Research Report

EYEBLINK CLASSICAL CONDITIONING AND AWARENESS REVISITED

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Abstract—*Dual-task performance was assessed in 140 adults during eyeblink classical conditioning (EBCC) and one of several secondary tasks (timed-interval tapping, recognition memory, choice reaction time, video viewing). Four groups received paired-EBCC stimulus presentation, and three groups received explicitly unpaired EBCC stimuli. Although the subjects were not told about the conditioning task, they acquired conditioned responses (CRs) at normal levels. Postsession interviews probed participants' awareness of EBCC stimulus contingencies and production of CRs. Reported awareness of paired-EBCC stimulus contingencies and CR production was not related to actual EBCC performance. Twenty-seven percent of the participants receiving explicitly unpaired stimuli reported a stimulus contingency when none existed. The dissociation between awareness and performance provides additional support for the categorization of simple EBCC as a form of nondeclarative learning.*

In some proposed memory systems models, conscious forms of memory are termed declarative or explicit, and unconscious memory is termed nondeclarative or implicit (Schacter, 1992; Squire, 1992). Simple eyeblink classical conditioning (EBCC) has been hypothesized to constitute one form of nondeclarative memory. In the simple delay EBCC paradigm, a neutral conditioned stimulus (CS; e.g., a tone) is followed about half a second after its onset with an unconditioned, blink-eliciting, stimulus (US; e.g., a corneal air puff), with the CS and US overlapping.

The role awareness plays in acquisition of conditioned responses (CRs) has been debated for more than half a century (e.g., Grant, 1973; Kimble, 1962; Spence & Taylor, 1951). In the present study, a dual-task paradigm was used as an alternative means to address this issue. Subjects were simultaneously engaged in paired EBCC and either timed-interval tapping, recognition memory, choice reaction time, or video viewing. These tasks were chosen on the basis of their presumed neurobiological substrates, with tapping and EBCC both engaging the cerebellum. We presumed the cerebellum was not the primary substrate for the other secondary tasks performed with EBCC (see Papka, Ivry, & Woodruff-Pak, 1995). Control subjects were simultaneously engaged in the explicitly unpaired EBCC paradigm and one of the secondary tasks (excluding video viewing). In the unpaired paradigm, either the CS or the US is presented on any given trial, but the two are never paired. This paradigm, therefore, does not involve learning that the stimuli are paired, but it does involve the same sensory and motor activity as paired EBCC (Thompson, 1986).

We have reported comparative conditioning data of these groups elsewhere (Papka et al., 1995), and these data are illustrated in Figure 1. As predicted, the primary result was impaired EBCC during concurrent tapping, but spared EBCC during other concurrent task conditions. In the present report, we assess the role of awareness in EBCC by analyzing data collected through postconditioning interview procedures.

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METHOD

Participants

The participants were 140 young, normal adults ranging in age from 18 to 29 years. All were undergraduate students enrolled in psychology courses at Temple University. They participated to satisfy course requirements or obtain extra credit. Subjects were assigned randomly to one of seven groups, each comprising 20 subjects. Age, natural blinks per minute, eye size, handedness, and gender distribution were comparable across groups.

Apparatus and Procedures

Subjects were tested individually by one experimenter (M.P.), and gave written consent prior to participation. Four groups simultaneously performed paired EBCC and either tapping, recognition, choice reaction, or video viewing; three groups simultaneously performed unpaired EBCC and either tapping, recognition, or choice reaction. The testing session lasted approximately 50 min.

Subjects were seated in front of either a computer or a television monitor, briefed on respective secondary-task procedures, fitted with the EBCC headgear, and then told that they would hear some tones and feel some air puffs in their eyes as they performed the assigned task. Subjects were instructed that despite these occurrences, they should focus their attention on the task assigned. Both tasks were performed simultaneously until 90 paired- or unpaired-EBCC trials were given.

Immediately following the dual-task procedure, subjects were given a semistructured postconditioning interview. Generally, they were asked if and how they responded to the tone and air puff and whether or not they noticed a relationship between the two stimuli. Subjects were also asked whether or not they purposefully blinked or withheld blinks during the session. Other questions addressed subjects' level of motivation during testing and how difficult they perceived the secondary task to be. Responses to questions asked during this interview were later used to evaluate subjects' awareness of the CS-US contingency and CS responding.

