Acta Psychologica 58 (1985) 31–44
North-Holland

EXPECTANCY FOR AIRPUFF AND CONDITIONED EYEBLINKS IN HUMANS *

Pierre PERRUCHET
Université René Descartes, Paris

Accepted December 1983

Three experiments were designed to test the hypothesis that expectancy for an unconditioned stimulus (US) serves as an intervening variable in the well-documented empirical relationship between the awareness of stimulus contingencies and the occurrence of conditioned reactions (CR) in human classical conditioning. Experiment 1 showed that, when subjects are instructed to respond by keypressing to US in a conditioning-like procedure, reaction time (RT) provides the same kind of information as a direct rating of expectancy. In experiment 2, the RT task was superimposed on an otherwise standard eyeblink conditioning procedure. Reliable discriminative conditioning failed to occur, although changes in RT give evidence of increasing expectancy for US. Experiment 3 aimed to repeat experiment 2 with several modifications in procedure, intended to facilitate conditioning. The between-subjects correlation between RT to US and frequency of eyeblink CRs was reasonably high (-0.52). However, when consecutive trials were considered, a shift was apparent between the two variables: RT changes occurred earlier than CR development. The implications of these results with respect to the expectancy theory of conditioning are discussed.

Analysis of the available experimental evidence strongly suggests that the development of awareness of salient features of a conditioning situation is a necessary condition for human classical conditioning to occur (e.g. Perruchet 1979, 1980). Two converging lines of evidence support this position. First, when subjects are categorised on the basis of awareness of interstimulus relationships, unaware subjects fail to demonstrate conditioning (Dawson and Reardon 1973; Fuhrer et al. 1973; Maltzman 1977; Morgenson and Martin 1969; Nelson and Ross

* This study was supported by the C.N.R.S. (ERA 79) Université René Descartes, E.P.H.E. (Laboratoire de Psychologie Différentielle), and C.N.A.M. (Service de recherches de l'I.N.O.P.).
Author's address: P. Perruchet, Laboratoire de Psychologie Différentielle, 28 rue Serpente, 75006, Paris.

1974; Perry et al. 1977). Second, when the evolution of awareness is monitored on a trial-by-trial basis, conditioning never occurs prior to the development of awareness in a given subject (Baer and Fuhrer 1982; Biferno and Dawson 1977; Dawson and Biferno 1973).

Nevertheless, the actual basis of this well-documented empirical finding is not yet clear. As noted by Pendery and Maltzman, "Cognitive approaches ... have uniformly failed to delineate how learning relations among stimuli are translated into observed changes in behavior ... To demonstrate convincingly that verbalisation and conditioning are causally related, it is necessary to establish how awareness, verbalisation, or the perception of relations, lead to the production of physiological changes" (Pendery and Maltzman 1977: 121).

The hypothesis addressed by the following experiments states that verbalisable knowledge of contingencies between a conditioned stimulus (CS) and an unconditioned stimulus (US) enables generation of a timed expectancy for US at CS occurrence. This expectancy in itself is presumably a major source of conditioned responses (CRs).

Yet, US expectancy does not appear equally relevant for all observed CRs. In order to clarify this point, an experiment carried out by Iwama and Abe (1952) will be described, which involved the prototypical salivary reaction. Metronome beats served as CS. On each trial, an acid solution, acting as US, was introduced into the subject's mouth at the end of 12 seconds of beats. Following repetition of trials, salivation was elicited by the CS, before US onset. Interestingly, the conditioned salivation appeared divided into two components, located respectively at the beginning and at the end of the CS–US interval. Elsewhere (Perruchet 1984), I have emphasised the empirical generality across paradigms and response systems of this dual component response, as well as its theoretical significance. Briefly, the initial response appears to be primarily elicited by the CS which, as a result of its pairing with the US, is endowed with new properties. These "backward-directed" CRs appear dependent on mediating processes without any relation to US expectancy. The source as well as the nature of these CRs will not be further considered here. Other responses appear to be "forward-directed": whatever the CS–US interval, they occur immediately before US onset, and they are essentially dependent on US properties. Conceivably, expectancy only addresses this latter category of CRs (Perruchet 1984).

