Flavor-evaluative conditioning is unaffected by contingency knowledge during training with color–flavor compounds

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In two experiments, participants inspected and drank a series of drinks, half of which contained sugar and half unpalatable Tween20 (tween). Each sugar and tween drink had a particular flavor and color. Following this training, the flavors of the sugar drinks were assigned higher hedonic evaluations than were those of the tween drinks, even though the participants did not reliably report which flavors had been present in the sugar and tween drinks during training. Moreover, the evaluative conditioning of the flavors was unaffected by whether or not the colors alone had been pretrained to predict the presence of sugar or tween in the drinks. In accord with Baeyens, Eelen, van den Bergh, and Crombez (1990), we conclude that flavor-evaluative conditioning is not mediated by contingency learning.

In a recent review, Lovibond and Shanks (2002) concluded that there is little evidence that human Pavlovian conditioning can be dissociated from knowledge of the contingency between the conditioned stimulus and the reinforcer. However, they identified a study by Baeyens, Eelen, van den Berg, and Crombez (1990) as one that provided some of the best evidence for such a dissociation. This study demonstrated the evaluative conditioning of flavors (De Houwer, Thomas, & Baeyens, 2001) in the absence of any explicit knowledge of the pairings of the flavors and the reinforcers, a finding that led Lovibond and Shanks (2002) to conclude that “efforts to replicate and explore the findings should be given high priority” (p. 20). The purpose of the present experiments was to reexamine the relationship between flavor-evaluative conditioning and contingency knowledge.

During training, Baeyens and his colleagues (1990) arranged for participants to taste flavored and colored drinks, half of which contained unpalatable Tween20 (tween) and the remainder just water. For one group, a given flavor was always present in tween drinks but never in the water drinks, whereas a particular color occurred equally often in the tween and the water drinks. Consequently, for these participants, the flavor was consistently associated with the tween, whereas the color was not. Another group experienced the opposite associations, so that it was the color, but not the flavor, that was consistently associated with the tween.

Following this training, the participants made two judgments. The first was to rate their hedonic evaluation of the flavors and colors when presented alone, whereas the second required them to report retrospectively the flavors and colors of the tween and water drinks. Although Baeyens

and colleagues (1990) reported evaluative conditioning of the flavors, in that the flavors of the tween drinks were assigned negative hedonic ratings, relative to the flavors of the water drinks, the participants could not consistently identify the flavors of the two types of drink. What makes this dissociation particularly compelling is that it did not appear to reflect the relative sensitivities of the evaluative conditioning and contingency knowledge measures. When asked to report the colors of the tween and water drinks, the participants could reliably do so, even though the conditioning procedure did not change their hedonic evaluation of the colors. On the basis of this dissociation, Baeyens et al. (1990) concluded that the evaluative conditioning of the flavors was not mediated by contingency learning.

The purpose of the present study was twofold. The first was to replicate the dissociation between evaluative conditioning and contingency learning for flavors. In doing so, we made two procedural changes. We replaced the water drinks with ones containing sugar, since Baeyens, Crombez, Hendrickx, and Eelen (1995) have shown that this procedure leads to strong differential evaluative conditioning of the flavors of the tween and sugar drinks. In addition, we attempted to make the measuring instruments for the two forms of learning, evaluative conditioning and contingency learning, as similar as possible, so that it was unlikely that any dissociation was due to the relative sensitivity of the measures.

Second, we manipulated whether or not the participants could anticipate which of the drinks contained sugar and which tween during flavor conditioning, in order to determine whether explicit contingency knowledge interacts with flavor-evaluative conditioning. Ever since Kamin (1969)

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first reported blocking, it has been suggested that surprising or unexpected reinforcers bring about stronger conditioning than do expected or predicted ones. Blocking refers to the finding that conditioning to a target cue during compound training is reduced, or blocked, if the other element of the compound has been pretrained as a predictor of the reinforcer. In one way or another, most theories of conditioning (Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1981; but see R. R. Miller & Matzel, 1988) assume that blocking reflects the fact that only surprising or unexpected reinforcers produced sustained conditioning. Blocking occurs because the pretrained element of the compound renders the occurrence of the reinforcer unsurprising or expected and, therefore, attenuates its ability to reinforce conditioning to the target cue.

