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I Think, Therefore Eyeblink: The Importance of Contingency Awareness in Conditioning

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Abstract

Can conditioning occur without conscious awareness of the contingency between the stimuli? We trained participants on two separate reaction time tasks that ensured attention to the experimental stimuli. The tasks were then interleaved to create a differential Pavlovian contingency between visual stimuli from one task and an airpuff stimulus from the other. Many participants were unaware of the contingency and failed to show differential eyeblink conditioning, despite attending to a salient stimulus that was contingently and contiguously related to the airpuff stimulus over many trials. Manipulation of awareness by verbal instruction dramatically increased awareness and differential eyeblink responding. These findings cast doubt on dual-system theories, which propose an automatic associative system independent of cognition, and provide strong evidence that cognitive processes associated with awareness play a causal role in learning.

Keywords

eyeblink conditioning, awareness, learning, attention

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The idea that humans possess multiple dissociable learning systems is widely endorsed by contemporary psychologists and neuroscientists. In particular, associative learning is often attributed to an automatic, unconscious link-based mechanism, and humans are thought to share this mechanism with other animals (e.g., McLaren et al., 2014; Squire, 2004). At the same time, humans are said to be uniquely capable of learning associations consciously, through a separate, symbol-based cognitive system. Such dual-system theories predict that learning should occur in the absence of awareness, especially when circumstances are unfavorable for learning through the cognitive system. In turn, these theories form the prototype for dual-system theories in a wide range of domains, including reasoning (e.g., Evans, 2008), judgment (e.g., Kahneman, 2011), decision making (e.g., Dijksterhuis & Aarts, 2010), and attitude formation (e.g., Olson & Fazio, 2001). Accordingly, it is important to critically examine the assumption that associative learning can occur unconsciously; overturning this assumption would have far-reaching consequences for dominant theories in many domains in psychology.

Pavlovian eyeblink conditioning is a cardinal example of associative learning that has been proposed to be independent of conscious knowledge (Squire, 1994). In this procedure, an initially neutral stimulus, such as a tone or picture (the conditioned stimulus, or CS), comes to elicit an anticipatory eyeblink response (the conditioned response, or CR) as a result of being paired closely in time with an airpuff to the eye (the unconditioned stimulus, or US). In a differential-conditioning design, a second, control CS is presented but is not paired with the US. Squire and his colleagues (Clark & Squire, 1998, 1999; Smith, Clark, Manns, & Squire, 2005) have reported that

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delay eyeblink conditioning, in which the CS overlaps the US in time, is uncorrelated with conscious awareness of the CS-US relationships (i.e., *contingency awareness*). However, studies of delay conditioning in a number of other laboratories, including our own, have found evidence for a strong correlation between conditioning and contingency awareness (Lovibond, Liu, Weidemann, & Mitchell, 2011; Ross & Nelson, 1973; Weidemann & Antees, 2012). More generally across a wide range of conditioning procedures, there is a close correspondence between conditioning and awareness, contrary to the predictions of dual-system theories (Lovibond & Shanks, 2002).

However, these studies have typically assessed the relationship between conditioning and awareness passively. The finding of a correlation suggests that these constructs are related, but it does not necessarily indicate that awareness is causal. Perhaps the correlation exists because two parallel learning systems reach the same conclusion from the same data (McLaren et al., 2014). A stronger test of the causal role of awareness would be a design in which awareness is experimentally manipulated. One such manipulation is distraction, typically accomplished by providing misleading instructions or by using an attention-demanding secondary task. This approach relies on the assumption that distraction will selectively impair the cognitive system and hence awareness (e.g., Clark & Squire, 1999). If CRs derive from the cognitive system, they too should be impaired; if, however, they derive from an independent link-based system, they should be unaffected.

Distraction manipulations vary in their effectiveness and do not always reduce or prevent contingency awareness (e.g., Carter, Hofstötter, Tsuchiya, & Koch, 2003; Clark & Squire, 1999). However, when distraction has been found to be effective in reducing awareness, it has usually also reduced the development of CRs. This pattern has been shown in electrodermal conditioning (Dawson & Biferno, 1973), startle modulation (Purkis & Lipp, 2001), evaluative conditioning (Kattner, 2012; Pleyers, Corneille, Yzerbyt, & Luminet, 2009), and eyeblink conditioning (Ross & Nelson, 1973). Furthermore, when awareness has been assessed on a trial-by-trial basis through US expectancy ratings, the development of CRs has been shown to align temporally with the development of conscious knowledge (Dawson & Biferno, 1973; Purkis & Lipp, 2001; Weidemann & Antees, 2012; Weidemann, Best, Lee, & Lovibond, 2013).

Taken at face value, these results are inconsistent with the predictions of dual-system theories; however, it could be argued that the distraction manipulation interferes not only with the cognitive system but also with the associative-link system. In particular, it is possible that by reducing attention to the CS or the US (or both), distraction impairs the development of CRs (e.g., Livesey & Harris, 2009). The idea that attention is required for learning is a feature of many associative theories (e.g., Kruschke, 2003; Mackintosh, 1975; Pearce & Hall, 1980). Accordingly, in the present research, we sought to manipulate awareness of the CS-US relationship through an instructional manipulation while maintaining attention to both the CS and the US. We used delay eyeblink conditioning because the strongest claims for unconscious conditioning have been made for this type of learning (e.g., Squire, 2004). We used a differential design in which one stimulus (the CS+) was paired with the US and the other (the CS−) was not, to provide a within-subjects control for learning.

