + among the aware subjects tended to increase across blocks of trials, responses to CS − showed a decline. The FIR–SCR data also yielded a significant Sex effect, $F(1, 35) = 6.61$, $p < .01$, with men showing larger responses to both CSs than did women. This sex difference in electrodermal responsiveness has been noted elsewhere in the literature and will be briefly discussed below.

In order to further investigate the effect of awareness on conditioning, separate analyses of variance were performed on aware and unaware groups for the FIR–SCR. A significant Conditioning effect was observed only in the aware group, $F(1, 16) = 17.67$, $p < .01$. The fact that there was a non-significant Conditioning effect in the unaware group, $F(1, 19) = 0.26$, provided a negative answer to the second experimental question. Differential conditioning of the FIR–SCR was not demonstrated in the subjects who were unaware of the CS–UCS contingency. In the group of aware subjects, a significant Conditioning × Block interaction was also observed, $F(3, 48) = 6.38$, $p < .01$.

Second interval response. A four-way analysis of variance was also performed on the SIR–SCR data. Results similar to those for the FIR–SCR were

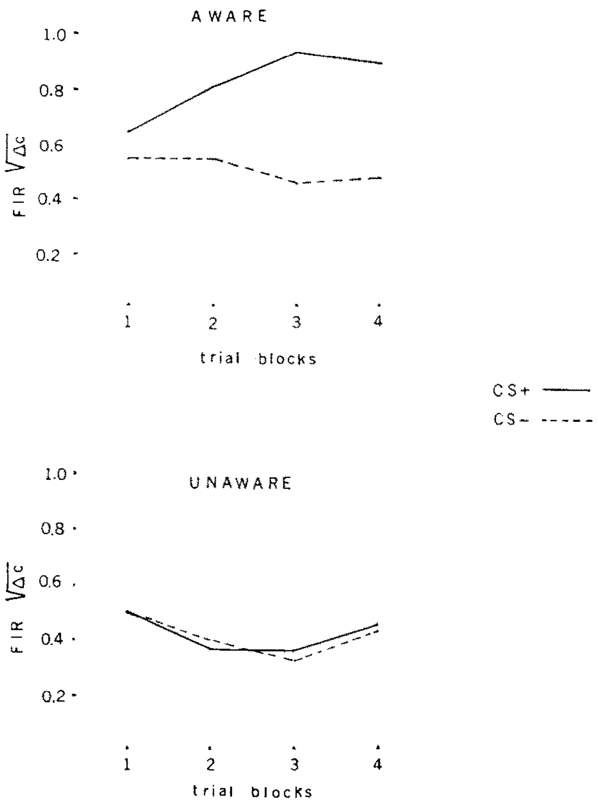

Fig. 2. FIR–SCRs during Acquisition to CS+ and CS− of Aware and Unaware groups of subjects.

obtained. There was a significant Conditioning effect, $F(1, 35) = 4.96$, $p < .05$, providing again an affirmative answer to the first experimental question and indicating that the SIR–SCR is a sensitive indicator of conditioning with olfactory stimuli.

A significant Awareness effect, $F(1, 35) = 5.11$, $p < .05$, depicted in fig. 3, revealed that the overall magnitude of the SIR–SCR was larger in the aware than in the unaware group. The Conditioning × Awareness interaction was also significant, $F(1, 35) = 6.07$, $p < .05$. As can be seen in fig. 3, differential responding to CS + and CS − is significantly greater among aware subjects than among unaware subjects. The tendency of the SIR–SCR to increase across blocks of trials resulted in a significant Block effect, $F(3, 105) = 3.12$, $p < .05$. In contrast to the FIR–SCR data, the SIR–SCR did not differ significantly between men and women.