The expectancy concept has been used as an explanatory construct in various areas of psychology for quite some time (Sanders 1966). With respect to learning, the importance of expectancy has been emphasised by Tolman (1932), and many other authors after him (e.g., Bolles 1972). Yet, despite its widespread acceptance as one of the cornerstones of the psychology of learning (e.g., Tarpy 1982), the expectancy theory of learning is all but securely founded. For example regarding classical conditioning in humans, there is little immediate empirical support. Few, if any, attempts have been carried out to develop experimental paradigms permitting a differential test of expectancy theory and other cognitive theories focusing on various hypothetical constructs, like "internal representation" (e.g., Rescorla 1975), "memory" (e.g., Weisman 1977), or "image" (e.g., King 1979) of the US.

Moreover, the few experiments potentially capable of supporting expectancies theory furnish rather scanty evidence. They have used ratings of expectancy regarding US, the usual procedure consisting of estimates, throughout the experiment, of the level of expectancy regarding the occurrence of the US on a continuous scale. Then, correlations are computed between the rated expectancy for US, generated by CS occurrence, and the amount of conditioning, either between subjects from the overall individual scores (Furedy and Schiffmann 1971, 1973; Schiffmann and Furedy 1977), or within subject on a trial-by-trial basis (Furedy and Schiffmann 1973; Schiffmann and Furedy 1977). In both cases the values of the correlations are found to be low or non-existent.

Yet, these negative results are not decisive, because the requirement of overtly expressing expectancy ratings throughout the experiment could interfere with conditioning. Thus, requiring continuous introspection may change the cognitive activity as normally displayed in conditioning. Furthermore, the hand movements required to carry out the rating could directly affect conditioned responses. All the experiments cited above have been concerned with autonomous conditioned responses, which are presumably sensitive to a concurrent motor task. Response interference is especially likely since the rating is carried out during the CS–US interval, at the same moment of recording electrodermal or vasomotor CRs.

One objective of the present experiments is to assess the validity of an experimental procedure devised to provide the same information on expectancy as the overt rating technique, while avoiding the abovementioned shortcomings. Subjects react to the US by pressing a key as fast as possible, and reaction time (RT) is recorded. It has been repeatedly argued that RT strongly depends on expectancy about the response stimulus. This is supported by studies showing that subjects react markedly faster to correctly predicted than to incorrectly predicted stimuli, when they verbalise which stimuli they expect prior to each trial in a choice RT paradigm (e.g., Geller and Pitz 1970). Expectancy is also an explanatory construct for several RT findings, including the effect of relative stimulus frequency on choice RT, which is accounted for by assuming that subjects' expectancy varies directly with the relative frequency of stimuli. In support of this interpretation, the relative frequency effect vanishes when verbalised expectations are recorded and partialised out (e.g., Hinrichs 1970). In the same way, RT depends on the length or variability of the foreperiod (e.g., Niemi and Näätänen 1981), which also fits an expectancy theory. Together this suggests that if CS takes the place of the warning signal and US the place of the response stimulus, RT to US could reflect CS generated expectancy for US, and thereby would provide the same kind of information about actual expectancy as overt ratings.

Yet, the relationship between RT and stimulus expectancy cannot be taken for granted in any situation, whatever the sources of variation. In a standard conditioning paradigm, two sources of variation are directly relevant: practice and subjects. To the best of my knowledge, no study has been concerned with the issues whether RT variations due to practice or subjects are due to expectancy variation. Experiment 1 was designed to investigate this relation. RT to US and on-line rating of expectancy for US were simultaneously recorded to assess the degree of parallelism between ratings and RT regarding the evolution of performance over trials (after averaging over subjects), and over individual differences (after averaging over trials).

The second objective of the experiments was to implement this new evaluative method in a standard conditioning paradigm. Experiments 2 and 3 examined the extent to which changes in expectancy, as indexed by RT measures, can account for CR growth with practice, on the one, and for individual differences, on the other hand. Eyeblink was preferred to an autonomous reaction which is more sensitive to interference. The choice of the eyeblink reaction is not possible with overt ratings of expectancy. This usually requires long CS–US intervals (longer than 1.5 sec) which does not allow the development of an eyeblink CR in humans (e.g., Kimble 1962: 40–41). The RT method does not require a specific value for the CS–US interval and, accordingly, enables investigation of expectancy in any paradigm. It should be noted that eyeblink CR anticipating the US occurrence unambiguously concerns forward-directed responses for which expectancy theory is relevant (Perruchet 1984).