EBCC paired and unpaired paradigms

A 500-ms tone (80 dB, 1 kHz) served as the CS, and a 100-ms corneal air puff (5–7 psi) served as the US. Onset of the US occurred 400 ms after onset of the CS in the paired-EBCC paradigm. In the explicitly unpaired paradigm, a CS trial was presented first, followed by a US trial, and then 44 CS and 44 US trials in random order, for a total of 90 trials, as in the paired condition. The apparatus consisted of customized computerized software and hardware.

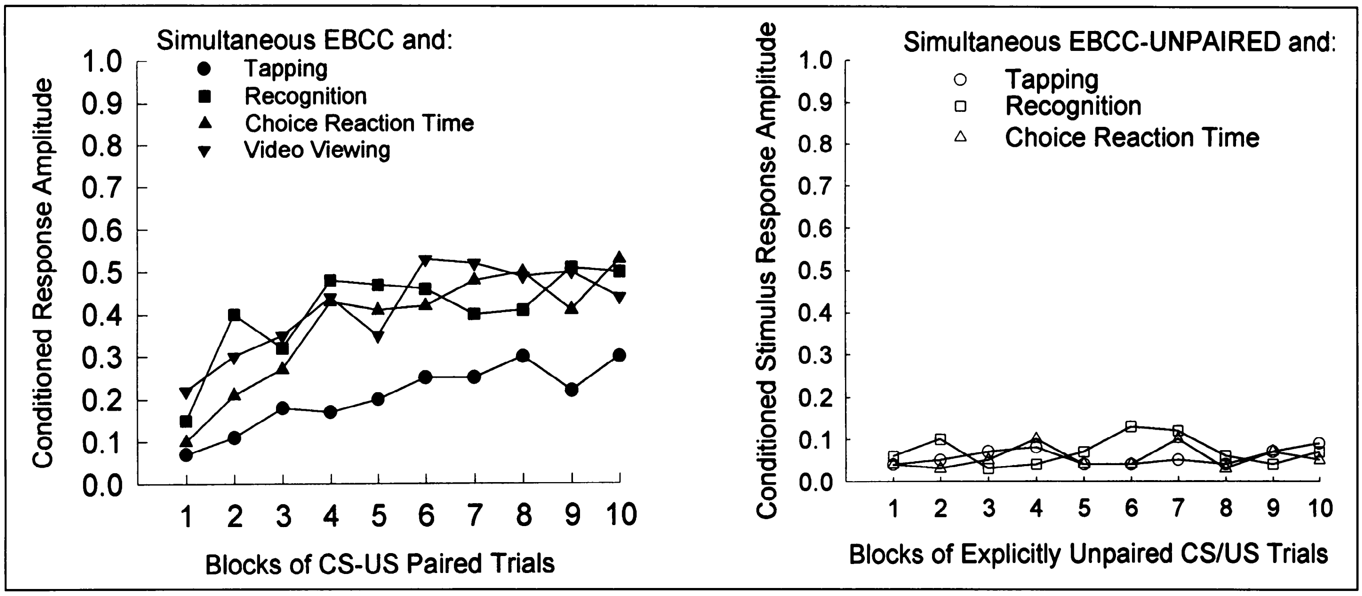

Fig. 1. Conditioned response (CR) amplitude across blocks for subjects in the paired and unpaired paradigms, grouped by secondary task. The left panel shows mean CR amplitude attained by subjects in each paired–eyeblink classical conditioning (EBCC) group (n = 20; N = 80) across 10 nine-trial blocks, each consisting of a trial with the conditioned stimulus (CS) alone, followed by eight trials in which the CS and the unconditioned stimulus (US) were paired. The right panel shows mean response amplitude to the CS for each unpaired-EBCC group (n = 20; N = 60) across 10 blocks of nine explicitly unpaired CS/US trials. The values are expressed as the ratio of CR amplitude to eye size. CR amplitude is measured as the deflection (in millimeters) of the first blink that occurred after the onset of the CS and before the onset of the US (paired-EBCC groups) or within the 400 ms following presentation of the CS (unpaired-EBCC groups). Eye size reflects the vertical distance (in millimeters) between the upper and lower eyelids when the eye was open and fixated straight ahead. Hence, a CR/CS amplitude of 0 represents no blink, and an amplitude of 1.0 represents a maximum blink.

Tapping

Subjects viewed red LEDs in the shape of a "+," each 50 ms in duration and with a 500-ms interstimulus interval. The subjects were instructed to tap in synchrony with the stimulus (see Ivry & Keele, 1989; Ivry, Keele, & Diener, 1988). Once a subject emitted a series of 12 taps, the lights stopped flashing, and the subject's task was to continue tapping at the same rate until a message on the monitor indicated the end of the trial. Completion of each trial occurred once the subject emitted a series of 31 unpaced taps.