Although there are a number of demonstrations of blocking in human conditioning, perhaps the most relevant is a recent evaluative-conditioning study by Tobler, O'Doherty, Dolan, and Schultz (2006). During the first stage, one visual stimulus predicted the delivery of a palatable fruit juice reinforcer, whereas another stimulus was nonreinforced. Then, in the second stage, these stimuli were reinforced, each in compound with a different novel target visual stimulus. When the participants were subsequently asked to evaluate the target stimuli, the one trained in compound with the reinforced stimulus was rated as less pleasant than the one trained in compound with the nonreinforced stimulus. Therefore, the presence of the reinforced stimulus during compound training ensured that the juice was predicted, with the consequence that it was unable to sustain evaluative conditioning to the target element of the compound. By contrast, the occurrence of the juice during compound training with the nonreinforced element was unpredicted and, therefore, capable of reinforcing conditioning to the target element.

We used a similar design to investigate the interaction between contingency knowledge and flavor-evaluative conditioning. It should be noted, however, that our purpose was not to determine whether prior evaluative conditioning to the pretrained stimulus blocks evaluative conditioning to the target flavor during compound training. Rather, we used the blocking procedure to render the occurrence of tween and sugar in a drink either expected or surprising on the basis of explicit contingency knowledge, in order to determine whether this contingency knowledge would modulate evaluative conditioning to the flavors.

An illustrative example of the designs of our two experiments is presented in Table 1. During color-flavor training, we used a procedure similar to that in Baeyens et al. (1990), which consisted of presenting drinks that were both colored and flavored, so that the participants first inspected the color of the drink before tasting it. However, we pretrained the colors in order to ensure that by inspecting the color of the drink, the participants should have had a specific expectation about whether the drink contained sugar or tween prior to tasting it. This color pretraining should, therefore, have rendered the actual contents of the drink either fully expected or surprising at the outset of the subsequent color-flavor training.

Table 1
Illustrative Assignment of Flavors and Colors
in Experiments 1 and 2

Color Pretraining			
	$G \rightarrow \text{tween}$		$Y \rightarrow \text{sugar}$
	$B \rightarrow \text{tween}$		$R \rightarrow \text{sugar}$
Color-Flavor Training			
Experiment 1			
Congruent	$4G \rightarrow \text{Ctween}$		$4R \rightarrow \text{Lsugar}$
Incongruent	$4Y \rightarrow \text{Btween}$		$4B \rightarrow \text{Vsugar}$
Experiment 2			
Congruent	$2G \rightarrow \text{Ctween}$	$2B \rightarrow \text{Ctween}$	$2R \rightarrow \text{Lsugar}$ $2Y \rightarrow \text{Lsugar}$
Incongruent	$2Y \rightarrow \text{Btween}$	$2R \rightarrow \text{Btween}$	$2B \rightarrow \text{Vsugar}$ $2G \rightarrow \text{Vsugar}$

Note—Flavors: B, banana; C, chocolate; L, lemon; V, vanilla. Colors: R, red; Y, yellow; G, green; B, blue. The number associated with each type of drink during the color-flavor training refers to the number of times that the drink type was presented during this training.

On each trial of color pretraining, the participants inspected and then drank one of four colored but unflavored drinks. Two of the drinks (e.g., green and blue) contained tween, whereas the other two (e.g., yellow and red) contained sugar. Immediately following this color pretraining, the participants in Experiment 2 received a test of contingency learning, to confirm that they had acquired the appropriate expectations of tween and sugar in the different-colored drinks. This test was omitted in Experiment 1 in case it affected evaluative conditioning during the subsequent training with colored and flavored drinks. However, because the color pretraining was identical in the two experiments, we assumed that the participants had the same expectations at the end of this pretraining in Experiment 1 as they did in Experiment 2.