To ensure that participants were attending to both the CSs and the US, we required them to make responses contingent on the presentation of these stimuli. To reduce awareness of the relationship between the CS+ and the US, we used a dual-task procedure inspired by a similar manipulation developed by Aczel (2010). Responses to the CSs and the US were initially trained separately in two distinct reaction time tasks. The tasks were then alternated during the conditioning phase such that there was a predictive relationship between the CS+ and the US across tasks. All participants performed exactly the same tasks, and we manipulated awareness by controlling how much information we provided about the CS-US relationship. If conditioning is an automatic process that occurs whenever an attended CS is presented in a predictive relationship to an attended US, we should see evidence of conditioning regardless of instruction and awareness. However, if awareness is causal, then instructions that draw attention toward or away from the CS-US relationship (as opposed to the CS and US themselves) should modulate conditioned responding, and this effect should be mediated by contingency awareness.

Method

Participants

The participants were 80 students (mean age = 22.5 years, age range = 18–36 years; 56 women and 24 men) from the University of New South Wales who were either paid $10 (Australian) for a half hour of participation or received credit toward a course requirement. There were 20 participants in each of the four experimental groups. We based our sample size on the sample sizes of two studies in which distraction was used to manipulate awareness in differential-delay eyeblink conditioning (Clark & Squire, 1998; Ross & Nelson, 1973). This sample size yielded greater than 80% power to detect group differences of the size we had previously observed in studies of awareness in eyeblink conditioning (e.g., Lovibond et al., 2011). Data from an additional 23 (consecutive) participants were discarded because of a malfunction in the airpuff-delivery system; we continued to collect data until we had 20 participants in each group. The experiment was approved by Human Research Ethics Advisory Panel D at the University of New South Wales.

Materials

The CS stimuli were four colored geometric shapes (a blue star, a yellow diamond, a green square, and a red circle) presented on a gray background in the center of a computer monitor. The shapes were approximately 5.5 cm across, subtending 5.5° of visual angle at an approximate viewing distance of 57 cm. The US was a 100-ms, 15-psi puff of air, as measured at the point of release via an electronically controlled pressure regulator. The puff was delivered via 2.5 m of flexible plastic tubing terminating in a 1-mm nozzle. The tubing was attached to an adjustable arm fitted to the head mount of a welder's mask, and the nozzle was adjusted so that it was approximately 1.5 cm from the participant's left eye. A second outcome stimulus was provided by an 80-dB, 1000-Hz tone presented for 100 ms via headphones (HD650; Sennheiser Electronik, Wedemark, Germany). Eyeblinks were recorded using a custom-built infrared emitter and sensor that was attached alongside the airpuff nozzle.

A box with five buttons on it was positioned on the table in front of the participants. The extreme right button (Button 5) was labeled "TONE" and was used in the go/no-go task. The extreme left button (Button 1) was labeled "SAME" and was used in the one-back task. Stimulus presentation and recording of the eyeblink and button-press responses were carried out using LabVIEW experimental control software (National Instruments, Austin, TX) running on a desktop PC.

Procedure

Participants were randomly assigned to one of four groups. For three of the groups (the informed group, the relational group, and the uninformed group), there was a predictive relationship between the shapes and the stimuli, such that one shape (the CS+) was always followed by the airpuff, and the other three shapes (the CS−s) were always followed by the tone. The only difference among these three groups was in the instructions that they were given at the beginning of the conditioning stage: The uninformed group was given no information about relationship between the two tasks, the relational group was told that there was a relationship between the two tasks but not what the relationship was, and the informed group was told that a particular shape predicted the occurrence of the airpuff. For the final group (the random group), there was no predictive relationship between the shapes and the airpuff or tone stimuli, and they were provided with no information about the presence or absence of a relationship.

All participants were told that they were taking part in an experiment that assessed their ability to switch between tasks. They were first trained on a go/no-go task (Fig. 1a). During this task, participants were presented with a series of tones and airpuffs; there was an interval of 2,650 ms from the onset of one stimulus to the onset of the next. Participants were instructed to press button 5 when the stimulus was a tone and to withhold their response when the stimulus was an airpuff. During the initial training on this task, participants were presented with 80 trials (60 trials with tones and 20 trials with airpuffs). Trial presentation was pseudorandom; airpuff trials were never presented consecutively.

The second task participants were trained on was a one-back task (Fig. 1b). In each trial, a single shape, selected from a set of four different shapes, each of a different color, was presented on the computer monitor. There was an interval of 2,650 ms from the onset of one stimulus to the onset of the next. Participants were instructed to press Button 1 whenever the shape was the same as in the previous trial. Each shape was presented for 1,350 ms. During the initial training on this task, there were 80 trials (20 of each shape); 20 of these trials were repetitions of the previous trial and therefore required a button-press response.