Recognition

This task consisted of a battery of word, picture, and digit recognition tests (Wesnes, Simpson, Christmas, Anand, & McClelland, 1989; Wesnes, Simpson, & Kidd, 1988). A 30-item word list was presented first, followed by a 40-item picture list. Word and picture recognition were subsequently tested several times using subtests consisting of 60 words (30 targets, 30 distractors) and 80 pictures (40 targets, 40 distractors), respectively. Digit recognition was tested by the presentation of different series of five digits, immediately followed by a series of 20 test items (5 targets, 15 distractors). The total recognition battery consisted of 12 subtests presented in the same order to all subjects. As each test stimulus was presented, subjects indicated whether the presented stimulus was a target stimulus by pressing a "yes" or "no" response key, as appropriate. The battery and apparatus were designed by CDR, Ltd. (Wesnes et al., 1988, 1989).

Choice reaction time

The test consisted of fourteen 60-trial (30 "yes," 30 "no") choice reaction time subtests (Wesnes et al., 1988, 1989). Stimuli were presented at random as subjects pressed the "yes" or "no" response key, as appropriate, as quickly as possible. The apparatus was the same as that used for the recognition task.

Video

The video, titled "Great Escapes," illustrated wildlife action sequences. Subjects were told that they would be tested later for information contained in the film; however, they were asked only about their engagement and interest in the film.

RESULTS

Reported Awareness of CS-US Contingency

Eighty-four percent of subjects in the paired-EBCC groups said that the tone preceded the air puff, whereas only 16% said that there was no CS-US relationship. In the unpaired-EBCC groups, 65% of participants accurately described no CS-US relationship. However, 27% of participants in the unpaired-EBCC conditions said that the tone preceded the air puff. In addition, 8% described some other CS-US relationship. In the paired-EBCC groups, perception of stimulus contingency did not differ as a function of secondary-task demands, as the frequency distribution of participants reporting the CS-US contingency was comparable across conditions, $\chi^2(3, N = 80) = 0.28$, $p > .05$. Differences in the frequency distribution of reported

CS-US contingency awareness across unpaired-EBCC groups were also nonsignificant, $\chi^2(4, N = 60) = 7.78, p > .05$.

To determine whether the frequency of reported awareness of CS-US contingency differed as a function of the degree of eyeblink conditioning, we divided subjects in the paired-EBCC groups into quartiles based on acquired mean percentage of CRs. Specific descriptions for group assignment and a complete frequency distribution are shown in Table 1. A chi-square analysis revealed no reliable differences, $\chi^2(3, N = 80) = 0.74, p > .05$, indicating that reported awareness of CS-US contingency did not differ as a function of actual EBCC performance. A comparable analysis was not conducted for unpaired-EBCC groups because consistent responding to the CS did not occur in these groups (12% mean response rate to the tone; $N = 60$). Consistent, reflexive blinks to the air puff were observed in unpaired-EBCC conditions, however, and did not differ across groups, $F(2, 57) = 0.17, p > .05$.

In the paired-EBCC groups, the 13 participants who reported that there was no contingency between the CS and US produced 59% CRs, which was slightly better conditioning than the 50% CRs produced by the 67 participants who reported that the tone preceded the air puff. At a minimum, the performance of participants who perceived no stimulus contingency was equal to the performance of participants who did perceive the contingency.

Reported Awareness of Responding to the Tone

As part of the interview, subjects were asked whether they made any responses to the tones. Their responses were categorized as shown in Table 2, which also shows the frequency of each response for the paired- and unpaired-EBCC groups, collapsed across secondary tasks. When these data were analyzed as a function of secondary-task demands, there were no significant differences, $\chi^2(12, N = 80) = 11.13, p > .05$, for paired-EBCC groups and $\chi^2(4, N = 60) = 5.25, p > .05$, for unpaired-EBCC groups. Moreover, awareness of responding to the CS was not related to the percentage of actual CRs as shown by a chi-square analysis using the quartile distribution described earlier, $\chi^2(12, N = 80) = 20.55, p > .05$.