During this color-flavor training, each drink was both colored and flavored, and again, half of the drinks contained tween and the remainder sugar. We scheduled two different types of drinks: congruent and incongruent ones. For congruent drinks, the participants could anticipate whether or not a drink contained tween or sugar prior to tasting it, because the colors of the tween and sugar drinks were the same during color-flavor training as they were during color pretraining. So, in the examples illustrated in Table 1, seeing the green (G) drink should have produced the expectation that it would contain tween, an expectation that was confirmed when the green chocolate-flavored (C) tween drink ($G \rightarrow \text{Ctween}$) was tasted. Consequently, the chocolate flavor of this drink was paired with a fully predicted tween reinforcer. If flavor-evaluative conditioning depends on whether or not the reinforcer is surprising, little conditioning should have accrued to the chocolate.

In contrast, the colors of the tween and the sugar drinks were reversed across the two stages of training for the incongruent drinks, so that the presence of the sugar and tween in each of these drinks during the color-flavor training should have been unexpected or surprising on the basis of its color. So, again in the examples illustrated in Table 1, seeing the yellow (Y) drink should have produced the expectation that it would contain sugar, an expectation that was disconfirmed when the yellow banana-flavored (B)

tween drink ($Y \rightarrow B$ tween) was tasted. Consequently, the presence of the tween in this drink should have been surprising or unexpected and, therefore, capable of supporting evaluative conditioning to the banana flavor of the drink.

The two experiments differed in the way that the target flavors were paired with pretrained colors during color-flavor training (see Table 1). In Experiment 1, each drink type had a unique flavor and color (e.g., chocolate–green, banana–yellow, etc.). Therefore, in this design, each target flavor was consistently paired with the same pretrained color, a feature that could have contaminated evaluation of the flavor. In human causal learning, Dickinson and his colleagues (Aitken, Larkin, & Dickinson, 2000; Dickinson & Burke, 1996; Larkin, Aitken, & Dickinson, 1998) have shown that such consistent pairings can produce within-compound learning, so that the presentation of one element of the compound retrieves a representation of the other element. As a consequence, the presentation of the flavor alone on test following color–flavor training could have retrieved a representation of the associated color, so that responding to the flavor may have reflected not only the direct conditioning to the flavor, but also responding mediated by the association with the color. There is evidence for such mediated responding in blocking-like procedures from studies of both animal conditioning (Holland, 1980; Rescorla, 1981; Rescorla & Durlach, 1981; Speers, Gillan, & Rescorla, 1980) and human causal learning (Dickinson, 2001).

Within-compound learning can be minimized by ensuring that during compound training, a target cue is not consistently paired with the same pretrained cue (Dickinson & Burke, 1996; Larkin et al., 1998). Table 1 illustrates how we arranged for variable color–flavor pairings in Experiment 2. For example, half of the congruent chocolate-flavored (**C**) drinks were colored green (*G*), and half were colored blue (*B*). Since both these colors were pretrained in tween drinks, the participants should have anticipated that the chocolate drinks were distasteful, which in fact they were. Correspondingly, the vanilla-flavored (**V**) drinks were also either green (*G*) or blue (*B*), so that the participants should have anticipated that these drinks would also contain tween. However, in fact, the vanilla drinks were unexpectedly sweet, thereby ensuring that they were incongruent. As Table 1 illustrates, congruency of the predicted and an actual contents of lemon-flavored (**L**) and banana-flavored (**B**) drinks was manipulated in the same way. Therefore, the design of Experiment 2 manipulated the congruency between the actual contents of the drinks, either tween or sugar, and the contents predicted by their color, while removing any consistent pairing of the color and flavor of the drinks in a way that should have minimized within-compound learning.

In summary, we were concerned with two issues. The first was whether we could replicate Baeyens et al.'s (1990) finding that evaluative conditioning occurs to flavors in the absence of detectable knowledge about the contingencies between the flavors and the sugar and tween. Second, we were concerned with whether evaluative conditioning would be affected by whether the sugar and tween drinks were predicted or unexpected. To the extent that evaluative

conditioning is facilitated by unexpected reinforcers, we predicted greater flavor conditioning by the incongruent drinks than by the congruent ones.