In the combined phase, participants were asked to perform both tasks simultaneously. The tasks were combined such that the conditioning manipulation was implemented across the tasks (Fig. 1c). The colored geometric shapes were presented for 1,350 ms every 2,650 ms. In the last 100 ms of each shape presentation, either the tone or the airpuff was presented such that the offset of the shape and the offset of the tone or airpuff coincided. During the combined phase, 240 trials were arranged in six 40-trial blocks; a trial was defined as a shape followed by an outcome—either a tone or an airpuff. In each 40-trial block, there were 10 presentations of each shape, 10 presentations of the airpuff, and 30 presentations of the tone (requiring the go/no-go button to be pressed). Of the 40 shape presentations, 10 were repetitions of the previous shape (requiring the one-back response button to be pressed). Airpuff trials were never presented consecutively.

For the random group, the number of airpuffs and tones presented was the same as in the other groups, but shape was not predictive of whether the tone or the airpuff would occur. The timing of the airpuff in the random group was the same as for the other three groups. For the other three groups, the airpuff was always presented

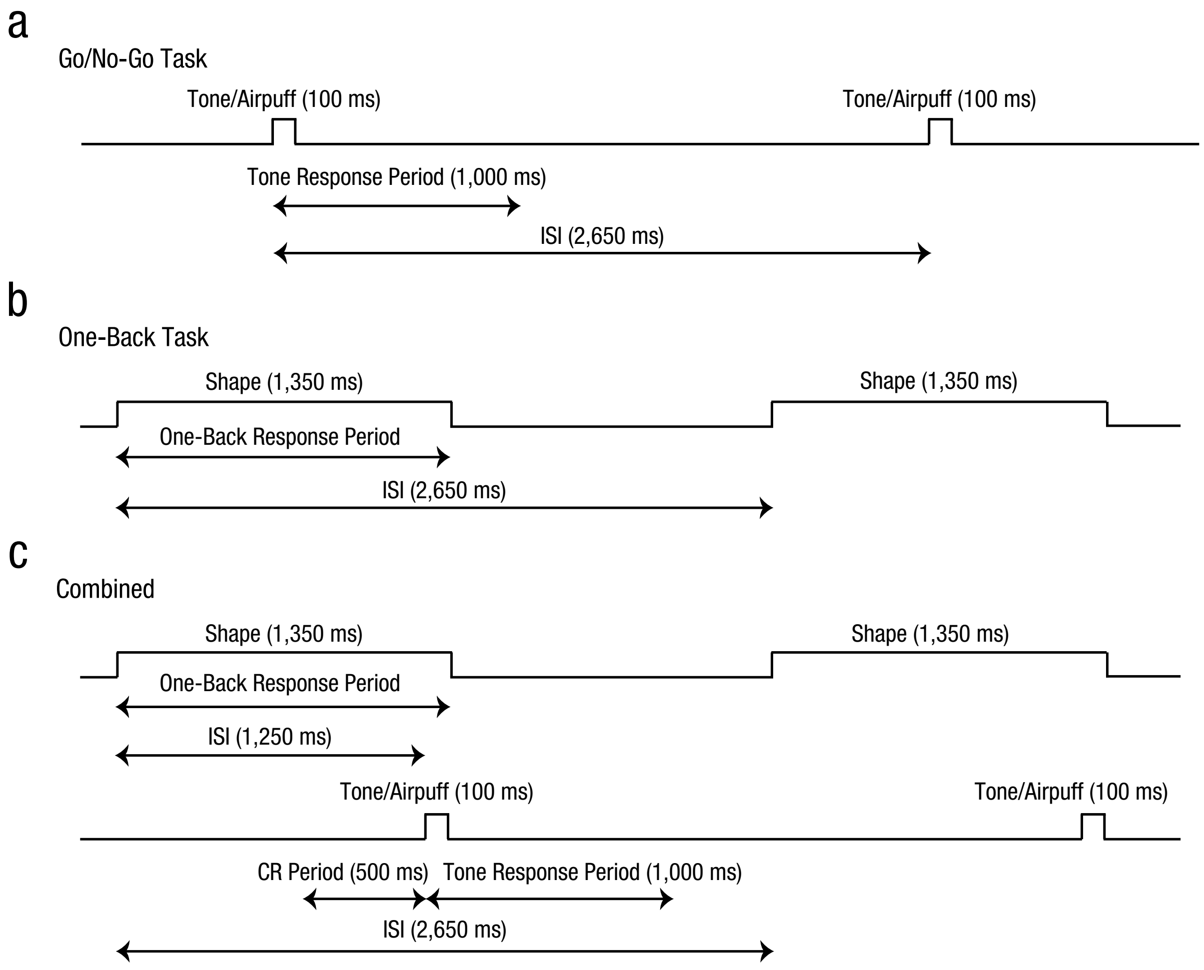

Fig. 1. Temporal arrangement of cues and response periods used in the three different phases of the experiment. In the go/no-go task (a), participants were presented with either a tone or an airpuff every 2,650 ms and were required to press Button 5 on tone trials only. In the one-back task (b), participants were presented with one of four different shapes, each of a different color, every 2,650 ms and were required to press Button 1 if the shape was the same as on the previous trial. In the combined phase (c), the two tasks were presented in an interleaved fashion. Trials commenced with a shape, which was followed 1,250 ms later by a tone or airpuff; the button-press requirements were the same as in the other tasks. In three groups (the informed group, the relational group, and the uninformed group), a conditioning contingency was embedded in the trial sequence such that one shape consistently predicted the occurrence of the airpuff, whereas the other three shapes predicted the tone. In the random group, the shapes did not differentially predict the airpuff or tone. The conditioned-response period (CR period) is the interval during which an eyeblink was classified as a conditioned response. ISI = interstimulus interval.