Although paired-EBCC groups did not differ in reported awareness of responding to the tone, the groups did differ in actual responding to the tone, $F(3, 76) = 3.96, p < .05$ (Fig. 1; also see Papka et al., 1995). These findings suggest an uncoupling of mechanisms associated with the production of CRs and awareness of responses. An analysis of variance comparing the percentage of CRs between groups of paired-EBCC subjects categorized by level of awareness of responding to the tone was nonsignificant, $F(3, 62) = 1.25, p > .05$, supporting the finding that acquired percentage of CRs did not vary as a function of reported awareness of responding to the CS. These results are illustrated in Figure 2. Because of the low percentage of

Table 1. *Reported awareness of the contingency between the tone and air puff for subjects in the eyeblink classical conditioning paradigm, grouped by acquired mean percentage of conditioned responses (CR%)*

Mean CR% grouping	Frequency of response: No relationship	Frequency of response: Tone preceded air puff	Total
CR% < 25	1	13	14
25 ≤ CR% < 50	3	17	20
50 ≤ CR% < 75	6	25	31
CR% ≥ 75	3	12	15
Total	13	67	80

Table 2. *Reported awareness of responding to the conditioned stimulus*

Reported response	Condition: Paired (n = 80)	Condition: Unpaired (n = 60)
"I didn't respond in any way."	32 (40%)	56 (93%)
"I expected/waited for the puff."	10 (13%)	2 (3%)
"I blinked reflexively."	20 (25%)	2 (3%)
"I blinked on purpose."	14 (18%)	0 (0%)
"Sometimes I blinked on purpose."	4 (5%)	0 (0%)

Note. Frequency of each response is reported, with the approximate percentage in parentheses.

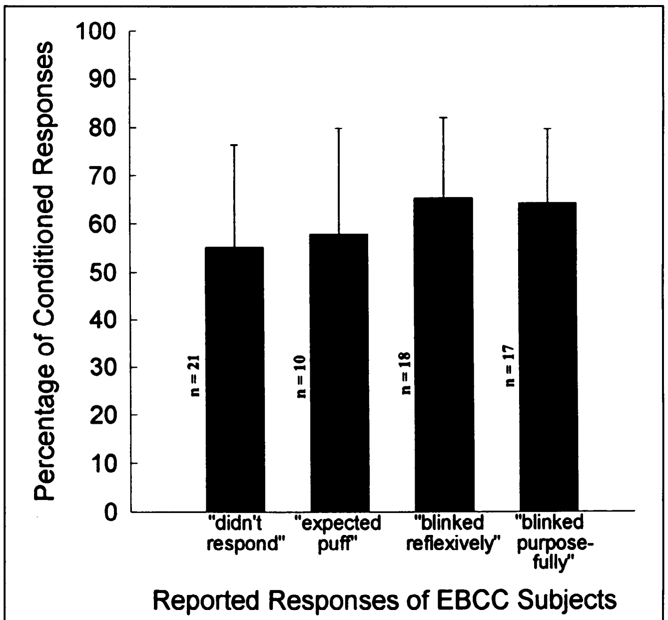

Fig. 2. Mean percentage of conditioned responses for subjects in the paired–eyeblink classical conditioning (EBCC) groups as a function of reported awareness of responding to the tone. Subjects who claimed to have "blinked on purpose" or to have "sometimes blinked on purpose" (see Table 2) were grouped together in the "blinked purposefully" category. Subjects who did not reach a criterion of 25% conditioned responses are excluded (n = 14). Error bars represent standard deviations.

responding in unpaired-EBCC conditions, statistical analyses were not appropriate.

Secondary-Task Performance

If subjects in the paired-EBCC groups were consciously attending to EBCC parameters during conditioning, deficient secondary-task performance relative to performance of unpaired-EBCC subjects might be expected; however, this was not the case. Separate analyses of variance revealed essentially no differences between paired- and unpaired-EBCC groups on secondary tasks, $p > .05$ (see Papka et al., 1995). Furthermore, neither simultaneous nor unpaired EBCC interfered with subjects' ability to attend to secondary tasks adequately; subjects' performance on these tasks was comparable to the performance of control subjects in other, single-task studies (Ivry & Keele, 1989, for tapping; C. Pincock, Cognitive Drug Research, Ltd., personal communication, October 1995, for the recognition and choice reaction time batteries).

It cannot be ascertained whether subjects switched attention from one task to the other during testing because subjects were not directly questioned about this during the postconditioning interview. However, none of the subjects voluntarily mentioned using such a strategy. Instead, some subjects reported trying to find a relationship between the two tasks. For example, one subject said she "was trying to find a relationship between the tone and the movie"; another subject thought "the tone [in the tapping task] symbolized the end of the trial"; still another proposed that the "tone and air puff had to do with right and wrong answers."

