Can Unaware Participants Show Eyeblink Conditioning?

An Analysis of Clark and Squire's (1998) Dual-Process Learning Theory

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

Recent research by Squire (Clark & Squire, 1998) suggests that although complex tasks like trace eyeblink conditioning are governed by a single learning process giving rise to both conditioned responses (CRs) and conscious awareness, simple tasks like delay conditioning are governed by two separate processes such that CRs can be dissociated from awareness. This thesis examined whether Squire's unconscious delay conditioning results can be accounted for by the poor sensitivity and validity of Squire's awareness classification methods. Experiment 1 attempted to replicate Squire's delay conditioning results with different awareness questionnaires and post-conditioning instructions. Regardless of awareness questionnaire or post-conditioning instruction used, no evidence for unconscious delay conditioning was found. Experiment 2 sought to directly compare delay and trace conditioning for evidence that they may be governed by different learning mechanisms. Although there was no strong evidence for an awareness-conditioning relation when Squire's long questionnaire was used, there was a statistically significant awareness-conditioning relation when a shorter questionnaire was used. Any suggestion that unaware participants may have acquired differential conditioning could be explained in terms of these participants using trial sequence knowledge to perform the task (i.e., they were aware). The data were consistent with a single-process model of learning.

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In the 1970s, cognitive psychologists Michael Posner and Richard Shiffrin proposed that there were two forms of information processing. The first form, *controlled processing*, was believed to be effortful, to depend on limited cognitive resources, to demand attention, and to map onto conscious experience (Shiffrin & Schneider, 1977). Subsequent researchers suggested that this form of processing was governed by working memory, a limited capacity system for manipulating information (e.g., Baddeley, 1993; 2003). On the other hand, *automatic processing* was believed to be independent of working memory: this form of processing required no attention, could occur in parallel with other cognitive pursuits, and could take place without conscious experience (Posner & Snyder, 1975).

The controlled-automatic distinction, which has its antecedents in 19^{th} century writings (James, 1890), broadly maps onto similar distinctions that have been made in other areas of psychology. Hence memory researchers, influenced by philosophy (Ryle, 1949) and artificial intelligence (Winograd, 1975), distinguish between the conscious *declarative memory system* for learning facts and episodes, and the unconscious *procedural memory system* for the acquisition of habits (e.g., Cohen & Squire, 1980; Squire, 1987). Within the learning literature, researchers have suggested that *explicit learning* is different from *implicit learning*, which is governed by low-level unconscious learning mechanisms (e.g., Reber, 1967; Reber & Lewis, 1977).

Common to all these distinctions is the notion that there are two processes: one process encodes information in a manner coupled with conscious awareness, whereas the other process allows learning to occur independently of awareness. Such a view is taught in introductory psychology textbooks (e.g., Baron, 2001) and is accepted as fact by many non-psychologists (e.g., Gladwell, 2005).

However, other psychologists have argued that there is no convincing evidence that learning can occur independently of conscious awareness (e.g., Baer & Fuhrer, 1982; Ross, 1971; Shanks & St. John, 1994). They argue that the evidence supports a view that task performance or long-lasting behavioural changes have to co-occur with explicit knowledge that certain aspects or events in the environment are associated. It is clear that humans can learn associations consciously (e.g., Grings, Schell & Carey, 1973; Lockhart, 1973); hence, the question is whether they can *also* learn these associations unconsciously. Much of the research addressing this question has been focused on classical conditioning, whereby individuals learn a conditioned response (CR) to a conditioned stimulus (CS) that has come to signal an unconditioned stimulus (US). Several researchers have contended that this domain of learning is so simple that human beings may have evolved an ability to carry it out reflexively (e.g., Eichenbaum, 1999; Frcka, Beyts, Levey & Martin, 1983; McNally, 1981; Razran, 1955; 1971). That is, individuals should be able to acquire conditioning independently of their contingency knowledge or awareness about the CS-US relation. Whether such unconscious conditioning can take place, however, has been a matter of debate (e.g., Lovibond & Shanks, 2002; Shanks & St. John, 1994).

Dual-Process Versus Single-Process Models

On the one hand, those who subscribe to the dual-process model of learning propose that conscious knowledge about CS-US relations is brought about by a different process from that which leads to conditioning performance (Lovibond & Shanks, 2002; Wiens & Öhman, 2002): whereas CS-US contingency awareness is believed to occur because one learns propositions about the environment, the conditioned response is thought to result from a separate mechanical and reflexive route (Clark, Manns & Squire, 2002). Hence, the dual-process model predicts independence between awareness of CS-US relations and production of CRs.

On the other hand, proponents of a single-process model claim that there is only one route by which individuals can learn about associations between stimuli: through learning propositions or beliefs about the environment (Lovibond & Shanks, 2002). This model does not deny that there may be low-level unconscious mechanisms involved in learning (e.g., perception); however the mechanisms are believed to contribute to propositional learning rather than constitute a separate learning system. Consequently, the single-process view predicts a close relation between CS-US awareness and conditioning: propositional learning is either said to precipitate both awareness and responding, or is said to lead to contingency awareness which in turn produces the conditioned response.

Can Awareness and Conditioning Be Dissociated?

In order to tease apart these two accounts, one needs to find evidence addressing the question of whether awareness and conditioning can be dissociated. Table 1 presents four possibilities of how individuals can be classified, depending on their conscious knowledge of CS-US contingencies as well as on their conditioning performances.

Table 1
Categorisation of Participants in a Conditioning Experiment Based on Their Awareness of CS-US Contingencies and Production of CRs

	Awareness	
Conditioning performance	Aware	Unaware
CRs	Aware Performers	Unaware Performers
No CRs	Aware Non-Performers	Unaware Non-Performers

Both single- and dual-process models agree that aware individuals can show conditioning (Aware Performers), and that at least some unaware individuals will not produce conditioned responses (Unaware Non-Performers). Both models also concur that aware individuals may not show conditioning (Aware Non-Performers): The single-process model allows for this category of individuals because it recognises that CS-US awareness is necessary but not sufficient for CR performance (i.e., other factors such as learning the appropriate timing of the CR can also affect CR performance; Brewer, 1974; Dawson & Schell, 1985; Grant, 1973; Prokasy, 1965), whereas the dual-process model accommodates Aware Non-Performers by virtue of its stance that awareness and performance have different underlying learning mechanisms. Thus, the single-process model only deviates from the dual-process model in predicting that there cannot be any unaware individuals conditioning (Unaware Performers); the dual-process model predicts that such Unaware Performers exist.

What Kind of Evidence is Needed?

The Inadequacy of Correlations

The question may then be asked, "What kind of evidence would constitute support for one model over another?" Several researchers (e.g., Clark & Squire, 1998) have attempted to answer this question by correlating conditioning performance and awareness, taking a high correlation as evidence supporting a single-process model and a low correlation as evidence supporting a dual-process model. Such a strategy is problematic because it assumes that the difference between the two models lies in the single-process model not predicting *both* Aware Non-Performers and Unaware Performers, as compared to the dual-process model predicting these. However, as mentioned earlier the single-process model permits Aware Non-Performing participants as well (Lovibond & Shanks, 2002). Hence, finding low correlations between conditioning performance and self-reports of awareness reveals little about the true number of processes involved in conditioning.