METHOD

Participants and Stimuli

Volunteer undergraduate students from Cambridge University drank a series of colored and flavored solutions in Experiments 1 (10 women and 6 men) and 2 (9 women and 7 men). Each drink consisted of a 3-ml solution presented in a 5-ml transparent plastic cup. The solutions were colored using the following flavorless food colorings (Supercook, Leeds, UK) in the following concentrations in tap water: yellow and blue, 1 ml/l; red, 3 ml/l; green, 6 ml/l. The drinks could also be flavored with one of four colorless flavors (Supercook), which were presented in the following concentrations in tap water: banana, 24 ml/l; chocolate, 16 ml/l; lemon, 25 ml/l; and vanilla, 28 ml/l. The training solutions also contained either 40 g/l of standard domestic granulated sugar or 2 ml/l of Tween20 (polysorbate; Sigma Chemicals, St. Louis).

Procedure

At the outset, each participant was informed that the experiment would investigate the perception of colors and tastes and that he or she would see, taste, and drink a variety of solutions and, sometimes, be asked questions about the drinks. It was explained that some of the drinks would contain sugar and, therefore, be sweet, whereas others would contain a substance called tween, which would make them unpalatable.

Flavor pretest. To provide initial evaluative ratings prior to any training, the participants were asked to rate their liking and disliking for the four flavors in water and the sugar and tween solutions on an evaluative rating sheet. There were six rating scales on the sheet, one for each of the four flavors and for sugar and tween. Each scale displayed the name of a flavor and the units from -5 on the left through 0 in the middle to 5 on the right on a horizontal line. Units 5 and 4 were labeled as *very liked*, unit 0 as *neutral*, and units -4 and -5 as *very disliked*. Each rating started with the presentation of a cup containing the appropriate colorless flavor, which was labeled with the appropriate flavor name. The participants were then asked, on the request “swirl,” to drink the fluid but hold and swirl it around in their mouth for 5 sec. Finally, on the request “swallow,” they were asked to swallow the drink, then rate their evaluation of the flavor on the appropriate scale, and finally, to eat a small piece of bread. The next rating started approximately 30 sec later, and the flavors were evaluated in the following order: banana, chocolate, lemon, vanilla, sugar, and tween.

Color pretraining. All the participants then received three 4-trial blocks. At the start of each trial, the experimenter handed the participant a drink and asked him or her to inspect it on the request “look.” Five seconds later, the participant was asked to follow the requests to “swirl” and “swallow” exactly as in the flavor pretest and then to eat a small piece of white bread. One trial was given approximately every 30 sec, yielding an intertrial interval of about 15 sec.

For half of the participants, the green and blue drinks contained sugar, and the red and yellow drinks tween, whereas the remaining participants received the opposite color–sugar and color–tween pairings (see Table 1). Each of these four drinks occurred once within each of the three trial blocks, with the order of the different drinks varying across blocks. The order of the drinks was the same for half of the participants in each experiment, with the other half receiving the inverse order. Following this color pretraining, the participants in Experiment 1 moved directly on to the color–flavor training. However, in order to determine whether this pretraining had established reliable contingency knowledge for the colors, the participants in Experiment 2 received a color test.

Color test. At the start of this test, the participants in Experiment 2 were given two rating sheets, one for the sugar drinks and one for the tween drinks. The rating sheets were headed with the

question, "Which, if any, of the following colors was SUGAR (or TWEEN) always presented with?" below which were four rating scales, one for each color. For each scale, -5 on the left was labeled with *definitely wasn't*, 0 in the middle with *don't know*, and 5 on the right with *definitely was*. The four scales were labeled *red*, *blue*, *yellow*, and *green*, which reflected the order in which these colors were presented in the test. The participants were asked to complete the relevant rating scale on both the sugar and the tween sheets during the inspection phase of the trial. As a result of this test, each color appeared in either the sugar or the tween drink four times across the color pretraining and test in Experiment 2, but only three times in Experiment 1.