with one particular shape (the CS+), and the tone was presented with the other three shapes (the CS–s). In these groups, the shape that predicted the airpuff was counterbalanced among participants. The random and uninformed groups were given no information about relationship between the two tasks and so were left to believe that the tasks were unrelated to each other (which was true for the random group). The relational group was told that there was a relationship between the two tasks and that working out this relationship would help them in performing both tasks. The informed group was told which particular shape predicted the occurrence of the airpuff (e.g., the blue star always comes before the airpuff).

After the combined phase, participants were given a short questionnaire about the conditioning relationships that had been embedded within the combined phase. This questionnaire started with open-ended questions about the relationship between the shapes and the airpuffs and tones, progressed to more specific questions about how often each shape was accompanied by the airpuff, and concluded with a forced-choice question about which shape was most often accompanied by the airpuff. Participants who indicated knowledge of the predictive relationship between the CS+ shape and the airpuff in the open-ended question, or who chose the correct shape in the forced-choice question, were classified as contingency aware; those who did not were classified as unaware.

Scoring and analysis

An eyeblink was defined as a CR if it occurred between 750 and 1,250 ms after CS onset (i.e., in the 500-ms interval before the onset of the airpuff or tone). In addition, to be scored as a CR, the amplitude of the blink had to be at least 20% of that participant's maximum blink amplitude in response to the first five presentations of the airpuff during the combined phase. Percentage CR scores for the CS+ and the CS−s were calculated from the percentage of trials on which a CR was recorded in each block of 40 trials (10 CS+ trials and 30 CS− trials) for each participant.

We eliminated from the analysis any trial on which the eyeblink commenced more than 300 ms before the airpuff, persisted until the end of the airpuff presentation, and showed a magnitude of greater than 70% of the mean unconditioned-response magnitude recorded on the first five trials of the conditioning phase. These early-onset and high-magnitude responses are claimed to be indicative of voluntary responding intended to avoid the airpuff (Spence & Ross, 1959). Although this method of identifying voluntary responses has been questioned (Gormezano, 1965), it is routinely used in human eyeblink-conditioning experiments, particularly if instrumental responding might inflate the relationship between awareness and conditioning (e.g., Clark & Squire, 1998; Lovibond et al., 2011; Weidemann & Antees, 2012; Weidemann et al., 2013). The filtering of voluntary responses was carried out with a computer algorithm using the criteria described.

We used a multivariate, repeated measures model and a set of planned contrasts to analyze the eyeblink data (O'Brien & Kaiser, 1985). In between-subjects contrasts, we compared the uninformed group with the random group (to test whether there was any differential responding in the uninformed participants) and with the informed group (to test the impact of the instructional manipulation). We also compared the relational group with the informed group and with the uninformed group. In within-subjects contrasts, we tested trial type (CS+ trials vs. the average across trials with any of the three CS−s) and linear trend across blocks of trials. All interactions were also tested. For each contrast, we calculated the corresponding standardized 95% confidence interval (CI) around the standardized effect-size estimate using the procedure described by Bird (2002).

Results

The levels of accuracy on the go/no-go and one-back tasks during both initial training and the combined phase were close to ceiling and were not significantly different among the four different groups. The manipulation of awareness as a function of group was successful in that all 20 participants in the informed group were classified as aware, 16 of 20 in the relational group were classified as aware, and only 9 of 20 in the uninformed group were classified as aware, $\chi^2(2, N = 60) = 16.53, p < .001$.

The primary data of interest were the eyeblink CRs during the combined phase. Figure 2a reveals that the instructional manipulation of contingency knowledge had a strong impact on whether participants responded differentially to CS+ and CS− trials. The informed group showed large differences in responding to CS+ trials versus CS− trials beginning with the first block of trials. Evidence for differential responding emerged in the relational group over the course of training, and the uninformed group showed little evidence of differential responding. The contrast analysis confirmed the reliability of these patterns.

There was a main effect of CS type (CS+ vs. CS−) averaged across groups and blocks, $F(1, 76) = 42.58$, $p < .001$, 95% CI for the difference between CS types = [0.29, 0.54], which demonstrates overall conditioning to the CS+. There was a significant interaction of CS type and the contrast between the uninformed and informed groups, which reflects the fact that the instruction given to the informed group greatly increased the degree to which participants in this group differentiated between the CS+ and the CS−, $F(1, 76) = 17.18$, $p < .001$, 95% CI = [−1.11, −0.39]. However, CS type did not interact significantly with the contrast between the uninformed and random groups; the uninformed group showed no better differentiation than the random group, $F(1, 76) = 1.29$, $p = .26$, 95% CI = [−0.16, 0.57]. Further interactions with CS type indicated that the relational group showed weaker differentiation than the informed group, $F(1, 76) = 11.29$, $p = .001$, 95% CI = [−0.97, −0.25], and no better differentiation than the uninformed group, $F < 1$. However, all of these effects were averaged over blocks. Three-way interactions with linear trend across blocks confirmed that the relational group showed the greatest acquisition of differentiation between the CS+ and the CS−s across training compared with both the uninformed group, $F(1, 76) = 5.84$, $p = .018$, 95% CI = [0.05, 0.49], and the informed group, $F(1, 76) = 8.54$, $p = .005$, 95% CI = [0.10, 0.55].