Unaware Performers

Instead, stronger conclusions about the number of learning processes involved in conditioning can be made when experiments find evidence that Unaware Performers exist (supporting the dual-process model) or that they do not (supporting the single-process model). Research addressing this issue has looked for two main types of evidence, namely *knock out evidence* and *comparison evidence*.

Knock out evidence. The first type of evidence involves attempts to “knock out” or eliminate individuals’ conscious learning path. The single-process model predicts that if this path was knocked out, there would be no other means of learning; hence, these individuals should show no acquisition of a task on any measure. However, the dual-process model predicts that these individuals would still have an unconscious learning path by which they could learn; that is, these individuals should still be able to acquire a task. In support of the dual-process model, there is evidence that conditioning can be acquired amongst populations commonly implicated to have no conscious learning route: hence, amnesics (e.g., Schacter, 1989), animals (e.g., Razran, 1955) and babies (for a review, see Rovee-Collier, 1997) have all been cited as naturally-occurring examples of Unaware Performers. However, the assumption that members from these populations have no conscious learning path has been questioned (e.g., in amnesics, Dunn & Kirsner, 1989; Shanks & St John, 1994; in animals, Dawson, 1973; Griffin & Speck, 2004; in babies, Rovee-Collier, 1997). Hence, the possibility remains that members from these populations are really Aware Performers who are conscious of CS-US contingencies at the time of learning. In other words, this line of research has offered little support for either the single-process or dual-process model.

Other researchers have attempted to experimentally knock out the conscious learning path in a normal human population: because the conscious route is believed to map onto working memory, these researchers have sought to load up participants’ working memory by having them engage in an effortful secondary task during conditioning. In general, such studies have found that when an individual’s working memory is sufficiently loaded up such that he or she has no remaining cognitive resources to acquire conscious contingency knowledge, he or she is also unable to acquire conditioning. This supports a single-process explanation of classical conditioning (for reviews see Boakes, 1989; Dawson & Schell, 1985).

Comparison evidence. A second type of evidence involves *comparisons* between aware and unaware participants. The typical design involves having participants take part in a conditioning experiment, discriminating aware and unaware participants, and then comparing these two groups of participants in their conditioning performances. Often, participants are required to engage in a secondary task as well; this secondary or *masking task* serves as a cover story to disguise the primary task of the experiment (i.e., conditioning). Unlike knock out designs, this secondary task is usually not very effortful: it is not intended to use up all working memory resources of every single participant, but rather to distract participants enough to result in a good mix of aware and unaware participants. Again, there has been no convincing evidence for Unconscious Performers using this experimental design (for reviews, see Boakes, 1989; Brewer, 1974; Dawson & Schell, 1985; Lovibond & Shanks, 2002).

Taken together then, the preponderance of evidence using different methodologies has consistently failed to identify conditioning amongst participants unaware of CS-US contingencies, thus supporting a single-process explanation of classical conditioning.

Is Delay Conditioning an Exception?

Squire's Claim

However, Larry Squire and his colleagues have recently argued that although many forms of conditioning require complex analyses carried out by the hippocampus (Clark et al., 2002; Clark & Squire, 2000; 2004), there exists a class of conditioning tasks which are simple enough that they are not subsumed by the hippocampal system; these hippocampus-independent tasks are believed to be governed by the dual-process model of learning (Clark & Squire, 2000; Squire, 1994). That is, Squire reasons that (i) hippocampal function can be neatly mapped onto awareness of CS-US contingencies (Bayley & Squire, 2002; Squire, 1992), and that (ii) tasks requiring the involvement of the hippocampus would generate awareness (i.e., these tasks are governed by a single learning process; Manns, Clark & Squire,

2000) whereas tasks that do not require the hippocampus can be acquired independently of consciousness (i.e., such tasks are governed by two learning processes; Manns & Squire, 2001).

Trace Versus Delay Conditioning

As an example, Squire highlights the distinction between *trace conditioning* and *delay conditioning* (e.g., Clark, Manns & Squire, 2001, 2002; Clark & Squire, 1999). Trace conditioning, characterised by a temporal interval separating the offset of the CS and the onset of the US, is typically viewed as a “difficult” task in the conditioning literature because it is associated with a slow rate of acquisition (Kehoe & Schreurs, 1986). Correspondingly, learning in a trace conditioning design has been found to require the hippocampus (Solomon, Schaaf, Thompson & Weisz, 1986). Squire argues that because this task is difficult enough to require the hippocampus, it is learnt consciously (Clark & Squire, 2004; Manns et al., 2000; Squire & Kandel, 1999).

The trace conditioning task is compared to the delay conditioning task, whereby the CS offset coincides or overlaps with the US onset. In animals, delay conditioning has been found to be acquired independently of the hippocampus (Solomon et al., 1986). Therefore, Squire makes the case that this form of conditioning is “simple” enough that it can be learnt unconsciously (e.g., Clark et al., 2001; Clark & Squire, 1998; 1999).

In other words, to account for both trace and delay forms of conditioning, Squire has proposed a variant of the dual-process model: both the low-level reflexive system and the high-level hippocampus-dependent system can produce CRs, but only the hippocampal system can give rise to self-reports of CS-US contingencies. The trace and delay forms of conditioning are believed to have different underlying learning mechanisms: trace conditioning entails a single hippocampal learning process giving rise to both awareness and CRs (i.e., trace conditioning is essentially governed by a single learning process), but delay conditioning engages separate processes for each of awareness and CR performance (i.e., delay conditioning is governed by two learning processes).

Experimental Comparisons

In support of this claim, Squire has presented data from both knock out and comparison designs. Much of Squire's knock out data have involved amnesics, whose awareness status during learning have been difficult to establish (e.g., Clark & Squire, 1998). The one exception involves an experimental attempt to knock out normal adults' conscious learning mechanism: with this method, Squire found that participants distracted by a secondary task (observing a pattern of digits presented on the screen) were able to acquire delay conditioning but not trace conditioning (Clark & Squire, 1999). However, in this study the participants in the trace conditioning group developed no contingency awareness whereas the participants in the delay conditioning group learnt the CS-US relations. That is, it appears that the secondary task was successful in knocking out the aware pathway when the primary task was trace conditioning, but not when the primary task was delay conditioning. Hence, the pattern of data lends support to Squire's claim that trace conditioning involves contingency awareness, but not that delay conditioning can be dissociated from awareness.

Better support for Squire's claim has come from comparison designs wherein participants engage in trace or delay conditioning trials within a differential eyeblink conditioning procedure (Clark & Squire, 1998; Smith, Clark, Manns & Squire, 2005). In such a procedure, two different sounds are used as CSs: one sound (CS+) signals the presence of the US whereas the other (CS-) signals the absence of the US. The US is an airpuff presented to the participant's eye, and a CR is said to have occurred if the participant learns to blink to the CS+ in anticipation of the airpuff. To ensure that not all participants become aware of the CS-US contingency, the conditioning trials are embedded within a movie masking task (Ross & Nelson, 1973). Participants are instructed to watch a movie for which their memory will be assessed, and are also told that the movie will proceed under conditions of distractions. In fact, the distractions – the sounds and airpuffs – are the conditioning stimuli; hence, conditioning trials proceed under this cover story of a memory experiment. Following the conditioning trials, participants are given a questionnaire to establish whether they had been aware of the CS-US relations. Participants' performance on this questionnaire can then be matched up with their performance of the conditioned response, permitting an analysis of the awareness-conditioning relation.