Color-flavor training. Again, half of the drinks contained sugar, and half of them tween, but each drink was now both colored and flavored. The congruency of the colors of the sugar and tween drinks across color pretraining and the color-flavor training was varied. For congruent drinks, the colors of the sugar and the tween drinks were the same in the two stages of training, whereas the colors of the two drinks were reversed across the two training stages for the incongruent drinks. Illustrative examples of the colors and flavors of the congruent and incongruent drinks are shown in Table 1. In both experiments, the color of each sugar and tween congruent drink was the same as the color of a sugar and tween drink, respectively, during color pretraining. By contrast, the color of each sugar incongruent drink during color-flavor training was the same as the color of a tween drink during color pretraining, and the color of each incongruent tween drink during color-flavor training was the same as that of a sugar drink during color pretraining.

Therefore, this design yielded four types of drinks: congruent-sugar, congruent-tween, incongruent-sugar, and incongruent-tween. The counterbalancing of flavors of these four types of drinks across participants was constrained in such a way that the drink types of the same congruency were always chocolate and lemon or banana and vanilla. Within this constraint, however, the flavors of the congruent and incongruent drinks and of the sugar and tween drinks were counterbalanced across participants.

The two experiments differed, however, in the consistency of the pairing of the flavors and colors. In Experiment 1, each drink of a particular flavor always had the same color, so that there was only one example of each of the four types of drink—for example, a congruent green-chocolate tween drink ($G \rightarrow C_{\text{tween}}$) and an incongruent yellow-banana tween drink ($Y \rightarrow B_{\text{tween}}$) (see Table 1). The constraint on the counterbalancing of the colors of the drinks was that drinks of the same congruency were green and red or yellow and blue. Within this constraint, the pairing of the colors and flavors was counterbalanced across participants. The counterbalancing of the color of the sugar and tween drinks during color pretraining ensured that the colors were counterbalanced in this respect during color-flavor training. Each type of drink occurred once within each of four 4-trial blocks in a semirandom order.

The design of Experiment 2 was the same as that of Experiment 1, except in one respect. Whereas the color of a particular flavored drink was always the same in Experiment 1, half of the drinks with a given flavor had one color and the remainder another color in Experiment 2, which yielded two examples of each of the four types of drink and, therefore, eight different drinks. Consequently, as is illustrated in the examples in Table 1, a congruent-tween drink (e.g., green-chocolate [$G \rightarrow C_{\text{tween}}$]) had the same color as an incongruent-sugar drink (e.g., green-vanilla [$G \rightarrow V_{\text{sugar}}$]) and a congruent-sugar drink (e.g., red-lemon [$R \rightarrow L_{\text{sugar}}$]) the same color as an incongruent-tween drink (e.g., red-banana [$R \rightarrow B_{\text{tween}}$]). The counterbalancing of the colors of the different drink types across participants was subject to the same constraints as those in Experiment 1. Each of the eight different drinks occurred once in each of two 8-trial blocks in a semirandom order, which meant that each flavor was presented four times, as in Experiment 1.

Flavor tests. In the tests of learning about the flavors, we decided to assess evaluative conditioning before contingency knowledge. Consequently, immediately following the last color-flavor training

trial, the participants were asked to rerate their evaluations of the four flavors and of the sugar and the tween, using exactly the same procedure as during the flavor pretest. Contingency knowledge for the four flavors was then assessed, using rating sheets and scales that were the same as those used in the color test, except for the instruction to rate flavors and the replacement of color names by the flavor names. We presented each participant with each of the four labeled flavored water drinks in turn to rate using the same procedure as that for the evaluative ratings. They initially rated the contingency between the flavors and the sugar and then the contingency with the tween.

Although it is possible that tasting the flavors alone during the evaluative ratings may have affected contingency judgments about their association with the tween and sugar, we were more concerned to control any possible impact of explicit contingency judgments on evaluative ratings that could have resulted from scheduling the tests in the reverse order. If a participant had just made a judgment that a flavor was consistently associated with the distasteful tween (or palatable sugar), he or she might well have assumed a spurious task demand that the evaluations should then be consistent with the explicit contingency judgments that he or she had just made. By contrast, since the evaluative ratings expressed a personal evaluation of the flavor, there was no apparent demand that subsequent contingency judgments should accord with these evaluations.