To determine whether the differences between experimental groups were mediated by contingency awareness, we pooled the participants from the uninformed and relational groups and divided them into groups of aware and unaware participants (Fig. 2b). The clear evidence of differential responding among the aware participants increased across blocks and was confirmed by a main effect of CS type, $F(1, 24) = 25.05$, $p < .001$, 95% CI = [0.20, 0.63], which interacted with linear trend over blocks, $F(1, 24) = 11.20$, $p = .003$, 95% CI = [0.07, 0.54].

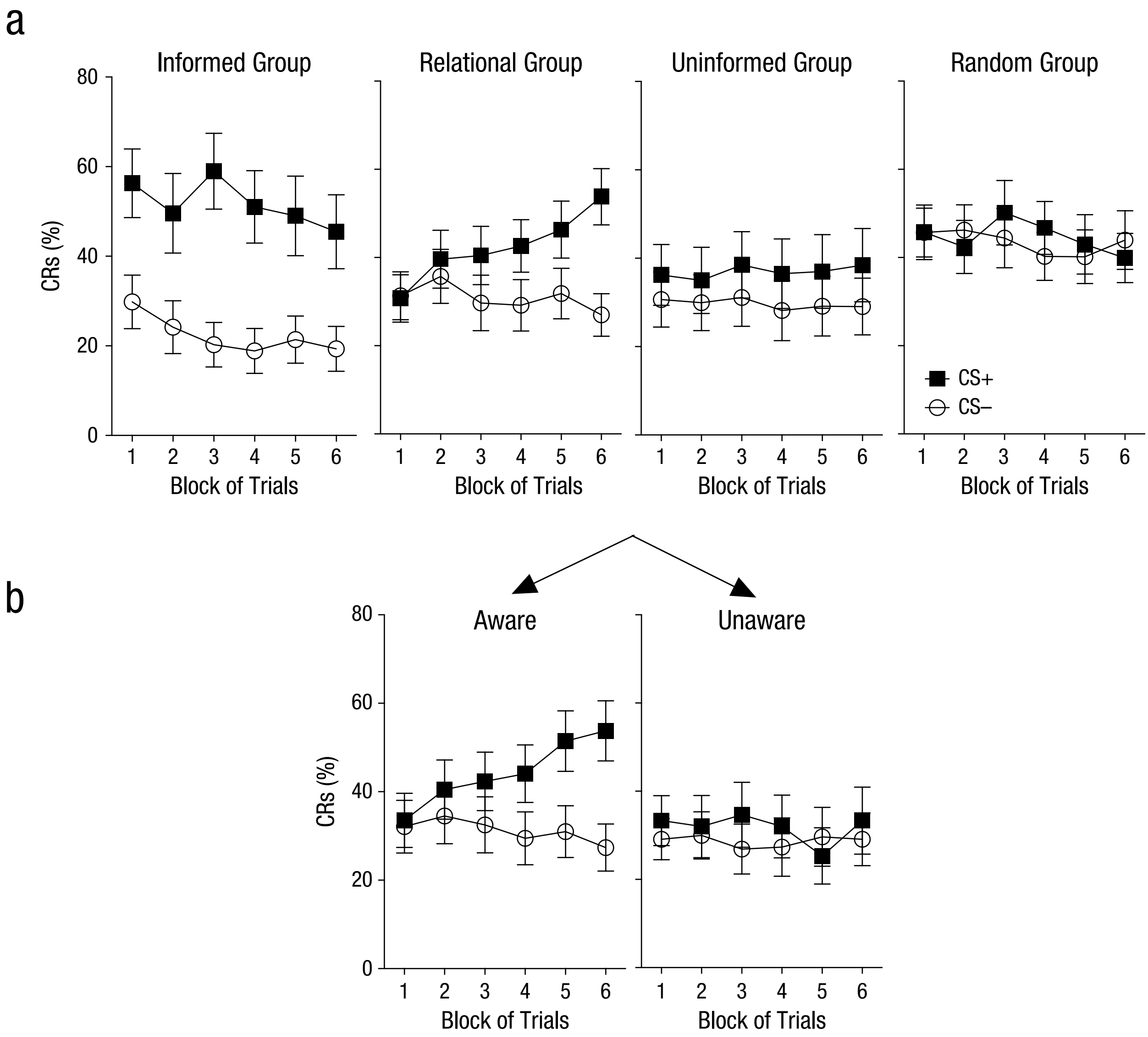

Fig. 2. Mean percentage of eyeblink conditioned responses (CRs) across blocks of 40 trials in the combined phase. The graphs in (a) show results for the CS+ (i.e., the conditioned stimulus that was paired with an unconditioned stimulus) and the three CS–s (i.e., conditioned stimuli not paired with an unconditioned stimulus) separately for each experimental group (n = 20 per group). In the final group (random), for which there was no actual relationship between shape and airpuff, CS+ refers to the shape most commonly associated with the airpuff (identified in the postexperimental questionnaire), and CS− refers to the other three shapes. The graphs in (b) show data from the relational and uninformed groups combined, separately for participants who were classified as aware (n = 25) and unaware (n = 15) of which shape predicted the airpuff. Error bars indicate ±1 *SEM*.