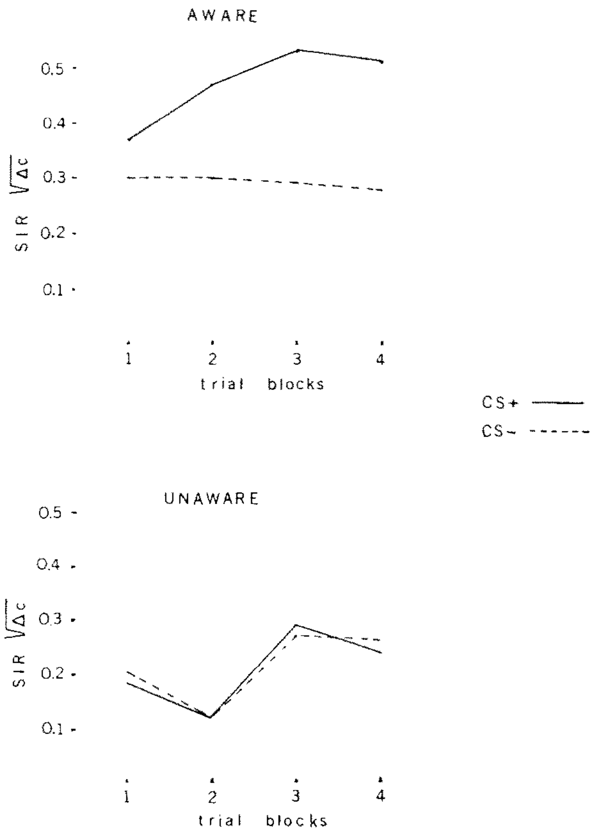

Fig. 3. SIR–SCRs during Acquisition to CS+ and CS− of Aware and Unaware groups of subjects.

As was done for the FIR–SCR, separate analyses of variance were performed on the SIR–SCR data of the aware and unaware groups. While there was no suggestion of a significant conditioning effect in the unaware group, $F(1, 19) = 0.06$, aware subjects showed significantly larger FIR–SCRs to CS + than to CS − , $F(1, 16) = 6.46$, $p < .05$. Again, it can be concluded that there is no differential conditioning in the subjects unaware of the conditioning contingency.

3.3.3. Temporal synchrony

Since no conditioning effect for any SCR measure was demonstrated in the unaware subjects, their data did not receive further analysis. However, since the conditioning effect was demonstrated in the aware subjects, it was necessary to explore more closely the temporal relationship between differential conditioning and the onset of contingency awareness. For this purpose, the first of the three consecutive pairs of trials on which a subject indicated positive expectancy of UCS on the CS + trial and negative expectancy of UCS on the CS − trial was considered to be the onset of awareness. Data from previous studies (Biferno & Dawson, 1977; Dawson & Biferno, 1973) indicate that differential conditioning among aware subjects appears at the point of onset of the dual contingency awareness. However, it has been argued that if pre-aware conditioning occurred, it might be most expected on the last trials before awareness onset, due to the cumulative effects of repetitive stimulus pairings (Baer & Fuhrer, 1973).

In order to investigate the possibility that differential conditioned responses occur slightly before the onset of contingency awareness, the trials immediately preceding the point of awareness onset were examined. For that purpose all subjects with at least three pairs of trials prior to the onset of awareness and three post-aware pairs of trials were selected. There were 13 such subjects: 7 males and 6 females. A four-way (Sex × Conditioning × Pre-aware/post-aware × Trial) analysis of variance was performed on the FIR–SCR and SIR–SCR data. The analysis of the FIR–SCR revealed a significant Conditioning effect for these subjects, $F(1, 11) = 5.19$, $p < .05$, and a significant Pre/post-awareness × Conditioning × Trial interaction, $F(2, 22) = 3.46$, $p < .05$. The top panel of fig. 4 shows that differential conditioning is obvious on post-aware trials, when compared with pre-aware trials.

In contrast to the FIR–SCR data, the SIR–SCRs of these 13 subjects for the three immediately pre- and post-awareness trials did not show a significant Conditioning effect, nor did any of the interactions of the Conditioning variable with other variables reach significance.

Separate analysis of the FIR–SCRs from the pre-aware and post-aware trials indicated that differential conditioning averaged across the last three pre-aware trials was not significant. The post-aware data, however, did reveal significant conditioning, $F(1, 11) = 5.71$, $p < .05$, with this subgroup of subjects.