RESULTS

The evaluative and contingency ratings were analyzed by mixed ANOVAs, in which the between-participants variable of experiment distinguished between the ratings from Experiments 1 and 2. The within-participants variable of valence distinguished the ratings of the flavors and colors of the sugar and tween drinks, whereas that of congruency distinguished between the flavors of the congruent and incongruent drinks. The reliability of these effects were assessed against a Type I error rate of .05.

Evaluative Conditioning

The analyses of evaluative ratings from the flavor pretest and test yielded neither a significant main effect nor significant interactions involving the experiment variable [$F_s(1,30) < 2.15$], and therefore, the ratings have been collapsed across experiments for presentation.

Figure 1 presents the change in evaluative ratings for the flavors from the flavor pretest ratings to the test ratings. Evaluative conditioning of the flavors occurred during the color-flavor training, in that evaluative ratings for the flavors of the sugar drinks increased, whereas those of the tween drinks decreased. Importantly, however, there was no evidence that the magnitude of these changes was affected by whether the flavors were trained in congruent, as opposed to incongruent, drinks. Although there was a significant main effect of valence [$F(1,30) = 15.06$, $MS_e = 1.76$], the F ratios for both the effect of congruency and its interaction with valence were less than one. Simple effect analyses yielded significant effects of valence for both the congruent [$F(1,30) = 10.45$, $MS_e = 3.89$] and the incongruent [$F(1,30) = 13.11$, $MS_e = 3.22$] drinks.

The interpretation of these changes in evaluative ratings was not compromised by differences in the pretest ratings. Neither the main effect of valence nor the interaction with congruency was significant [$F_s(1,30) < 3.18$] for the flavor pretest ratings. There was, however, a signifi-

Figure 1. Mean change in evaluative ratings of the flavors of the congruent and incongruent sugar and tween drinks from the flavor pretest to the flavor test.

cant main effect of congruency [$F(1,30) = 4.92$, $MS_e = 2.80$], reflecting the fact that, on average, the flavors of the congruent drinks with a mean rating of 0.41 were initially more liked than those of the incongruent drinks, which had a mean pretest rating of -0.25 . Since the flavors had not been trained at this stage and were counterbalanced in their assignment to the congruent and the incongruent drinks, this effect must reflect fortuitous variance in the participants' initial liking for the flavors. However, as evaluative conditioning is assessed by the change in ratings of the flavors of the sugar drinks, relative to the change for the tween drinks, this difference in the absolute liking does not compromise the conclusion that the similar magnitudes of evaluative conditioning were induced by training with the congruent and the incongruent drinks.

Finally, it should be noted that the sugar solution was consistently more liked than the tween solution in both the flavor pretest and the test [$F(1,30) = 541.93$, $MS_e = 3.02$]. Moreover, the contrast between the pretest and the test ratings interacted with valence [$F(1,30) = 19.57$, $MS_e = 0.85$], indicating that the ratings of the sugar and tween diverged across training. The rated liking for the sugar increased from a mean of 2.2 to 3.2 [$F(1,30) = 17.77$, $MS_e = 0.85$], whereas the tween solution became marginally but reliably more disliked [$F(1,30) = 7.05$, $MS_e = 0.50$], with the rating decreasing from a mean of -4.2 to -4.7 .

Contingency Knowledge

In the tests of contingency knowledge, increasing certainty that a sugar or tween drink had a particular flavor or color was registered by more positive ratings for the respective flavors and colors, whereas more negative ratings reflected increasing certainty that the drinks did not have the particular flavor or color. Therefore, contingency knowledge was assessed by contrasting the ratings for each flavor and color for the drink with which they

were paired, either tween or sugar, with the ratings for the drink with which they were unpaired. Contingency knowledge was, therefore, registered by a positive rating for the paired drink and a negative rating for the unpaired drink. This within-participants variable of contingency was entered into an ANOVA along the variable of the type of drink, either tween or sugar.