By contrast, there was no evidence of differential responding to the CS+ and the CS− among the unaware participants, $F(1, 14) = 1.42$, $p = .254$, 95% CI = [−0.16, 0.41], and no interaction with linear trend over blocks, $F < 1$. We then compared the aware participants with the participants in the informed group on eyeblink CRs in the final block of training. There was a main effect of CS type, $F(1, 43) = 31.26$, $p < .001$, 95% CI = [0.55, 1.17], but CS type did not interact with group (i.e., aware group vs. informed group), $F < 1$. This result indicates that the aware participants from the relational and uninformed groups reached the same terminal level of discrimination as participants in the informed group.

Finally, the RT data from the go/no-go task offered an additional measure of learning. Specifically, participants who learned the predictive relationship between shapes and tone or airpuff outcomes would be primed by the shape to either perform or withhold the button press. Analysis of the go/no-go RT data indeed showed evidence of learning and supported the conclusions reached on the basis of the primary eyeblink measure. Full details of this analysis are available in the Supplemental Material available online.

Discussion

Experimentally manipulating participants' awareness of the relationship between the CS+ and the US dramatically influenced differential eyeblink conditioning. Participants in the informed group, who were given explicit information about the relationship between the CS+ and the US and were universally categorized as aware, showed differential responding beginning from the first block of trials. Participants in the relational group, who were told that the two tasks were related, but not exactly how, were mostly categorized as aware and showed gradual development of differential responding across training. By contrast, participants in the uninformed group, who were given no information about the relationship between the CS+ and the US and were led to believe that the stimuli were in fact part of two unrelated tasks, showed little awareness and little evidence of differential conditioning. In fact, participants in the uninformed group did not differ significantly from those in the random group, for whom there was no relationship between the CS+ and the US. Finally, within the two groups that were partially aware, participants classified as unaware showed no evidence of differential eyeblink responding, whereas those classified as aware reached the same level of discrimination as the informed group by the end of training.

The present design provided three advantages relative to past strategies used to assess the relationship between awareness and conditioning. First, we manipulated contingency knowledge by disguising the contingency and then providing instructions to affect awareness. This design allowed a stronger conclusion about the causal role of awareness than previous studies, in which the correlation between awareness and conditioning was passively assessed (Clark & Squire, 1998; Lovibond et al., 2011; Smith et al., 2005). Second, we gave all participants exactly the same tasks; only the instructions varied. Previous studies have sought to manipulate awareness by giving participants different tasks during conditioning (Clark & Squire, 1999; Ross & Nelson, 1973; Weidemann & Antees, 2012), leaving open the possibility that differences in conditioning were due to differences in task demands. Finally, the present design ensured that all participants paid attention to the CS+ and the US, because attention was required to maintain performance in the two reaction time tasks. Therefore, the lack of evidence of conditioning among the unaware participants in the present experiment cannot have been due to failure to attend to the stimuli.

The present results strongly contradict the predictions of dual-system theories, which postulate an independent, unconscious conditioning system (e.g., McLaren et al., 2014; Squire, 2004). In particular, participants in the uninformed group were exposed to a set of experiences that should have been nearly ideal for the operation of such a system, if it existed. They were attending to a salient, easily discriminable CS that stood in a contingent and contiguous relationship to a biologically potent US, over many trials. Yet they showed limited evidence of differential eyeblink conditioning, and that evidence was attributable solely to the subset of participants who were aware. The informed group, which differed only in that the participants received a verbal instruction about the CS-US relationship, showed both differential eyeblink CRs and conscious awareness. The greater evidence of conditioning in the informed group than in the uninformed group clearly indicates that differential delay eyeblink conditioning is not independent of awareness, as has been suggested by Clark and Squire (1998). Furthermore, the absence of differential conditioning among unaware participants casts doubt on the existence of a robust automatic conditioning system that is based on the concurrent activation of two stimulus representations.

Instead, the present results suggest that attention to the *relationship* between the stimuli (and not just attention to the individual stimuli) is critical to learning a novel association. This learning is strongly influenced by verbal information and gives rise to conscious knowledge of the relationship. In other words, associative learning in humans has all the hallmarks of a controlled cognitive process. Although the present experiment is a particularly strong demonstration of this finding, it is consistent with the broader literature in human associative learning, which reveals surprisingly little evidence for unconscious learning (e.g., Dawson & Schell, 1987; Lovibond et al., 2011; Lovibond & Shanks, 2002; Weidemann & Antees, 2012). A few notable results in the literature appear to be inconsistent with a single-process account. For example, Perruchet's (1985) study of human eyeblink conditioning under conditions of partial reinforcement showed that under some circumstances, it is possible to dissociate performance of conditioned eyeblink responses and conscious expectancy for the airpuff. However, for this finding to be regarded as evidence for a dual-systems account, changes in eyeblink CRs must be the result of associative learning, a claim that is currently contested (Weidemann & Lovibond, 2015).