Although pre-aware conditioning averaged over all pre-aware trials or over only the last three pre-aware trials was not significant, inspection of fig. 4 reveals an increase in differential responsiveness of the FIR–SCR on the last pre-aware trial. Because we wished to investigate any possibility that pre-aware conditioning might have occurred at some point, post hoc tests were done on these data even though the analysis of variance did not show a conditioning effect. In order to test the significance of differential responding on each of the pre-aware trials individually, a series of t tests was performed. However, differential responding on the last pre-aware trial reached only marginal significance, $t(12) = 1.58$, $p < .15$. In contrast, the t test for the immediately following first post-aware trial was significant for these 13 subjects, $t(12) = 2.56$, $p < .03$.

In order to determine whether this marginal degree of pre-dual contingency

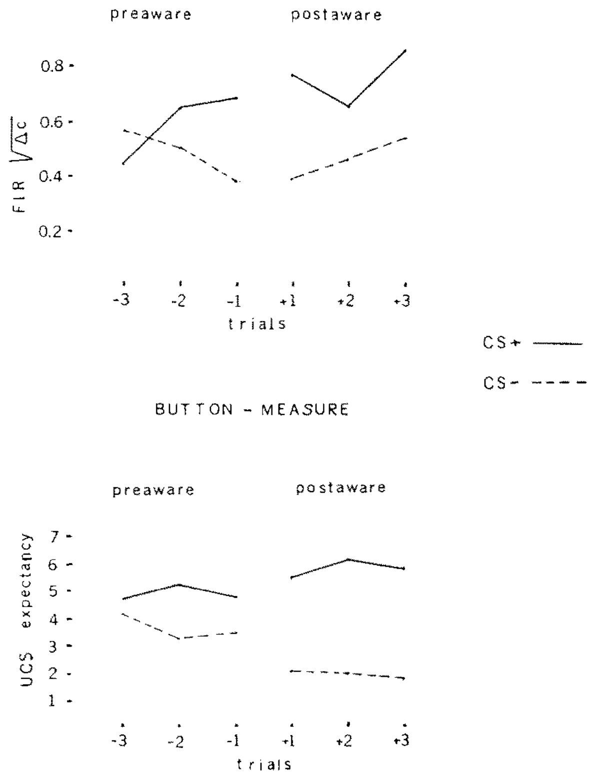

Fig. 4. Top panel: FIR–SCRS of Aware subjects to CS+ and CS− three trials pre- and three trials post-dual contingency awareness. Bottom panel: button expectancy responses of Aware subjects to CS+ and CS− three trials pre- and three trials post-dual contingency awareness.

awareness differential responding actually represents some level of conditioning without awareness, the button data for the three pre- and post-awareness trials were analyzed. The bottom panel of fig. 4 shows the development of contingency awareness as measured by the buttons during each of the three pre-aware and three post-aware trials. A marked divergence in expectancies of the shock on CS + and CS − trials is obvious on the first post-aware trial. However, trial-by-trial *t*-tests show that, in fact, a significant difference in expectancies already existed on the second and third pre-aware trials, $t(12) = 3.20$ and 3.28, respectively, $p < .01$. Thus it is clear that, prior to the development of dual contingency awareness, subjects as a group develop what could be termed a kind of single contingency awareness. They do not have a strong positive expectancy of the UCS after the CS + coupled with a strong negative expectancy after CS −, but they do expect the UCS after CS + more than after CS −.

Since it is obvious that the dual contingency criterion did not entirely serve its purpose and that some difference in expectancies of the shock on CS + and CS − trials did in fact exist before that point, a single contingency criterion was employed. This criterion defines the onset of awareness as the first of three pairs of trials on which there is a higher expectancy of the shock on the CS + than on the CS − trial, even if both of the expectancies are positive, or both are negative. The question is whether there will be any differential conditioning of the skin conductance response when there is no greater expectancy of the UCS after the CS + than after the CS −.

The first pair of Acquisition trials could not be considered as pre-aware trials on which conditioning due simply to CS–UCS temporal contingency could have occurred, since temporal contingency had not occurred prior to the first pair of Acquisition trials. Therefore, data of all the subjects who did not have at least one pre-aware pair of trials following the first pair were eliminated. There were only 10 subjects (5 males and 5 females) with two or more pre-aware pairs of trials, when awareness was defined according to the single contingency criterion. With this paradigm, if a subject became aware of the CS + –UCS contingency, he or she tended to do so early in the Acquisition trial series.