Using this methodology, Clark and Squire (1998) reported that awareness of CS-US relations was found to be necessary for trace conditioning: In their trace conditioning task, only aware participants showed acquisition of the conditioned response; unaware participants failed to respond more to the CS+ than to the CS-. However, Clark and Squire (1998) and Smith et al. (2005) claimed to have found evidence for unconscious acquisition of CRs within the delay conditioning task: in five separate experiments, unaware participants showed as much acquisition of the conditioned response as did aware participants.

Conflicting Results

Squire and his colleagues' trace conditioning results are consistent with the single-process model of learning and are in line with the broader literature on the role of awareness in classical conditioning. However, Squire's delay conditioning results, in supporting a dual-process model of learning, are in contradiction with this broader literature. The delay conditioning results also stand out because other researchers who have examined delay conditioning with very similar methodology (i.e., with a differential eyeblink conditioning task concealed as a memory task) have found no evidence of unaware participants conditioning (Bellebaum & Daum, 2004; Knuttinen, Power, Preston & Disterhoft, 2001; Nelson & Ross, 1974).

Because these opposing findings limit the conclusions that can be made about the number of processes involved in conditioning, the overriding aim of the present thesis was to investigate why Squire and his colleagues have found conflicting delay conditioning results to those of the bulk of the literature. Specifically, this thesis sought to identify the possible factors that could have led to different conclusions regarding the awareness-conditioning relation. It is believed that this line of investigation would permit stronger conclusions to be made about both the single-and dual-process models of learning, thereby affording a better understanding about the true nature of delay eyeblink conditioning as well as of learning in general.

To understand why Squire's results on delay eyeblink conditioning are at odds with those of other researchers, one needs to examine the subtle points of methodology on which Clark and Squire's (1998) and Smith et al.'s (2005) experiments diverge from those of other delay eyeblink conditioning studies. These points of departure can be categorised under differences in the experiments': (i) awareness questionnaires and (ii) post-conditioning instructions.

Sensitivity and Validity of Awareness Classification Methods

In a limiting case, any of the awareness classification methods used in previously conducted delay eyeblink conditioning studies could have been inappropriate. That is, a particular classification method may have classified participants as aware or unaware on a random basis, or may even have erroneously classified all aware participants as unaware and all unaware participants as aware. Such a classification method would have worked in favour of the dual-process model: any aware participants misclassified as unaware would have appeared to provide evidence that Unaware Performers existed, if these misclassified participants also showed differential conditioning. No erroneous rejection of either model would have been made if unaware participants had been misclassified as aware, because these participants would have been mistakenly accommodated into the single- or dual-process model as Aware Performers or Aware Non-Performers. Should all unaware participants have been wrongly classified as aware, one would have merely concluded that neither theory could be tested because of the resulting inability to evaluate unaware participants' conditioning performances. That is, a conclusion that unaware participants exist could be an artefact of an awareness classification method that was erroneous in categorising participants' true awareness status (Page, 1971); however, the contrary conclusion that unaware participants did not exist could not be explained by such an artefact. If a particular experiment found evidence in favour of a single-process model of learning, it would have to be because participants have been classified with a sufficient level of accuracy.

The question, then, is whether Squire's method of classifying participants is accurate enough to have provided a fair test of the single- versus dual-process models of learning. Shanks and St. John (1994) define an accurate method as one which first, is sufficiently sensitive to detect participants' awareness and second, has content validity in that it addresses the information participants are actually using to solve the task. The present research evaluated whether Squire's awareness questionnaire and post-conditioning instructions met these two criteria, thus permitting an analysis of whether the Unaware Performers from his delay conditioning experiments were "true" unaware participants or were in fact misclassified aware participants.

Awareness Questionnaires

Sensitivity of Questionnaire

In the experiments in which Squire found evidence for unconscious delay eyeblink conditioning, an extended post-conditioning questionnaire was used to establish participants' awareness status (Clark & Squire, 1998; Smith et al., 2005). This questionnaire involved asking participants 10 questions about the movie they had watched followed by 40 true or false questions regarding the experimental stimuli involved in conditioning (R.E. Clark, personal communication, July 27, 2005; Clark & Squire, 1999). Of these 50 questions, only 17 tapped into participants' knowledge of the CS-US relations; these questions, which were used to classify participants as aware or unaware, came on the sixth page of the questionnaire, after participants had answered 28 questions on the movie and on their responses to each individual stimulus. That is, the critical questions only came after participants had responded to five pages of questions irrelevant to the issue of whether they had noticed the CS-US contingencies.

In contrast, other studies that have examined delay eyeblink conditioning have used much shorter questionnaires to assess awareness: Bellebaum and Daum's (2004) awareness measure involved only 18 questions (C. Bellebaum, personal communication, August 29, 2005), whereas Nelson and Ross's (1974) measure involved only 12. Critically, both of these shorter questionnaires had the relevant CS-US contingency questions appearing at the very beginning.

Prior research on the psychometric properties of awareness questionnaires in conditioning suggests that short questionnaires are more sensitive than long questionnaires (Dawson & Reardon, 1973). Hence, it could be the case that Squire and his colleagues' 50-item questionnaire was less than ideal, resulting in inappropriate classification of participants' awareness status (Lovibond & Shanks, 2002): perhaps aware participants were misclassified as unaware in Clark and Squire's (1998) and Smith et al.'s (2005) studies, resulting in an erroneous conclusion that unaware participants could show CRs. In other words, the discrepancy between Squire's results and those from other researchers could be an artefact of the poor sensitivity of Squire's use of a long questionnaire. To test this possibility, Clark and Squire's (1998) and Smith et al.'s (2005) delay conditioning results need to be replicated using a shorter awareness questionnaire.

Validity of Questionnaire

Apart from the questionnaire's sensitivity, another criterion for the suitability of Squire's questionnaire is its content validity or its ability to have captured all possible rules that participants may have used to anticipate the onset of the US (Shanks & St. John, 1994). A valid questionnaire should be able to tap into participants' knowledge of the experimenter's intended rules (in this case, the differential conditioning rules that the CS+ predicts the airpuff will occur and the CS- predicts the airpuff will not occur) as well as their knowledge of any correlated hypotheses that may enable them to correctly predict the US. A participant who shows awareness of *any* valid rules should be classified as "aware" (Lovibond and Shanks, 2002).