DISCUSSION

In accordance with the findings of previous studies, these results indicate that EBCC performance is not related to awareness of CS-US contingency (e.g., Grant, 1973; Kimmel, 1988) or to awareness of responding to the CS (Frcka, Beyts, Levey, & Martin, 1983; Kimble, 1962; McAllister & McAllister, 1958; Woodruff-Pak & Finkbiner, 1995). Approximately 40% of subjects in the paired-EBCC groups claimed that they did not respond to the tone in any way, even though the majority produced a high percentage of CRs. Approximately 25% of paired-EBCC subjects who were aware of responding to the CS also said that the response was not purposeful, but reflexive, or "subconscious." It is not clear whether these subjects were aware of their eyeblink response at the time of learning or whether their perceptions were influenced by the postconditioning interview, which became more suggestive through the progressive series of questions. Approximately 93% of subjects in the unpaired-EBCC groups accurately identified having not responded to the tone, and 3% said that they responded reflexively. Thus, it is clear that some of the subjects did become aware of the contingency in the paired-EBCC groups. However, the level of awareness was not related to the degree of conditioning.

An interesting and unexpected finding was that 27% of subjects in the unpaired-EBCC control conditions erroneously reported that the tone preceded the air puff. This considerable false-positive rate may indicate that, upon entering the experimental situation, subjects expected, and even looked for, a relationship between stimuli. For example, one subject "assumed there was a relationship, but didn't know what it was." Also, many subjects did not realize that they were actually engaged in two different tasks, and tried to find a relationship between the two. Because the first trial of the unpaired-EBCC paradigm was a tone and the second trial an air puff, subjects looking for a relationship between stimuli may have been led to believe that the tone preceded the air puff.

Another proposed explanation for the notable false-positive rate in the unpaired-EBCC conditions is that some subjects may have recently learned about classical conditioning and applied this knowledge to the experimental situation. However, this possibility cannot fully account for the observed results because subjects ranged in their level of psychology education and in the time during the semester that they were tested. A more likely alternative is that the bias reflects the tendency of people to rely on confirmatory evidence rather than disconfirmatory evidence (e.g., Wason & Johnson-Laird, 1972). For example, if the tone and air puff occurred in close proximity a few times, a subject might develop the hypothesis that there is a relationship between these two events and be reluctant to abandon this hypothesis despite subsequent, copious disconfirming evidence.

The false declaration of a CS-US relationship among subjects in unpaired-EBCC control conditions also may suggest that questions asked during postconditioning interviews persuade subjects to "find" a relationship between stimuli even when one does not exist. Some subjects in the unpaired-EBCC groups seemed perplexed when asked if there was a relationship between the tone and the air puff, but then reported that there was, in fact, a relationship between the two. Although some paired-EBCC subjects readily identified the CS-US contingency, others seemed to recognize the contingency only when specifically asked about it.

Precise measurement of the awareness construct has proved to be quite difficult. Shanks and St. John (1994) argued that subjects' inability to articulate verbally what they have learned, despite successful task performance, is not sufficient evidence of unconscious learning, and may simply reflect differences in measurement sensitivity. Measurement of subjects' degree of awareness during conditioning procedures is equally problematic. Baeyens, Eelen, and Van den Bergh (1990) found that self-reported awareness of stimulus relationships in postconditioning procedures was 18% when interviews occurred only after conditioning, but 77% when subjects also gave estimates of awareness during acquisition.

In accord with previous studies (e.g., Frcka et al., 1983; Spence & Taylor, 1951), we observed that reported awareness of CS-US contingency was not related to better performance or to knowledge of how to respond. The majority of subjects in the paired-EBCC groups (84%) were reportedly aware of the CS-US contingency, but only 48% claimed to have blinked, either reflexively or purposefully, to the tone. Thus, simply being aware of the CS-US contingency did not inform participants on how to respond. Furthermore, awareness of CS-US contingency did not facilitate EBCC performance, as subjects who attained higher CR percentages were no more aware of stimulus contingencies than other subjects.

The different secondary tasks seemed to require different levels of attention and engagement. Although subjects' perceptions of, or opinions about, secondary-task difficulty were not measured quantitatively in the present study, subjects' qualitative comments following the experimental procedure suggested that the recognition task was most engaging, followed by video viewing; choice reaction time and tapping were regarded as more monotonous. Nonetheless, EBCC performance did not vary as a function of the difficulty of the secondary task

(Papka et al., 1995). Collectively, the results suggest strongly that simple EBCC is an unconscious, nondeclarative task, because awareness of parameters, procedures, and learning were not related to, or necessary for, high levels of performance.

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