A dual-system model could be modified in several ways to accommodate the present data, but each of them has drawbacks. For example, it could be argued that the low-level associative system was not activated for some reason in this experiment, but this approach would greatly reduce the applicability and the falsifiability of the model. Alternatively, it could be argued that the observed CRs were generated by the cognitive system (e.g., Clark & Squire, 1998) or that the associative system is subservient to the cognitive system, but such arrangements would add little to the predictions of a pure cognitive model and would be less parsimonious. Instead, we see great value in developing new models of associative learning that build on and extend our understanding of human cognitive architecture. There is already a good deal of cross-fertilization among the fields of learning, memory, and cognition; concepts such as attention and expectancy feature in learning theories. However, in our view, true integration is hampered by a reluctance to move on from the seductive but ultimately misleading idea of an automatic, reflexive learning system. For an initial exploration of what an integrated single-system model of learning might look like, see Mitchell, De Houwer, and Lovibond (2009).

Our conclusion that human associative learning is a high-level cognitive process has two important implications. First, this conclusion suggests that it would be valuable to critically evaluate dual-system models in other domains of psychology, particularly those that make reference to an associative basis for the automatic or implicit system. The study of apparently simple associative-learning tasks has identified a range of procedural and conceptual issues regarding the type of evidence that would be required to support claims for the existence of an implicit system that is applicable to other domains (e.g., Lovibond & Shanks, 2002; Shanks & St. John, 1994; Vadillo, Konstantinidis, & Shanks, 2015; Wiens, Katkin, & Öhman, 2003).

Second, the idea that associative learning is achieved by the cognitive system has quite different practical applications compared with the traditional reflexive view. In the domain of education, for example, such an idea would suggest that relying on the incidental development of tacit or implicit knowledge would be unwise; instead, learners would benefit from structured learning environments that promote the development of explicit knowledge and rules. In the domain of clinical psychology, this idea implies that behavioral interventions such as exposure therapy can be tailored to target the same maladaptive beliefs as cognitive or verbal interventions. These are exciting applications that in our view illustrate the potential value of an integrated model of how the brain achieves learning (Miller & Cohen, 2001; Weidemann et al., 2013).

Author Contributions

G. Weidemann conceived the experiment. All authors contributed to the design of the study and the interpretation of the data. M. Satkunarajah and G. Weidemann analyzed the data, and G. Weidemann drafted the manuscript. P. F. Lovibond provided critical revisions to the manuscript. All authors approved the final manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

Open Practices

The awareness questionnaire and the visual stimuli are available from G. Weidemann (g.weidemann@westernsydney.edu.au). The data are available from the Western Sydney University Research Data Repository at http://handle.uws.edu.au:8081/1959.7/531985. The complete Open Practices Disclosure for this article can be found at http://pss.sagepub.com/content/by/supplemental-data.

References

Aczel, B. (2010). *Attention and awareness in human learning and decision making* (Unpublished doctoral dissertation). Cambridge University, Cambridge, England.

Bird, K. D. (2002). Confidence intervals for effect sizes in analysis of variance. *Educational and Psychological Measurement*, *62*, 197–226. doi:10.1177/0013164402062002001

Carter, R. M., Hofstötter, C., Tsuchiya, N., & Koch, C. (2003). Working memory and fear conditioning. *Proceedings of the National Academy of Sciences, USA*, *100*, 1399–1404. doi:10.1073/pnas.0334049100

Clark, R. E., & Squire, L. R. (1998). Classical conditioning and brain systems: The role of awareness. *Science*, *280*, 77–81. doi:10.1126/science.280.5360.77

Clark, R. E., & Squire, L. R. (1999). Human eyeblink classical conditioning: Effects of manipulating awareness of the stimulus contingencies. *Psychological Science*, *10*, 14–18. doi:10.1111/1467-9280.00099

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

Dawson, M. E., & Schell, A. M. (1987). Human autonomic and skeletal classical conditioning: The role of conscious cognitive factors. In G. Davey (Ed.), *Cognitive processes and Pavlovian conditioning in humans* (pp. 27–55). Oxford, England: John Wiley & Sons.

Dijksterhuis, A., & Aarts, H. (2010). Goals, attention, and (un)consciousness. *Annual Review of Psychology*, *61*, 467–490. doi:10.1146/annurev.psych.093008.100445

Evans, J. St. B. T. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology*, *59*, 255–278. doi:10.1146/annurev.psych.59.103006.093629

Gormezano, I. (1965). Yoked comparisons of classical and instrumental conditioning of the eyelid response: And an addendum on “voluntary responders.” In W. F. Prokasy (Ed.), *Classical conditioning: A symposium* (pp. 48–70). New York, NY: Appleton-Century-Crofts.

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Macmillan.