Squire's choice of trial sequences involved the stipulation that a particular type of trial (either that comprising the CS+ followed by the US, or that comprising the CS- presented alone) will not occur more than twice in a row. It is conceivable that participants who became aware of this trial sequence may have predicted that: *if one of the sounds occurs twice, each without an airpuff, the next sound would be accompanied by an airpuff* and/or that *if one of the sounds occurs twice, each with an airpuff, the next sound would not be accompanied by an airpuff*. Knowledge of both of these rules would have enabled participants to correctly anticipate the occurrence of the US (and hence show a conditioned response) on an average of one third of the trials, thus permitting them to attain a level of conditioning performance that would have been interpreted as successful differential conditioning. However, Squire's questionnaire did not assess participants' knowledge of either of these rules. That is, participants who did not realise that the CS+ signalled the occurrence of the US but discovered the correlated trial sequence rule would nonetheless have been classified as unaware, potentially leading to the incorrect conclusion that they were Unaware Performers.

That such a situation may have arisen in Squire's experiments is supported by findings by Wiens, Katkin and Öhman (2003) that a trial sequence restriction of two trials is sufficient for conditioning to occur. They reported that the use of a non-random trial order similar to that used in Squire's experiments could explain results that they had previously interpreted as evidence for unconscious conditioning; this apparent effect of unconscious conditioning collapsed when the trial sequence was randomised. However, Wiens et al.'s (2003) study did not employ a movie masking task and further research is needed to examine whether participants can also acquire trial sequence awareness while being distracted by a movie.

Post-Conditioning Instructions

The questionable psychometric properties of Squire's questionnaire cannot explain the discrepancy between Squire's results and those of Knuttinen et al. (2001), because Knuttinen et al. (2001) failed to replicate Clark and Squire's (1998) findings of unaware participants conditioning despite using the same trial sequence and awareness questionnaire. Instead, the difference between these two outcomes may have been due to different post-conditioning instructions in Clark and Squire's (1998) versus Knuttinen et al.'s (2001) studies, resulting in different sensitivities of the methods used to classify participants as aware or unaware.

Research from social psychology suggests that demand characteristics, or participants' expectations about what responses the experimenter wants them to give, can affect participants' performance in an experiment (Orne, 1962; Orne & Whitehouse, 2000; Rosenthal, 2002). Such effects are seen in any type of experiment involving humans (Rosnow, 2002), including conditioning experiments (Page, 1969; 1970; Page & Lumia, 1968). Hence, one reason for the discrepancy could be different expectations conveyed to participants regarding the importance of the post-conditioning questions concerning CS-US relations. As Dulany (1968) states:

> If reports are to behave in lawful manner, … questioning must be presented as a serious and central part of the experiment. Lawfulness cannot be expected if the experimenter conveys, however unintentionally, that the real business of science is over and he merely wants to ask a few incidental questions. (p. 355)

Perhaps Clark and Squire (1998), in successfully carrying through their cover story that the experiment was about participants' memory of the movie (R.E. Clark, personal communication, July 27, 2005), had inadvertently given participants the impression that the questions about CS-US contingencies were merely incidental. As a result, participants may not have given enough attention to these questions, resulting in inaccurate classification of participants' awareness status and hence, the finding that unaware participants showed differential eyeblink conditioning. Conversely, it could be that Knuttinen et al. (2001), prior to participants completing the post-conditioning questionnaire, conveyed the message that the true focus of the experiment was whether participants had learnt anything about the CS-US contingency rather than the movie. As a result, participants may have paid more attention to those questions relating to the conditioning stimuli, resulting in more accurate classification of their awareness status and hence, a stronger association between awareness and differential conditioning. In order to test this demand characteristics explanation of the discrepancy between Squire's and Knuttinen et al.'s (2001) results, research needs to be carried out to manipulate the post-conditioning instructions given to participants before they are presented with the awareness questionnaire.

Aims and Hypotheses

This thesis aimed to address the question of whether any of the hitherto identified methodological differences between Squire's studies and those of other delay eyeblink conditioning studies could have led to the discrepancies in the results. Specifically, an attempt was made to replicate Squire's results but with manipulation of several potentially important factors, namely the questionnaire used to classify participants as aware or unaware and the post-conditioning instructions given to participants.

If the single-process model is correct, it should be possible to explain any conditioning observed in participants classified as unaware in terms of the insensitivity and invalidity of the method used to determine participants' awareness status. That is, one should only find "unaware" participants showing conditioning when Clark and Squire's (1999) extended questionnaire is used and/or when participants are led to believe that the experiment is not concerned with their knowledge of CS-US relations. Under conditions allowing more accurate classifications of aware and unaware participants – that is, when a short questionnaire is used to establish participants' awareness status and when the experimenter conveys that the CS-US relations are of importance – the single-process model predicts that there should be no unaware participants showing CRs.

Conversely, if the two-process model is correct, manipulations of the awareness questionnaire or the post-conditioning instructions should not matter. That is, as long as there are unaware participants, it should be possible to show conditioning in the absence of CS-US awareness.

EXPERIMENT 1

Experiment 1 manipulated the awareness questionnaire and post-conditioning instructions within Squire's delay conditioning design in order to examine how these variables may impact the conclusions made about the awareness-conditioning relation.

Additionally, the first experiment investigated the impact of using different CR definitions during data analysis. This was another area of methodological discrepancy within previous delay conditioning studies, and could have contributed to Knuttinen et al.'s (2001) failure to replicate Squire's results (Clark & Squire, 1998; Smith et al., 2005). For example, Squire and his colleagues counted as a CR any blink occurring within the 500 ms window prior to US onset (Smith et al., 2005) whereas Knuttinen et al. (2001) defined a CR as any blink falling within the larger window of 1250 ms before US onset. The question of which CR definition is the most sensitive is an empirical question that has yet to be examined: it could be the case that either of Squire's or Knuttinen et al.'s (2001) CR definitions was not optimal for testing the number of processes involved in delay conditioning.

Further, Squire's data analyses included provisions to delete trials if the trials' waveforms involved "large amplitude, early onset responses that were maintained until the termination of the US airpuff" (Smith et al., 2005, p. 80). These waveforms were not considered to be true CRs because they were thought to be "voluntary" responses made by participants to avoid the airpuff (Manns, Clark & Squire, 2002). Squire suggested that, because Knuttinen et al. (2001) made no such deletions, their finding that awareness was closely related to conditioning was purely spurious (Manns et al., 2002). Squire also noted that Knuttinen et al. (2001) attached electromyography (EMG) electrodes to participants' eyelids to measure eyeblinks, whereas Squire's studies used infrared recording. As a result, Squire proposed that Knuttinen et al.'s (2001) eyeblink recording method was somehow selectively sensitive to voluntary responses but not true CRs. In support of this argument, Squire pointed out that Knuttinen et al.'s (2001) unaware participants failed to show differential conditioning because they did not respond to either CS+ or CS-, whereas unaware participants in other delay conditioning studies have failed to show differential conditioning because they responded to *both* CS+ and CS- and could not discriminate between the two (Smith et al., 2005). The suggestion, then, is that any true CRs that Knuttinen et al.'s (2001) unaware participants may have shown were not detected by the insensitive eyeblink recording method; if Knuttinen et al. (2001) deleted their aware participants' voluntary responses, these aware participants should likewise show no differential conditioning.