For each of these 10 subjects an average was taken for FIR–SCRs and SIR–SCRs to CS + and CS − during the preaware trials using the single contingency criterion and during all of the post-aware trials. Analyses of variance of these data indicated that the Conditioning effect did not approach significance for either the first or second interval response during the pre-aware trials, $F(1, 9) = 0.05$ and 0.06, respectively. However, for the post-aware trials, the first interval response for this subgroup did show at least marginally significant conditioning, $F(1, 9) = 4.01$, $p < .10$.

3.4. Respiration

When odors are used as CSs and when perception of the relevant stimuli involves active respiratory participation by the subjects, it is necessary to monitor respiration activity as a check against possible artifacts in skin conductance measures caused by respiration patterns. The necessity of such monitoring was demonstrated by Stern and Anschel (1968), who found a significant difference between the SCRs accompanied by slightly deeper than normal breaths and by deep and fast breaths. In the present study, peak-to-peak magnitude (mV) of the largest respiratory cycle observed during each CS odor presentation was measured.

3.4.1. Adaptation

A four-way analysis of variance (Sec × Awareness × Conditioning × Trials) for the respiration magnitude measure of the Adaptation data did not reveal any significant effects. This indicates that there were no initial differences in respiration activity between the groups of subjects, or in response to CS + and CS − .

3.4.2. Acquisition

The respiration data obtained during the acquisition period were analyzed and presented in four blocks with three pairs of trials in each block. Results of the overall analysis of variance of respiration magnitude revealed a significant effect of Sex, $F(1, 35) = 5.36$, $p < .05$, with males having larger respiratory amplitude than females (respective means were 4.7 mV and 2.6 mV). There was also a significant effect of Awareness, $F(1, 35) = 4.45$, $p < .05$, with the aware subjects having significantly smaller respiration magnitudes than unaware subjects (respective means were 2.7 mV and 4.36 mV).

Separate analyses of variance were performed for the Acquisition data for the aware and unaware subjects. For the aware subjects the stimulus effect was significant, $F(1, 16) = 4.86$, $p < .05$. Aware subjects showed smaller respiratory responses to CS + than to CS − , evidently being less willing to inhale the odor associated with the shock. In the unaware group, the only significant effect was the Sex effect, $F(1, 19) = 4.96$, $p < .05$, with males showing larger respiratory magnitudes than females.

As mentioned previously, Stern and Anschel (1968) observed significantly larger skin conductance responses with deep and fast breaths than with the slightly deeper than normal breaths. In the present study, it was observed that aware subjects had significantly deeper breaths on CS − than on CS + trials. Thus, if any respiratory artifacts existed in the skin conductance data, they should have influenced responding to the CS − to a greater extent than responding to the CS + , working against the conditioning effect. In spite of that, significant skin conductance response conditioning was observed in the aware subjects.

In order to explore further the relationship between respiratory response magnitude and skin conductance response magnitude, correlation coefficients were computed for the CS + respiration and first interval skin conductance responses in the 18 male subjects, each response being averaged over all Acquisition trials. The analysis was performed on the data of males only, because the correlations obtained by using all subjects might have been artificially amplified due to different response patterns in the two sexes. Males on the whole tend to have larger FIR–SCRs and larger respiration magnitudes, while females, as a group, tend to have smaller SCRs and smaller respiration magnitudes. The correlation for all male subjects was non-significant, $r(16) = -.28$. Because awareness of the CS + –UCS contingency had opposite effects on the skin conductance and respiratory responses to the CS + , enhancing the former and diminishing the latter relative to responses to the CS − , in order to explore the basic physiological relationship between the skin conductance response and respiratory magnitude, it was necessary to analyze the data of the unaware subjects alone. These data were free of the differential influence of contingency awareness. For these subjects, the correlation between FIR–SCR and respiratory response magnitudes was near zero, $r(7) = .03$. Thus it appears that during Acquisition respiratory activity actually had little, if any, effect on the skin conductance response.