Experiment 1

Method

Subjects

Twenty paid, right-handed volunteers served as *S*s (14 females, 6 males). The results of 4 additional *S*s were discarded: one due to instrumentation malfunctioning, two due to misunderstanding instructions, and one for abnormally slow RT. The *S*s' mean age was 23.9 yrs (range: 19–35 yrs).

Apparatus

The response signal (US) consisted of increasing the illumination of a translucide circle of 23 mm in diameter. The permanent illumination of the circle was accomplished by a LED diode. Illumination was increased by superimposing a 0.5 V., 0.1 A. lamp for 300 msec. The warning signal (CS) was a tone of 500, 1000, 2000, or 4000 cps, presented for 2 sec, produced by a Dufour signal generator and presented through stereo earphones at an intensity of 60 dB. Intertrial and interstimulus intervals were controlled by an Electromed timer, and RT to US was measured to the nearest msec by an Electromed clock.

Expectancy for the US was indicated on a cursor at the *S*'s left hand. The cursor could be moved from front to back, with a maximum displacement of 7 cm. Cursor position was linearly recorded on a Racia polygraph (0.50 cm/sec paper speed).

Procedure

The *S*s were escorted into a sound-attenuated, dimly lit room, separate from the apparatus room. They were seated in a chair facing the permanent signal light. Instructions were given via a tape recorder. *S*s were asked to press the button as fast as possible upon detection of an increased illumination and were warned against anticipatory responses. *S*s were instructed to indicate moment by moment changes of expectancy about the occurrence of the light signal by moving the cursor either forward or backward.

All *S*s received 150 trials, divided into 10 blocks of 15 trials each. Each block contained 3 tones of each frequency. Tones (CS^+) of 500 cps for half the *S*s, and 4000 cps for the remaining *S*s, were always paired with the light signal with an interstimulus interval of 1800 msec. Other tones (CS^-) were always presented alone. Additionally, 3 unpaired light signals were given. These 15 trials (3 CS^+US, 3×3 CS^-, and 3 US) were randomly presented with a mean intertrial interval of 5.5 msec (range: 3 to 8 sec).

Data analysis

Expectancy for US (on CS^+US or US alone trials) was accounted for by the cursor position at the moment of US onset. The ratings were scored from zero (light not expected) to 10 (light expected).

RTs less than 100 msec and more than 1000 msec were discarded and replaced by the mean score of the *S*. They represented respectively 1.3% and 0.3% of RTs for all *S*s and trials.

Results and discussion

Covariations with trials

Table 1 shows the development of RT and expectancy ratings for each of two consecutive blocks of trials. Regarding "US alone", effects of blocks were not significant for RT ($F(9,190) = 0.76$; n.s.) as well as for expectancy ratings ($F(9,190) = 0.41$; n.s.). Ratings for CS^+US increased ($F(9,190) = 8.99$; $p < 0.01$) to peak beginning with the sixth blocks of trials; the statistical analysis was significant for both linear ($F(1,190) = 67.71$; $p < 0.01$) and quadratic ($F(1,190) = 7.50$; $p < 0.01$) trends. The RTs to CS^+US decreased in the course of the blocks ($F(9,190) = 2.50$; $p < 0.05$); only the linear trend was significant ($F(1,190) = 18.85$, $p < 0.01$; F quad. $(1,190) = 2.24$; n.s.).

The fact that the quadratic trend was significant for expectancy but not for RT may be due to the metric properties of scales. The quadratic trend corresponds to a break in the increase of subjective expectancy; conceivably, this break may be due to a ceiling effect: rated expectancy approaches its possible maximum value at the 6th blocks of trials, whereas RT still decreases.

Covariation between subjects

Data were averaged on all CS^+US trials, so that a single value was obtained for each *S* for rated expectancy on the one hand, and for RT, on the other. The between *S*s correlation between the two variables was -0.56 ($p < 0.01$). As expected, high expectancy associated with fast RT.