Squire's arguments are problematic for two reasons. First, it is difficult to conceive how an eyeblink recording method could be selectively sensitive to waveforms that appear voluntary but not be sensitive to waveforms that appear involuntary. In fact, researchers disagree as to whether the distinction between voluntary and conditioned responses is genuine (e.g., Fishbein & Gormezano, 1966; Gormezano, 1965; Ross, 1965), and if so, what method is best suited to differentiate between these responses (see Coleman, 1985 and Coleman & Webster, 1988 for reviews of different methods that have been employed in previous studies). If researchers themselves could not agree on how to differentiate voluntary eyeblinks from true CRs because the distinction was not clear-cut, it seems unlikely that a method of recording eyeblinks could be selectively able to detect one and not the other. A second problem for Squire's argument lies in the suggestion that Knuttinen et al.'s (2001) eyeblink recording method was insensitive because their unaware participants showed low levels of responding to both CS+ and CS-. This pattern of responding has been found in Squire's own unaware participants in trace conditioning experiments: when a shorter trace interval separated the CS+ from the US, their unaware participants did not acquire differential conditioning because they showed high responding to *both* CS+ and CS-; however, when a longer trace interval separated the CS+ from the US, their unaware participants failed to show differential conditioning because they did not respond to *either* CS+ or CS- (Clark & Squire, 2000). This pattern suggests that it may be task difficulty (e.g., using longer trace intervals constitutes a harder task than using shorter trace intervals) rather than insensitive eyeblink recording methods that determines the pattern of unaware participants' responses. In Knuttinen et al.'s (2001) study, both old and young participants were included: because Knuttinen et al. (2001) only reported CS+ and CS- difference scores, it is ambiguous whether the report of unaware participants' low overall responding referred to old participants, young participants, or all participants averaged across age group. If the pattern of unaware participants' low responding referred to old participants or to all participants, it could be that these unaware participants found the delay conditioning task harder than those in previous studies using younger participants have found them to be. This is supported by Knuttinen et al. (2001)'s finding that conditioning is more difficult for older participants than for younger participants. Hence, the result that Knuttinen et al.'s (2001) unaware participants showed low responding to both CS+ and CS- may not be as aberrant as Squire suggested it was.

Nonetheless, the present experiment sought to circumvent the criticisms that Squire has made of Knuttinen et al.'s (2001) study. To record participants' eyeblinks, Experiment 1 used an infrared reflective sensor and did not attach any EMG electrodes to participants' eyelids: because this is the same method that Squire used (Clark & Squire, 2000), it should be sensitive to detecting true CRs. If eyeblink recording methods were seen to be sufficiently sensitive to detecting CRs, then deleting any apparent voluntary blinks should not affect the conclusions one makes about whether unaware participants can condition. This is because one needs to be aware of CS-US relations in order to make a conscious choice to blink more to the CS+ than to the CS-. Hence, deleting apparently voluntary blinks may eliminate any advantage that aware participants may have, but cannot make any unaware participants show more differential conditioning than they would if these voluntary blinks were not eliminated. Even so, to prevent the possibility that the present experiment's results could be interpreted as an artefact of such voluntary eyeblinks, Experiment 1 examined the conditioning-awareness relation with and without the application of Squire's exclusionary criterion for voluntary eyeblinks.

To summarise, Experiment 1 explored how the usage of different awareness questionnaires and post-conditioning instructions could have an impact on the conclusions made regarding the abilities of unaware participants to acquire delay conditioning. By closely following Clark and Squire's (1998) delay conditioning procedures, Experiment 1 sought to investigate how the awareness-conditioning relation might be captured differently when using the long Clark and Squire (1999) questionnaire as compared to a shorter questionnaire. Further, the possible differential effects of post-conditioning instructions were examined by instructing participants to focus on the CS-US relation or on the movie masking task.

Method

Design

This experiment involved two levels of the independent variable Instructions (CS-US vs. movie), with a further independent variable Awareness (aware vs. unaware) created based on participants' responses on two different measures of awareness (long vs. short questionnaire). Analysis of variance (ANOVA) was used to test these effects, with participants' discrimination performance in the delay eyeblink conditioning task as the dependent variable.

Participants

The participants involved in this study were 60 students from the University of New South Wales who volunteered to participate for course credit in an introductory psychology course. Of these 60 participants, two were removed from the study because of computer failures half-way through the experimental sessions. The remaining 58 participants were randomly allocated to the different instructional conditions: 30 participants (*M* age = 20.30 years, *SD* = 4.08 years) comprising of 15 men and 15 women formed the first group receiving instructions focused on the CS-US contingency; the other 28 participants (*M* age = 19.45 years, *SD* = 2.06 years) comprising of 12 men and 16 women formed the second group receiving instructions focused on the movie masking task.

Materials

Movie Masking Task

Following Clark and Squire (1998) and Smith et al. (2005), the silent movie *The Gold Rush* (Chaplin, 1925) was used as the stimulus that participants had to attend to throughout the conditioning session. This movie was screened on a 30 cm x 36 cm Mag Innovision monitor.

Delay Conditioning Task

Two auditory stimuli delivered via Sennheiser HD515 headphones served as the CSs: the first stimulus was a 1350 ms, 85 db 1000 Hz tone and the second stimulus was a 1350 ms, 85 db white noise. The amplitudes of these stimuli were calibrated by attaching an artificial ear (Brüel & Kjær, Type 4152) and precision sound level meter (Brüel & Kjær, Type 2235) to the earphones.

The US comprised of a 100 ms, 0.09 MPa airpuff which was administered by an eyeblink airpuff unit (San Diego Instruments). This airpuff was dispensed through a nozzle of 1 mm diameter that was fastened to the left frame of a pair of spectacles. The nozzle (San Diego Instruments) was also attached to an infrared sensor through which eyeblink recordings were made.

Conditioning and recording was carried out by an experimental interface (Med Associates Inc. SG-500) connected to an Intel Pentium computer. Med-PC experimental control software (version 1; Med Associates Inc. & Tatham, 1991) was used to program the conditioning session. There were 120 trials, half of which involving a CS+ occurring with the US (CS+ trials) and the other half involving a CS- occurring without the US (CS- trials). The allocation of the tone and white noise to CS+ was counter-balanced across participants. In accordance with the delay conditioning design, the CS and US terminated concurrently, with a 1250 ms inter-stimulus interval (ISI) between CS and US onsets (see Figure 1). Each trial was separated from the next with an interval of 10-15 s, with trial type (CS+ or CS-) being randomised within the restrictions that no one trial type could occur more than twice in a row (see Appendix A for trial sequences used).

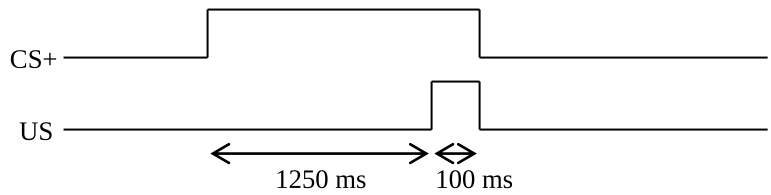

Figure 1. Time sequence of events within a CS+ trial in Experiment 1.

Awareness Assessments

Two post-conditioning questionnaires were used to establish participants' awareness of CS-US contingencies. These were stapled together in a booklet wherein the order of questionnaire presentation was counter-balanced across participants.