The color ratings in Figure 2 show that the participants in Experiment 2 acquired good contingency knowledge about the color cues during color pretraining. The paired color cues attracted positive ratings, whereas the unpaired cues received negative ratings. There was a significant effect of contingency [$F(1,15) = 26.44$, $MS_e = 10.14$], which interacted with that of the type of drink, sugar or tween [$F(1,15) = 4.75$, $MS_e = 0.33$], reflecting the fact that the effect of contingency was smaller for the tween drink than for the sugar drink. However, as Figure 2 shows, this difference was small in absolute magnitude, and the effect of contingency was significant for both the sugar [$F(1,15) = 29.29$, $MS_e = 5.30$] and the tween [$F(1,15) = 22.14$, $MS_e = 5.17$] drinks.

In contrast, there was little evidence that the participants learned about the flavors of sugar and tween drinks during color-flavor training. Although, on average, the paired flavors were rated more positively than the unpaired flavors, as Figure 2 shows, the numerical magnitude of the difference was small and unreliable [$F(1,30) = 2.66$, $MS_e = 14.13$]. Moreover, these ratings were close to zero, which reflected the uncertainty about the flavor contingencies. The contingency variable interacted with neither type of drink nor congruency [$F_s(1,30) < 2.56$], except for a three-way interaction with experiment and congruency in the overall analysis [$F(1,30) = 4.48$, $MS_e = 10.18$]. However, separate analyses of each experiment yielded neither

Figure 2. Mean contingency ratings in color and flavor tests as a function of whether the colors and flavors were (paired) or were not (unpaired) present in the sugar and tween drinks.

main effects of contingency [$F_s(1,15) < 3.74$] nor reliable interactions with congruency [$F_s(1,15) < 4.08$], suggesting that the interaction does not compromise the interpretation of the absence of a reliable effect of contingency on the ratings for the flavors.

Finally, we correlated the change in the evaluative ratings for a particular flavor with a measure of the contingency knowledge for that flavor. This measure consisted of the contingency rating for the drink type with which it was paired minus the rating for the drink type with which it was unpaired. If a participant knew whether the flavor was present in a sugar or tween drink, the former rating should be positive, and the latter rating should be negative, so that the magnitude of this difference score should reflect overall contingency knowledge. When these correlations were computed for each of the four different drinks, they ranged from .10 to -.20. The uniformly low values for these correlations confirm that there was no reliable relationship between the contingency and the evaluative ratings of the flavors.

DISCUSSION

The experiments yielded two main findings. First, we replicated Baeyens et al.'s (1990) observation that evaluative conditioning of flavors can occur in the absence of detectable knowledge about the contingency between the flavors and the sugar and tween. Of course, one has to be cautious about interpreting such a single dissociation in terms of a process dissociation (Shanks & St. John, 1994)—in this case, between evaluative conditioning and contingency learning. For example, it is possible that the measure of contingency of knowledge is less sensitive to what has been learned than is the measure of evaluative conditioning. However, in this respect, it is notable that we used the same instrument to measure both evaluative conditioning and contingency learning and that our measure of contingency learning was highly sensitive to the relationship between the colors and the sugar and tween during color pretraining. Therefore, we think that it is unlikely that our failure to detect flavor contingency learning can be attributed to the relative insensitivity of the measure.

Our second finding was the absence of any detectable effect of congruency on evaluative conditioning to the flavors during color-flavor training. The magnitude of flavor conditioning was just as large when the participants could predict whether the drink would contain sugar or tween as when the type of drink was the converse of their expectations. Although one has to be cautious about interpreting a null result, there was no detectable effect of congruency in two experiments with different color-flavor training procedures, one of which (Experiment 2) was designed to minimize any contribution of within-compound learning to evaluative ratings. Furthermore, our failure to detect an effect of congruency should be set within the context of two observations. The first is that we have good evidence from the color test in Experiment 2 that the participants did, in fact, anticipate whether the drink would have contained sugar or tween on the basis of its color. Second, there is extensive evidence that human learning (e.g., Ait-

ken et al., 2000; Dickinson & Burke, 1996) and conditioning (e.g., Tobler et al., 2006) is sensitive to whether or not the reinforcer or the outcome is predicted. Therefore, these results suggest that flavor-evaluative conditioning proceeds independently of contingency knowledge.