Table 1
Rated US expectancy (scale: 0–10) and RTs as a function of trials in experiment 1, for US preceded by CS^+ (CS^+US) and US alone. Each value is the mean of 120 measures (6 trials per subject × 20 subjects).

	Blocks of trials					Mean
	1–2	3–4	5–6	7–8	9–10	
Rated expectancy						
CS^+US	5.70	7.03	8.29	9.15	8.94	7.82
US	5.06	5.42	5.18	4.97	5.28	5.18
RT						
CS^+US	351	315	290	274	269	299.7
US	391	350	394	400	384	383.8

Although this correlation is fairly high, it can be still considerably higher. RT to the CS^+US does not only depend on the degree of expectancy for the US, but also on factors like individual differences in speed and in speed-accuracy trade-off. In the same way, rated expectancy probably depends on the subjective interpretation of the experimenter's instructions pertaining to the meaning of the scale: for the same level of actual expectancy, *S*s may be more or less inclined to displace the cursor to the extreme of the continuum. In order to eliminate such factors, "US alone" trials were presented randomly during the experiment. RT and expectancy ratings to "US alone" might be affected by all these superimposed factors, so that the algebraic differences between the results in CS^+US and US alone should be a more refined measure. Indeed, between-*S*s correlation between RTs and expectancy ratings computed from the difference scores was much higher: -0.83.

An overall examination of the results of experiment 1 supports the view that RT to US provides information similar to that of overt ratings. Consequently, RT can be used in eyeblink conditioning experiments to test the expectancy/conditioning relationship.

In experiment 2, a slight puff of air on the cornea replaced the innocuous response stimulus on the first experiment. The other features of the two experiments were similar. A major difference concerned the CS–US interval which was 1800 msec in experiment 1 to allow adjustment of the cursor position; in order to obtain eyeblink conditioning, it was less than 1 sec in experiment 2.

Experiment 2

Method

Subjects

Six paid, right-handed volunteers (4 females, 2 males), mean age 21.6 yrs, served as *S*s. One additional *S* was eliminated because of malfunctioning of the apparatus.

Apparatus

The US was a puff of nitrogen of 2 psi (pound square inch), and had a duration of 50 msec. It was delivered to the left cornea through a 1 mm tubing. The CS was a 60 dB, 1 sec tone of 500, 1000, 2000, or 4000 cps, produced by a Dufour signal generator, and presented through stereo earphones. The eyeblink responses were recorded by means of two photodiodes capturing the reflectance at the orbit of an infrared light-emitting diode (LED). In order to make the device insensitive to ambient light variations, the output of the LED was modulated with a 3300 cps signal. The output of the photodiodes was processed so that only the 3300 cps component of the reflected signal was detected. Photodiodes and LED were fixed on the left hand of a pair of spectacles, which also carried the airpuff. Eyeblinks and marker signals were recorded on 2 FM channels of a 4 channel R61 TEAC magnetotape. RT was directly recorded to the nearest msec on an APPLE II microcomputer. Stimulus presentation and duration were also controlled by the microcomputer.

Procedure

The *S*s were seated in a sound-attenuated, dimly lit room, separate from the apparatus room. They were facing a light fixation point located approximately 1 m in front of them. Instructions required *S*s to react as quickly as possible to the onset of the airpuff by pressing a key. The occurrence of the tones was mentioned but their function was not specified. *S*s were only told not to react to a tone. Regarding eyeblink responses, *S*s were requested not to promote or inhibit their natural reactions. One tone of each of the frequencies and 4 airpuffs were presented in random order with the aim of adjusting the recording apparatus and familiarising the *S*s with the RT task.

Subsequently, all *S*s received 180 conditioning trials divided into 12 blocks of 15 trials each. Intertrial interval ranged from 6 to 11 sec with a mean of 8.5 sec. Each block contained 3 CS^+ paired with US (with an interstimulus interval of 810 msec), 9 CS^- (3×3 unpaired frequencies), and 3 US unrelated to a warning tone. These 15 trials were randomly intermixed. Half of the *S*s were conditioned to 500 cps and half to 4000 cps tones.