The first questionnaire (Long Questionnaire) was the original questionnaire used by Squire and his colleagues in their experiments on differential delay eyeblink conditioning (see Appendix B; R.E. Clark, personal communication, July 27, 2005). This questionnaire consisted of 50 true or false questions, of which questions 29 to 45 (the questions regarding the relation between conditioning stimuli) were used to establish an individual's awareness of the CS-US contingency (Clark & Squire, 1999). In the original scoring methods (Long Questionnaire 13/17 criterion; Clark & Squire, 1998), participants who correctly answered 13 to 17 of these questions were classified as aware whereas those who scored 12 or less were classified as unaware. In Clark and Squire's subsequent paper on delay eyeblink conditioning (Smith et al., 2005), two other scoring methods were introduced. In the first (Long Questionnaire 10/17 criterion), participants were classified as aware if they attained a score between 10 to 17 and unaware if they attained a score of 9 or less; in the second scoring method (Long Questionnaire 5/8 criterion), only the 8 questions directly tapping into the CS-

US relations were used to establish participants' awareness status (that is, the questions on the relations between the two CSs were excluded; C. Smith, personal communication, February 2, 2006): An individual was designated as aware if he or she correctly answered 5 or more questions, or unaware otherwise.

The second questionnaire (Short Questionnaire; see Appendix C) was designed for this experiment with Dawson and Reardon's (1973) recommendations on awareness questionnaires in mind. Hence, this questionnaire involved short recognition questions and had the key questions on the CS-US relations appearing at the start (so as to reduce the possibility of participants forgetting these relations by the time they answer the critical questions; Baeyens, Eelen & van den Bergh, 1990; Dawson & Reardon, 1973). The questionnaire was also designed to assess any trial sequence knowledge that participants may have used to successfully complete the differential conditioning task.

Hence, the final questionnaire involved eight items. The first two items, the key questions on the CS-US relations, were Visual Analogue Scales (VAS) requiring participants to rate how often a tone (in the first question) or a static noise (white noise; in the second question) was accompanied by the airpuff. Participants indicated their belief by making a mark on a 10-cm horizontal line anchored on one end with "0% Never" and on the other with "100% Always." Using these two questions (Short 50% Difference criterion), participants were classified as aware of the differential conditioning relations if they discriminated between the two CSs by at least 50% in the right direction; that is, if their CS+ score was at least 50% higher than their CS- score.

The next two items sought to measure trial sequence awareness: participants were required to indicate the veracity of the rule that two sounds in a row presented *without* the airpuff would be followed by a sound presented *with* the airpuff, or that two sounds presented *with* the airpuff would be followed by a sound presented *without* the airpuff. Again, participants showed their knowledge of these two rules on a VAS labelled "0% not true at all" on one end and "100% completely true" on the other end. Participants who marked 75% or more on either of these questions were considered to be "trial sequence-aware" (Short Trial Sequence criterion).

Finally, the last four items were included as alternative methods for participants to show how well they had learnt the CS-US relations. Item 5 involved a VAS, anchored on one end with "0% not true at all" and on the other with "100% completely true," requiring participants to rate the truth of the statement that one type of sound was usually accompanied by the airpuff whereas the other was not; high ratings on this question indicated awareness that the two sounds differed in their predictability of the airpuff. Item 6 followed up on the previous question by informing participants that one sound had indeed been accompanied by the airpuff more than the other sound had been. Participants were then required to make a forced choice between the tone and the static noise as to which sound this had been. The next item required participants to estimate when they had discovered the CS-US relations; this was examined by having participants mark a VAS which had "0 mins start of movie" and "20 mins end of movie" on either end of the scale. Finally, item 7 was a forced choice question asking participants to indicate whether the sound or the airpuff came on first.

Procedure

The procedure followed Clark and Squire's (1998) and Smith et al.'s (2005) procedures as closely as possible, except where experimental manipulations required the departure from their procedures. All participants were individually tested. (See Appendix D for the script used in this experiment.)

Pre-Conditioning Instructions

At the start of the experiment, participants were instructed that they would be taking part in a study on how distractions of noises and airpuffs would affect their memory of a movie. They were thus asked to pay attention to the movie because they would later be asked about it. Participants were further assured that their data would be anonymous and confidential.

Calibration and Conditioning

Next, participants were moved into a soundproof room where they were seated approximately 50 cm from a computer screen. Participants were then asked to put on a pair of specially fitted spectacles from which the airpuff would be administered; the experimenter adjusted the airpuff nozzle to ensure that it pointed directly at participants' left pupil from a distance of approximately 1.5 cm. Participants were also asked to put on a pair of headphones.

To ensure that eyeblink recording could proceed in an accurate manner, pre-conditioning calibration trials were administered whereby each of the sound and airpuff stimuli was presented twice. Participants were informed that these trials were intended for them to familiarise themselves with the "distractions" before the movie commenced. If participants' eyeblinks were not being captured in a proper manner, the experimenter re-adjusted the nozzle attached to the spectacles under the cover story of having to ensure that the airpuff was a sufficient distraction. The experimenter then turned off the lights in the room and shut the door before commencing the silent movie and the 120 delay conditioning trials.

Post-Conditioning Instructions

After the conditioning session, participants in the CS-US Instructional Condition were informed that the true focus of the experiment was to examine what they had learnt about the relations between the tone, white noise and airpuff. They were instructed to think carefully about these relations when filling in the questionnaire. Conversely, participants allocated to the Movie Instructional Condition were reminded of the movie memory task and were told to think carefully about the movie when filling in the questionnaire. Additionally, all participants were told that they could not change their answers once they had proceeded to the next question. Participants were then administered the awareness questionnaires and were fully debriefed on completion of the questionnaires.

Data Analyses

To examine the awareness-conditioning relation, an Awareness group variable was created with aware participants classified into one group and unaware participants into another. This analysis also tested the effects of different post-conditioning instructions and of the different orders in which participants completed the questionnaires. Following Squire (Clark & Squire, 1998; Smith et al., 2005), trials were combined into six blocks of 20 trials each. Hence, the final analysis involved planned orthogonal contrasts in a (2) x (6) x 2 x 2 x 2 ANOVA analysis with Trial Type (CS+ or CS-), Trial Blocks (1 to 6), Awareness Status (Aware or Unaware), Instructions (CS-US or Movie) and Questionnaire Order (Long Questionnaire first or second) as the factors. The dependent variable was conditioning performance per block. This ANOVA was then repeated with the application of Squire's criterion to exclude "voluntary" eyeblinks. The Type 1 Decision Wise Error Rate (DWER) was controlled at α=0.05.

Results and Discussion

CR Definitions

In order to maximise power, an attempt was first made to establish which CR definition would be most sensitive to conditioning performance. Using Revolution Studio software (version 2.7; Runtime Revolution, 2006), a computer program was written to compute various possible CR definitions in terms of six blocks of 20 trials, each block containing 10 CS+ and 10 CS- trials. Analyses were restricted to aware participants (as defined by the Long Questionnaire 13/17 criterion), because both single- and dual-process models concur that aware participants should show greater responding to the CS+ than to the CS-.