The present findings join other failures to detect an interaction between color and flavor in evaluative conditioning. For example, Baeyens, Crombez, De Houwer, and Eelen (1996) interspersed colored and flavored tween drinks with drinks in which the flavor was presented alone to generate an occasion-setting or conditional learning contingency. However, the participants failed to learn a flavor evaluative discrimination based on the presence of the color, in that the evaluations of the flavor were the same in the presence and the absence of the color. On the basis of the original analysis of Martin and Levey (1987), Baeyens and colleagues (see De Houwer et al., 2001, for a recent statement of this idea) proposed that evaluative conditioning reflects the operation of what they call a *referential system*, as opposed to an expectancy or signaling system that mediates contingency learning and standard forms of Pavlovian conditioning. Unlike contingency learning, which is sensitive to predictive redundancy of cues, referential learning is determined solely by the temporal contiguity of the conditioned stimulus, the flavor, and the reinforcer.

However, before accepting that different learning processes mediate evaluative conditioning and contingency learning, we should consider analogous dissociations that have been documented in animal conditioning procedures. Grill and Norgren (1978) reported that the taste of an attractive fluid elicits a set of appetitive oral-facial reactions by rats, such as rhythmic tongue protrusions and mouth movements, whereas distasteful solutions elicit aversive reactions, such as gapes and head shakes. Berridge (2000) noted that these basic patterns of reactions are exhibited by a wide range of species, including human infants, and has argued that they reflect an immediate hedonic evaluation of the flavor. Moreover, these hedonic responses can be modified by conditioning. For example, pairing consumption of sucrose with gastric malaise not only suppresses the subsequent intake of the sucrose, but also shifts the hedonic responses from appetitive to aversive (Berridge, Grill, & Norgren, 1981).

Importantly, the conditioned suppression of intake can be dissociated from the conditioning of the evaluative responses. Pelchat, Grill, Rozin, and Jacobs (1983) reported that the punishment of sucrose drinking by an electric shock led to an equivalent suppression of intake as flavor aversion conditioning, without changing the appetitive evaluative responses to the sucrose. One interpretation of this dissociation is that the punishment was mediated by expectancy or contingency learning, whereas the change in the hedonic responses was mediated by *referential* evaluative learning. In accord with this account, it has long been known that flavor aversion conditioning, like human gustatory evaluative conditioning, is sensitive to the modality of the conditioned stimulus. Aversions reinforced by gustatory malaise are preferentially conditioned to flavors, rather than to nongustatory conditioned stimuli, such as a visual stimulus, whereas the reverse holds for those

reinforced by external somatic consequences (e.g., Garcia & Koelling, 1966; V. Miller & Domjan, 1981).

The important point about this parallel between human evaluative conditioning and rat aversion conditioning for flavors lies with the issue of whether these forms of conditioning engage nonstandard learning processes. It is generally agreed that flavor aversion conditioning shows all the main phenomena of Pavlovian conditioning (Revusky, 1971), including blocking (Gillan & Domjan, 1977), and, therefore, the fact that two forms of conditioning can be dissociated in terms of their effective conditioned stimuli and response measures does not necessarily imply that they recruit learning processes that operate according to different principles. It may well be that evaluative conditioning and contingency learning are mediated by dissociable systems but that both these systems are governed by similar principles. The critical test of whether pretraining a flavor as a predictor of the sugar or tween would block evaluative conditioning to another flavor during compound flavor training remains to be examined.

In conclusion, whether or not human evaluating conditioning and contingency learning are mediated by learning processes with different operating rules, the present experiments provide a further demonstration that flavor-evaluative conditioning proceeds independently of explicit expectations about the sensory and hedonic content of the learning experience.

AUTHOR NOTE

This research was supported by the University of Cambridge Behavioural and Clinical Neuroscience Institute, which is supported by a joint award from the Medical Research Council and the Wellcome Trust. Correspondence should be addressed to A. Dickinson, Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, England (e-mail: ad15@cam.ac.uk).

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(Manuscript received February 21, 2005;
revision accepted for publication June 21, 2006.)