Data analysis

Eyeblink recordings were processed by microcomputer following transmission via an A/D transducer. An eyelid response was defined as a blink equal to or greater than 5 percent of the complete closing of the eyelid, occurring at least 500 msec after CS onset, and prior to US onset.

Results and discussion

The results are summarized in table 2. Regarding eyelid responses, the lack of discrimination learning is apparent: frequency of responses did not increase through trials, and the mean percentage of responses to the CS^+ was very low (18.52%), barely higher than the mean percentage of responses to CS^- (13.88%) ($\chi^2 = 1.70$, n.s.).

The changes of RT remain of interest to check the development of expectancy. The RT data exclude the possibility that the lack of discrimination is due to a failure in the development of expectancy. The statistical analysis [1] showed that the presence of CS^+ had a strong effect on RT ($F(1,115) = 31.01$; $p < 0.01$). The trial type $\times$ block interaction was also significant ($F(11,115) = 3.06$; $p < 0.01$). Mean RT to US alone remained stable, while RT to CS^+US decreased with practice ($F(11,55) = 10.26$; $p < 0.01$), according to significant linear ($F(1,55) = 64.83$; $p < 0.01$) and quadratic ($F(1,55) = 12.99$; $p < 0.01$) trends. This clear-cut discrepancy between conditioning and RT raises problems for an expectancy theory of conditioning. Further comments on this issue are postponed to the general discussion. Here it is only noted that the results do not necessarily invalidate the idea that conditioning depends on US expectancy. Yet US expectancy may be a necessary but not a sufficient prerequisite to obtain conditioning. Experiment 3 aimed to investigate this possibility.

[1] Data from experiments 2 and 3 were submitted to ANOVA through a BASIC program permitting the processing of any combination of between- and within-subject factors, and allowing any type of planned comparison and trend analysis (Perruchet 1982).

Two main characteristics of the experimental design may have prevented the development of conditioning. First, the requirement of a manual reaction to US onset may operate as a masking task, the negative effects of which are well-known (Perruchet 1979, 1980). Yet, it is unlikely that keypressing entirely prevents the appearance of conditioning. In an autonomic classical conditioning arrangement, Dawson et al. (1982) showed that a reaction to a signal presented before, after, or during the CS–US interval did not hamper the development of conditioning. In this last study, the reaction signal differed from the US, which could divert attention from discrimination learning. Hence, if any, it should have caused stronger masking than the present design.

A second possible source preventing conditioning could be the composition of the trial blocks. Only 36 of the 180 trials were CS^+US pairings. The remaining trials were either CS^- or US alone. In particular the occurrence of US alone (e.g. Rescorla 1968) can have a negative effect on conditioning. CS^- and US alone trials have a control function, respectively in relation to conditioning and to RT, but their number may be reduced without much loss of information. Therefore, experiment 3 repeated experiment 2, with a substantial reduction of the CS^- and US alone trials.

Experiment 3

Method

Subjects

Twenty-four paid, right-handed students from psychology classes (7 men, 17 women), with a mean age of 23.25 yrs, served as *S*s. Three additional *S*s were eliminated because of malfunctioning of the instrumentation.

Apparatus and procedure

Apparatus and general procedure was identical to those of experiment 2. One hundred and eighty conditioning trials were presented in 20 blocks of 9 trials each.

Table 2
RTs and percentage of eyelid CRs as a function of trials is experiment 2, for CS^+ US and appropriate control trials (see text). Each value is computed from 36 trials (6 trials per subject × 6 subjects).

	Blocks of trials						Mean
	1–2	3–4	5–6	7–8	9–10	11–12	
RT							
CS^+ US	375	292	282	279	266	230	287.3
US	342	338	374	337	375	364	355
% CRs							
CS^+ US	33.3	16.7	11.1	25	8.3	16.7	18.52
CS^-	16.7	22.2	2.8	16.7	19.4	5.6	13.88

Each block contained 4 CS^+US trials, 4 CS^- trials, and one US alone trial, which were randomly intermixed. The CS were tones of 500 cps and 3000 cps. Tones used as CS^+ for half of the *S*s were used as CS^- for the remaining *S*s, and vice versa.