3.5. Preference scale ratings

Because of the great importance of hedonic aspect in influencing responses to odors, a 7-point preference rating scale was used in the present study prior to and following the experiment itself. We wished first to be sure that the CS + and CS − did not differ in pleasantness prior to the beginning of the experiment, and specifically that the CS + was not perceived as being unpleasant (not all people like all perfumes). If the CS + was perceived as unpleasant (to a greater extent than the CS −), sensitization to its presentation could have developed during the experiment, leading to SCRs which were unrelated to the CS + –UCS contingency. Second, we wished to determine if subjects who were unaware of the CS + –UCS contingency might still show a change in their global affective response to the CS + , coming to rate it as less pleasant than the CS − by the end of the experiment.

A four-way analysis of variance (Awareness × Sex × Conditioning × Time-of-presentation) revealed only a significant Time-of-presentation effect, $F(1, 35) = 9.92$, $p < .01$), with lower ratings of both CSs after the experiment. The mean rating of the CS + dropped from 4.4 to 3.8, and the mean rating of the CS − dropped from 4.5 to 3.7. This effect is probably the result of the aversive conditioning paradigm; subjects simply showed less preference for the odors used in the experiment because of their association with a generally aversive situation. The degree of reduction was not affected by CS type (CS + vs. CS −), awareness or sex. It was clear that there were no original differences in preference for CS + and CS − , and that neither aware nor unaware subjects altered their preferences differentially.

4. Discussion

Results of the present study are in general agreement with most of the previous research regarding the issue of awareness of the CS–UCS contingency in the classical conditioning paradigm. The general conclusion has been that awareness is necessary for the establishment of differential conditioning in humans, when using auditory stimuli (Biferno & Dawson, 1977; Dawson, 1970; Dawson & Biferno, 1973; Fuhrer & Baer, 1969) and visual stimuli (Dawson, Catania, Schell & Grings, 1979; Dawson et al., 1986) embedded in a masking task. The results of the present study indicated that the same rules demonstrated for the visual and auditory modalities, when using a masking task in the conditioning paradigm, can be applied to olfactory stimuli. No differential conditioning was demonstrated in subjects who were unaware of the conditioning contingency, as assessed by the concurrent (buttons) and post hoc (recognition questionnaire) measures of contingency awareness. Differential conditioning was established, on both measures of skin conductance responsiveness, only in the subjects who were aware of the CS–UCS contingency. Also, temporal synchrony between the development of conditioned response and contingency awareness was observed. That is, differential conditioning was demonstrated only on trials following the onset of contingency awareness. It seems reasonable to conclude that the widely assumed "uniqueness" of olfactory stimuli, seen in their capacity for recollection of long-forgotten memories and feelings, does not extend to the learning of the original associations.

The sex differences obtained in this study, with men having larger FIR–SCR magnitudes, are consistent with numerous previous findings (see Schell et al., 1988, for a review). Both hormonal (Silver, Montagna, & Karacan, 1964) and psychosocial (Maltzman, Gould, Barnett, Raskin, & Wolff, 1979) explanations have been offered for these differences.

The finding that males have less confidence in their olfactory abilities, as shown by Cain (1982), tends to suggest that males were perhaps more threatened and felt less comfortable in this aversive situation involving olfactory stimuli than did females. Males did in fact perform more poorly on the olfactory memory task than did females. The fact that the olfactory memory task was more difficult and demanding for males than for females might have also contributed to their greater autonomic responsivity. However, the degree of differential classical conditioning that occurred did not differ between men and women.

The present experiment leads to the conclusion that: (1) it is possible to establish autonomic conditioned responses using olfactory stimuli as CSs; (2) no differential conditioning occurred among subjects unaware of the CS–UCS contingency; (3) differential conditioning does not occur in aware subjects prior to the development of contingency awareness, thus offering support for the necessary-gate hypothesis (Dawson & Furedy, 1976); (4) sex differences in SCR responsivity were demonstrated, with males being more responsive than females; (5) the females outperformed males in the task of matching the odors.

These conclusions should be qualified in at least one respect. The present study employed non-biological, rather similar, pleasant and difficult to verbally discriminate (give a differential verbal description of) odors. It would be extremely interesting to determine whether or not conditioning without or prior to contingency awareness could occur if biologically prepared or significant odors were used as CSs. Such substances as androstenol (Gustavson, Dawson, & Bonett, 1987), musk (chemically related to human sex hormones), the characteristic smell of predator urine, and so on, might function as prepared olfactory CSs with unusual properties.

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