ANOVAs carried out using PSY (Bird, Hadzi-Pavlovic, & Isaac, 2000) were then used to examine orthogonal contrasts testing responding to CS+ versus CS- trials as well as the linear and quadratic trends across the six 20-trial blocks. These analyses were conducted with all possible combinations of: (i) the time window whereby eyeblinks would be counted as CRs, namely 100 ms, 500 ms, 800 ms, 1050 ms, or 1150 ms before US onset; and (ii) the mathematical formulae used to compute mean CRs per block, namely the average magnitude of CRs computed as a percentage of the mean UR magnitude for each participant (capped at 0% and 100% per trial; CR Magnitude), or the percentage of trials per block in which the CR was at least 20% of the mean UR magnitude (% CR). (See Equations 1 to 3 for these formulae as written for 500 ms window within a single trial of a block.)

$$\text{Base Mean} = \text{Ave. eyeblink amplitude (350 ms before CS onset)} \tag{1}$$

$$\text{CR Magnitude} = \frac{\text{Max. eyeblink amplitude (500ms window prior to US onset)} - \text{Base Mean}}{\text{Ave. over all CS+ trials [Max. eyeblink amplitude (200 ms after US onset)} - \text{Base Mean]}} \times 100\% \tag{2}$$

$$\%\,\text{CR} = \begin{cases} 1 \text{ if CR Magnitude} \geq 20\% \\ 0 \text{ otherwise} \end{cases} \tag{3}$$

Because F ratios give a good indication of effect size relative to the error term, large F ratios for the Trial Type main factor as well as for the Trial Type x Block interaction were taken as evidence for the sensitivity of a CR definition. Based on this criterion, the % CR definition for a 500 ms window was selected for subsequent analyses: it provided a good balance between the detection of differential conditioning performance averaged across blocks ($F(1,42) = 17.08$, $p < 0.01$) and the detection of the linear increase of differential conditioning performance across blocks ($F(1,42) = 20.46$, $p < 0.01$). Further, it was the definition that Squire used in his delay conditioning studies (Smith et al., 2005), permitting direct comparisons between the data from his studies and those from the present research. (Appendix E lists the contrasts tested as well as the F ratios for the different possible CRs.)

Awareness Questionnaires

There were no significant main effects or interactions involving the Instruction factor (CS/US versus movie) or Questionnaire Order (Long Questionnaire first versus second) on either CR performance (largest $F(1,50) = 1.68$, $p = 0.20$; see Appendix F for analyses) or proportion of participants classified as aware (largest Chi-Square(1, $N = 58$) = 1.07, $p = 0.30$; see Appendix G for analyses). Hence, subsequent analyses collapsed across these two factors.

Table 2 shows how participants' awareness classifications by the Long Questionnaire (Long Questionnaire 13/17 criterion) and Short Questionnaire (Short 50% Difference criterion) match up. There was a moderately strong association between these two measures, Phi = 0.57, which was statistically significant, Chi-Square(1, $N = 58$) = 18.93, $p < 0.01$. Other comparisons between the various awareness definitions of the Long Questionnaire and the Short Questionnaire showed that in general, the Long Questionnaire and Short Questionnaire either disagreed equally in both directions (i.e., the Long Questionnaire classified a participant as aware but the Short Questionnaire classified the same participant as unaware and vice versa), or the Long Questionnaire classified more aware participants whom the Short Questionnaire classified as unaware than vice versa. (See Appendix G for analyses and cross-tabulations relating to the different awareness definitions.)

Table 2
Number of Participants Classified as Aware or Unaware by the Long and Short Questionnaires in Experiment 1

Long Questionnaire (13/17 criterion)	Short Questionnaire (50% Difference criterion)	
	Aware	Unaware
Aware	37	6
Unaware	4	11

Awareness and Conditioning

To examine how the results of the present study matched those of Squire's delay conditioning studies, the awareness-conditioning relation was first examined using Squire's Long Questionnaire and cut-off score for assessing awareness (Long Questionnaire 13/17 criterion). With this definition of awareness, there were a total of 43 aware and 15 unaware participants. Figure 2 shows the mean percentage of CRs that participants made to CS+ and CS- over the six trial blocks. As can be seen from the graph, there was a significant overall linear decrease in mean percentage of CRs across the six blocks of 20 trials (averaged across trial type), $F(1,50) = 6.70$, $p = 0.01$. This linear trend depended both on participants' awareness status and on trial type: averaged over participants' awareness status, over the six blocks there was a significantly larger linear decrease in responding to CS- trials than there was to CS+ trials, $F(1,50) = 7.24$, $p = 0.01$. However, aware and unaware participants differed significantly in terms of the above interaction (triple interaction: $F(1,50) = 4.32$, $p = 0.04$): specifically, aware participants showed a lesser decrease in responding to CS+ across the six blocks than they did to CS-, whereas unaware participants showed similar decreases in responding to both CS+ and CS- across the six blocks.

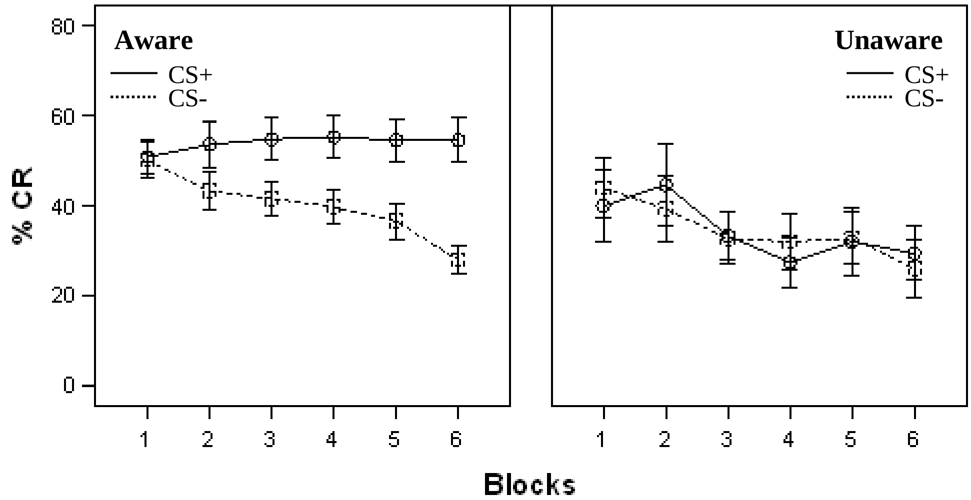

Figure 2. Experiment 1. Percentage of eyeblink conditioned responses (CRs) for aware and unaware participants (defined by a cut-off of 13 on the Long Questionnaire), across 6 blocks of 20 trials. CS+ = stimulus signalling the presence of the unconditioned stimulus; CS- = stimulus signalling the absence of the unconditioned stimulus. Points represent the mean percentage of trials per block in which the CR magnitude was at least 20% of the unconditioned response (UR) magnitude; vertical lines represent standard errors of the means.