Results and discussion

Table 3 shows the percentage of conditioned eyeblinks to CS^+ and CS^- on each of two consecutive blocks of trials. A rough examination suggests that eyeblink conditioning occurred. If the expectancies for US in terms of RT are related to the extent of conditioning, a covariation between RT and conditioning should be observed, irrespective of the basis of this variation, i.e. trials or *S*s.

Covariation with trials

Eyeblink responses. The choice of the tones used as CS^+ and CS^- (500 or 3000 cps) had no significant effect ($F(1,22) = 0.284$; n.s.). The effect of trial type (CS^+ vs CS^-) was significant ($F(1,22) = 10.46$; $p < 0.01$), as was the trial type × blocks interaction ($F(19,418) = 2.02$; $p < 0.05$). The number of CS^- responses remained stable while the number of CS^+ responses increased ($F(19,418) = 1.79$; $p < 0.05$) according to a linear trend (F lin $(1,22) = 4.45$; $p < 0.05$; F nonlin $(18,396) = 0.97$; n.s.).

Reaction times. The choice of tone used as CS^+ had no significant effect ($F(1,22) = 1.35$). Table 3 shows mean RT as a function of blocks, both for the US preceded by CS^+ and for US alone. As expected, the presence of CS^+ had a strong effect ($F(1,22) = 170.37$; $p < 0.01$), and the trial type × blocks interaction was also significant (F $(19,418) = 2.13$; $p < 0.05$). Mean RT to CS^+US decreased with practice ($F(19,418) = 12.02$; $p < 0.01$), with significant linear ($F(1,22) = 29.76$; $p < 0.01$) and quadratic ($F(1,22) = 22.60$; $p < 0.01$) trends.

Table 3
RTs and percentage of eyelid CRs as a function of trials in experiment 3, for CS^+US and appropriate control trials. RT to US is the average of 48 measures (2 trials per subject × 24 subjects). Each of the other values is computed from 192 trials (8 trials per subject × 24 subjects).

	Blocks of trials										Mean
	1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	
RT											
CS^+US	322	257	257	243	235	239	227	218	221	226	244.7
US	401	365	354	390	371	366	375	344	376	365	370.9
%CRs											
CS^+US	18.7	33.3	26	33.3	29.7	34.9	43.8	42.7	44.3	42.2	34.9
CS^-	19.3	21.9	25.5	19.8	20.8	16.1	14	10.4	21.9	17.2	18.7

Table 4
Mean RTs as a function of trials for US preceded by CS^+ in experiment 3. "Good" and "bad" conditioners are defined as the extreme quartiles of the distribution of CRs to CS^+. Each value is the mean of 120 RTs (20 trials per subject × 6 subjects).

	Blocks of trials				Mean
	1–5	6–10	11–15	16–20	
"Good" conditioners	291	198	179	166	208.6
"Bad" conditioners	315	289	277	275	288.9

A comparison of the evolution of CR and RT suggests that the quadratic trend discrepancy is due to the fact that RT decreased earlier and faster than CR increased. Differences in RT to US alone and to CS^+US were apparent as early as the first two blocks of trials (although not yet significant: $F(1,121) = 1.21$; n.s.), and RTs at blocks 9–10 approached their terminal level. Conversely, differences between eyelid responses at CS^+ and CS^- appeared gradually, and the number of CRs at blocks 9–10 was still far from its terminal value.

Covariation between subjects

There were considerable individual differences, both for eyeblink (0–72 CRs) and RT (135–380 msec for CS^+US reactions). These differences allow for a test of the hypothesis that the best conditioners are also the fastest responders.

In support of this hypothesis, the product-moment correlation between the number of eyeblink CRs and the RTs to CS^+US was moderately high (-0.45; $p < 0.05$). When the differences between RT to US alone and to CS^+US is used as RT score, the RT/conditioning correlation rises to -0.52.

In order to further refine this relationship, the decline of RT to CS^+US was calculated for the extreme quartiles of the CRs distribution (table 4). "Good" and "bad" conditioners showed pronounced differences: on the last five blocks of trials, mean RT differed by 108 msec. It is not clear how these differences can be attributed to causes other than learning: they appear gradually during the session, and, furthermore, "good" and "bad" conditioners did not differ with respect to their RTs to US alone, the means of which were respectively 336 and 338 msec.