Kattner, F. (2012). Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus. *Cognition & Emotion*, *26*, 166–175. doi:10.1080/02699931.2011.565036

Kruschke, J. K. (2003). Attention in learning. *Current Directions in Psychological Science*, *12*, 171–175. doi:10.1111/1467-8721.01254

Livesey, E. J., & Harris, J. A. (2009). Is there room for simple links in a propositional mind? *Behavioral & Brain Sciences*, *32*, 212–213. doi:10.1017/S0140525X09001010

Lovibond, P. F., Liu, J. C. J., Weidemann, G., & Mitchell, C. J. (2011). Awareness is necessary for differential trace and delay eyeblink conditioning in humans. *Biological Psychology*, *87*, 393–400. doi:10.1016/j.biopsycho.2011.05.002

Lovibond, P. F., & Shanks, D. R. (2002). The role of awareness in Pavlovian conditioning: Empirical evidence and theoretical implications. *Journal of Experimental Psychology: Animal Behavior Processes*, *28*, 3–26. doi:10.1037/0097-7403.28.1.3

Mackintosh, N. J. (1975). A theory of attention: Variation in the associability of stimuli with reinforcement. *Psychological Review*, *82*, 276–298. doi:10.1037/h0076778

McLaren, I. P. L., Forrest, C. L. D., McLaren, R. P., Jones, F. W., Aitken, M. R. F., & Mackintosh, N. J. (2014). Associations and propositions: The case for a dual-process account of learning in humans. *Neurobiology of Learning and Memory*, *108*, 185–195. doi:10.1016/j.nlm.2013.09.014

Miller, E. K., & Cohen, J. D. (2001). An integrated theory of prefrontal cortex function. *Annual Review of Neuroscience*, *24*, 167–202. doi:10.1146/annurev.neuro.24.1.167

Mitchell, C. J., De Houwer, J., & Lovibond, P. F. (2009). The propositional nature of human associative learning. *Behavioral & Brain Sciences*, *32*, 183–198. doi:10.1017/S0140525X09000855

O’Brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. *Psychological Bulletin*, *97*, 316–333. doi:10.1037/0033-2909.97.2.316

Olson, M. A., & Fazio, R. H. (2001). Implicit attitude formation through classical conditioning. *Psychological Science*, *12*, 413–417. doi:10.1111/1467-9280.00376

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review*, *87*, 532–552. doi:10.1037/0033-295X.87.6.532

Perruchet, P. (1985). A pitfall for the expectancy theory of human eyelid conditioning. *Pavlovian Journal of Biological Science*, *20*, 163–170.

Pleyers, G., Corneille, O., Yzerbyt, V., & Luminet, O. (2009). Evaluative conditioning may incur attentional costs. *Journal of Experimental Psychology: Animal Behavior Processes*, *35*, 279–285. doi:10.1037/a0013429

Purkis, H. M., & Lipp, O. V. (2001). Does affective learning exist in the absence of contingency awareness? *Learning and Motivation*, *32*, 84–99. doi:10.1006/lmot.2000.1066

Ross, L. E., & Nelson, M. N. (1973). The role of awareness in differential conditioning. *Psychophysiology*, *10*, 91–94. doi:10.1111/j.1469-8986.1973.tb01089.x

Shanks, D. R., & St. John, M. F. (1994). Characteristics of dissociable human learning systems. *Behavioral & Brain Sciences*, *17*, 367–447. doi:10.1017/S0140525X00035032

Smith, C. N., Clark, R. E., Manns, J. R., & Squire, L. R. (2005). Acquisition of differential delay eyeblink classical conditioning is independent of awareness. *Behavioral Neuroscience*, *119*, 78–86. doi:10.1037/0735-7044.119.1.78

Spence, K. W., & Ross, L. E. (1959). A methodological study of the form and latency of eyelid responses. *Journal of Experimental Psychology*, *58*, 376–381.

Squire, L. R. (1994). Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. In D. L. Schacter & E. Tulving (Eds.), *Memory systems* (pp. 203–231). Cambridge, MA: MIT Press.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory*, *82*, 171–177. doi:10.1016/j.nlm.2004.06.005

Vadillo, M., Konstantinidis, E., & Shanks, D. (2015). Underpowered samples, false negatives, and unconscious learning. *Psychonomic Bulletin & Review*. Advance online publication. doi:10.3758/s13423-015-0892-6

Weidemann, G., & Antees, C. (2012). Parallel acquisition of awareness and differential delay eyeblink conditioning. *Learning & Memory*, *19*, 201–210. doi:10.1101/lm.024851.111

Weidemann, G., Best, E., Lee, J. C., & Lovibond, P. F. (2013). The role of contingency awareness in single-cue human eyeblink conditioning. *Learning & Memory*, *20*, 363–366. doi:10.1101/lm.029975.112

Weidemann, G., & Lovibond, P. F. (2015). *The role of US recency in the Perruchet effect in eyeblink conditioning*. Manuscript submitted for publication.

Wiens, S., Katkin, E. S., & Öhman, A. (2003). Effects of trial order and differential conditioning on acquisition of differential shock expectancy and skin conductance conditioning to masked stimuli. *Psychophysiology*, *40*, 989–997. doi:10.1111/1469-8986.00117