General discussion

Experiment 1 demonstrated that RT to US preceded by CS^+ provides information that closely covaries with the direct rating of CS-generated expectancy for US, irrespective of whether the sources of variation are repetition of trials or subjects. Accordingly, the implementation of the RT task in a paradigm of eyelid conditioning was intended in experiments 2 and 3 to assess the covariation between RT indexed expectancy and conditioning. Conditioning never occurred without an increase in expectancy. Furthermore, between-subjects correlations between CR and RT reached about -0.50 in experiment 3, and the differences in RT between "good" and "bad" conditioners were pronounced. These results are consistent with the notion that US expectancy is a mediator in the awareness-conditioning relation.

Another part of results, however, was not anticipated. Experiment 2 and the trend analysis of mean performances in experiment 3 show unambiguously that CS-generated expectancy for US may improve and elicit substantial reductions of RT to US, without simultaneous conditioning. This implies at least that US expectancy, as operationalised above, is not a sufficient condition for CR growth.

It is possible that mediating processes other than expectancy are involved. Alternatively, expectancy could be the major intervening variable, but the above experiments might have partially failed to provide a suitable setting for its operation. Further analyses of experiments 2 and 3 suggest an interesting specification for this last alternative. RT (and also rating) could be *too* sensitive as indicators of expectancy: they might be affected by even slight increases in the subjective state of expectation, while conditioning might require more sizeable changes in expectancy. The fact that RT starts decreasing before CR even appeared in experiment 3 is obviously consistent with such a view. More significantly, the discrepancy between experiment 2 and 3 may be accounted for by the same assumption. Mean RT to CS^+US was larger (by 43 msec) in experiment 2 where no conditioning appeared, than in experiment 3 where conditioning occurred. It is worth noting that a stable conditioned discrimination appeared in experiment 3 when RT fell under 250 msec (from about block 7–8). This low value was only reached during the last block of trials in experiment 2. Thus, the assumption that an RT of less than about 250 msec is required to match the threshold value of expectancy needed for CR generation, allows a simple account for the findings of both experiments.

Such a post-hoc interpretation is obviously speculative. The issue whether another major factor plays a role, or whether variations in US expectancy fully determine the occurrence and the amount of conditioning requires further investigation.

A final comment is in order. The experiments described here exhibit a better matching of expectancy/conditioning than is usually reported with correlational data (Furedy and Schiffmann 1971, 1973; Schiffmann and Furedy 1977). This difference is probably due to procedural differences concerning either the measure of expectancy used (overt rating vs RT to US) or the reactive system employed (autonomous vs eyelid response), or conceivably a combination of these two. Before this ambiguity is solved, generalisation of the present findings to forward-directed CR other than eyelid responses does not appear warranted.

References

Baer, P.E. and M.J. Fuhrer, 1982. Cognitive factors in the concurrent differential conditioning of eyelid and skin conductance responses. Memory and Cognition 10, 135–140.

Biferno, M.A. and M.E. Dawson, 1977. The onset of contingency awareness and electrodermal classical conditioning: an analysis of temporal relationships during acquisition and extinction. Psychophysiology 14, 164–171.

Bolles, R.C., 1972. Reinforcement, expectancy, and learning. Psychological Review 79, 394–409.

Dawson, M.E. and M.A. Biferno, 1973. Concurrent measurement of awareness and electrodermal classical conditioning. Journal of Experimental Psychology 101, 55–62.

Dawson, M.E. and P. Reardon, 1973. Construct validity of recall and recognition postconditioning measures of awareness. Journal of Experimental Psychology 98, 308–315.

Dawson, M.E., A.M. Schell, J.R. Beers and A. Kelly, 1982. Allocation of cognitive processing capacity during human autonomic classical conditioning, Journal of Experimental Psychology: General 111, 273–295.

Fuhrer, M.J., P.E. Baer and C.O. Cowan, 1973. Orienting response and personality variables as predictor of differential conditioning of electrodermal responses and awareness of stimulus relations. Journal of Personality and Social Psychology 27, 287–296.

Furedy, J.J. and K. Schiffmann, 1971. Test of the propriety of the traditional discriminative control procedure in Pavlovian electrodermal and plethysmographic conditioning. Journal of Experimental Psychology 91, 161–164.

Furedy, J.J. and K. Schiffmann, 1973. Concurrent measurement of autonomic and cognitive process in a test of the traditional discriminative control procedure for Pavlovian electrodermal conditioning. Journal of Experimental Psychology 100, 210–217.

Geller, E.S. and G.F. Pitz, 1970. Effects of prediction, probability, and run length on choice reaction speed. Journal of Experimental Psychology 84, 361–367.

Hinrichs, J.V., 1970. Probability and expectancy in two-choice reaction time. Psychonomic Science 21, 227–228.

Iwama, K. and M. Abe, 1952. Electroencephalographic study of conditioned salivary reflexes in human subjects. The Tohoku Journal of Experimental Medicine 12, 1–64.

Kimble, G.A., 1962. 'Classical conditioning and the problem of awareness'. In: C.W. Eriksen (ed.), Behavior and awareness. Durham, NC: Duke University Press.

King, D.L., 1979. Conditioning: an image approach. New York: Gardner Press.

Maltzman, I., 1977. Orienting in classical conditioning and generalisation of the galvanic skin response to words: an overview. Journal of Experimental Psychology: General 106, 111–119.

Morgenson, D.F. and I. Martin, 1969. Personality, awareness and autonomic conditioning. Psychophysiology 5, 536–547.

Nelson, M.N. and L.E. Ross, 1974. Effects of masking tasks on differential eyelid conditioning: a distinction between knowledge of stimulus contingencies and attentional or cognitive activities involving them. Journal of Experimental Psychology 102, 1–9.

Niemi, P. and R. Näätänen, 1981. Foreperiod and simple reaction time, Psychological Bulletin 89, 133–162.
Pendery, M. and I. Maltzman, 1977. Instructions and the orienting reflex in 'semantic conditioning' of the galvanic skin response in an innocuous situation. Journal of Experimental Psychology: General 106, 120–140.
Perruchet, P., 1979. Conditionnement classique chez l'homme et facteurs cognitifs: 1- Le conditionnement végétatif. Année Psychologique 79, 527–557.
Perruchet, P., 1980. Conditionnement classique chez l'homme et facteurs cognitifs: 2- Le conditionnement moteur. Année Psychologique 80, 193–219.
Perruchet, P., 1982. Programmes de description et d'analyses inférentielles de données expérimentales pour micro-ordinateurs. Informatique et Sciences Humaines 13, 87–101.
Perruchet, P., 1984. 'Dual nature of anticipatory classically conditioned reactions'. In: S. Kornblum and J. Requin (eds.), Preparatory states and processes. Hillsdale, NJ: Erlbaum.
Perry, L.C., D.A. Grant and M. Schwartz, 1977. Effects of noun imagery and awareness of the discriminative cue upon differential eyelid conditioning to grammatical and ungrammatical phrases. Memory and Cognition 5, 423–429.
Rescorla, R.A., 1968. Probability of shock in the presence and absence of CS in fear conditioning, Journal of Comparative and Physiological Psychology 66, 1–5.
Rescorla, R.A., 1975. 'Pavlovian excitatory and inhibitory conditioning'. In: W.K. Estes (ed.), Handbook of learning and cognitive processes, II. New York: Wiley.
Sanders, A.F., 1966. Expectancy: application and measurement. Acta Psychologica 25, 293–313.
Schiffmann, K. and J.J. Furedy, 1977. The effect of CS-UCS contingency variation on GSR and on subjective CS-UCS relational awareness. Memory and Cognition 5, 273–277.
Tarpy, R.M., 1982. Principal of animal learning and motivation. Glenville, IL: Scott, Foresman and Company.
Tolman, E.C., 1932. Purposive behaviors in animals and man. New York: Appleton-Century.
Weisman, R.G., 1977. 'On the role of the reinforcer in associative learning'. In: H. Davis and H.M.B. Hurwitz (eds.), Operant-Pavlovian interactions. Hillsdale, NJ: Erlbaum.