Both aware and unaware participants did not show a typical acquisition curve (a linear increase in CRs) across blocks. Instead, all participants showed a high proportion of CRs from Block 1, suggesting that they had acquired conditioned responses to *both* auditory stimuli very rapidly (i.e., participants had learnt to respond to the CS-US relations within the first 20 trials). However, learning to condition *differentially* to CS+ and CS- took a longer time: amongst aware participants, responding to the CS- steadily decreased across blocks so that a maximal difference in responding to CS+ and CS- was only seen in Block 6. Unaware participants showed high responding to both CS+ and CS- on Block 1, but showed decreased responding to both stimuli across blocks; this appears to have been due to habituation to the airpuff US. Presumably aware participants also showed habituation, but this was offset by their associative learning to the CS+.

Averaged across blocks of trials, aware participants showed a significantly larger difference in responding to CS+ and CS- than unaware participants did, $F(1,50) = 5.12$, p =

0.03. That is, aware participants showed better acquisition of differential conditioning than did unaware participants.

Nonetheless, the possibility remains that the unaware participants successfully acquired differential conditioning, albeit at a lesser degree than did aware participants. Hence, separate follow-up analyses of aware and unaware participants were conducted to provide a more powerful test of whether unaware participants were able to show any differential conditioning. Amongst unaware participants alone, there was no significant difference in responding to CS+ and CS- averaged across all blocks, $F(1,14) = 0.01$, $p = 0.92$. As can be seen in Figure 2, this was because unaware participants showed CRs to *both* CS+ and CS-. Unaware participants also did not show any significant difference in the linear effect of training between CS+ and CS- trials, $F(1,14) = 0.13$, $p = 0.72$. Conversely, aware participants alone displayed significant more CRs to CS+ than CS-, $F(1,42) = 19.28$, $p < 0.01$; they also showed a greater linear trend across CS- than CS+ trials, $F(1,42) = 22.65$, $p < 0.01$. Hence, the present experiment found no evidence for unaware differential conditioning; only aware participants were able to acquire differential conditioning (see Appendix F for details of these analyses). This pattern of results was also observed when analyses were repeated using CRs as defined by various combinations of methods (CR Magnitude or % CR) and time windows (100 ms, 500 ms, 800 ms, 1050 ms or 1150 ms before US onset). Similarly, the same pattern was obtained when the Short Questionnaire was used to classify participants' awareness status.

In other words, using Squire's definition of awareness (Long Questionnaire 13/17 criterion), Experiment 1 failed to replicate Squire's results that differential delay conditioning can be found amongst participants classified as unaware. This undercuts the rationale for examining other definitions of awareness hypothesised to be more sensitive; the same pattern of results were obtained when alternative definitions of awareness based on Squire's Long

Questionnaire or based on the Short Questionnaire were used. Further, because the unaware participants did not show differential conditioning regardless of awareness definition used, Experiment 1 was unable to test whether these participants were able to use knowledge about the trial sequence to show apparent differential conditioning. Nonetheless, there was evidence that some contingency-unaware participants had acquired conscious knowledge about the trial sequences: of the 15 participants classified as unaware by the Long Questionnaire (13/17 criterion), 8 were classified as aware by one of the trial sequence questions on the Short Questionnaire (Short Trial Sequence Criterion); 1 was classified as aware by both questions. Theoretically, these "unaware" participants were not actually unaware: their knowledge of the trial sequences alone could in principle have been enabled them to show apparent differential conditioning.

To eliminate the possibility that the unaware participants' failure to show differential conditioning was due to the eyeblink recording equipment's selective sensitivity to voluntary blinks and insensitivity to true CRs, additional analyses were conducted whereby Squire's exclusionary criterion for voluntary blinks was applied. Squire identified these waveforms by hand (R.E. Clark, personal communication, January 24, 2006), but the present experiment used the Revolution Studio computer program to discard these waveforms according to an algorithm similar to what Squire's humans raters were instructed to use (R.E. Clark, personal communication, January 24, 2006): Eyeblinks were considered to be voluntary if they commenced before the 500 ms window before US onset, they persisted until the end of the US presentation, and the CR Magnitude for the particular trial was more than 70%. The computer program was found to have moderately high agreement (Kappa = 0.72) with a human scorer in identifying voluntary blinks from a random sample of 120 trials drawn from 40 different participants. However, deleting these apparently voluntary blinks did not affect the pattern of results that was found when these blinks were included as CRs (see Appendix F for details).

Summary

In summary, Experiment 1 found no evidence for unconscious conditioning regardless of CR and awareness definitions used. It was originally hypothesised that if the single-process model was correct, one would be able to explain any apparent unaware conditioning in terms of inaccurate classification of participants' awareness status. It was proposed that such inaccurate classification may have been due to an insensitive or invalid questionnaire, and/or post-conditioning instructions that suggested the questions about the conditioning stimuli were unimportant. However, there was no support for these hypotheses in the present experiment. First, Squire's Long Questionnaire was sensitive enough to detect an awareness-conditioning relation and the Short Questionnaire, modelled on best practices from the psychometric literature, fared no better at detecting this relation. Second, manipulations of post-conditioning instructions had no effect on awareness classifications, conditioning or the awareness-conditioning relation. Consequentially, Experiment 1 found support that Squire's classification methods (using the Long Questionnaire and the Movie instructions) and CR definitions (% CRs for a 500 ms window, with voluntary blinks deleted) can be sensitive enough to detect a close relation between awareness and conditioning, if indeed there is one.

However, Experiment 1 found no support for the dual-process theory's contention that awareness and conditioning can be dissociated in a delay conditioning design. Instead, the results of this experiment replicated Knuttinen et al.'s (2001) findings of no unaware conditioning, even when Squire's Long Questionnaire (13/17 criterion) was used. Unlike in Knuttinen et al.'s (2001) study, the results of Experiment 1 cannot be explained as an artefact of the use of EMG electrodes, of voluntary responses or of unaware participants' failure to respond to any stimulus.

EXPERIMENT 2

Experiment 1 found that, regardless of awareness questionnaire or post-conditioning instruction used, unaware participants were unable to acquire differential conditioning. That is, even when the experimental methodology closely matched those of Squire's (i.e., when Movie instructions were given, the Long Questionnaire was administered first, and the Long Questionnaire 13/17 was used to classify participants' awareness status), Experiment 1 failed to replicate Squire's previous results of unconscious conditioning within a delay conditioning task (Clark & Squire, 1998; Smith et al., 2005). Instead, Experiment 1's pattern of data within a delay conditioning task was similar to that found by Squire within a trace conditioning task (Clark & Squire, 1998). This suggests that both delay and trace conditioning may be governed by a single learning process which is closely linked to conscious awareness.

Nonetheless, it could be the case that a direct comparison between delay and trace conditioning would provide support for Squire's view that the two tasks have different underlying mechanisms for acquisition (Clark & Squire, 1999). For example, such a comparison may yield evidence suggesting that the awareness-conditioning relation is stronger for trace conditioning than it is for delay conditioning. To test this possibility, Experiment 2 compared the differential conditioning performances of aware and unaware participants who were given delay or trace conditioning tasks.

Squire has previously made such a delay versus trace conditioning comparison: analysing the delay and trace conditioning groups separately, he found that awareness was dissociated from conditioning in delay but not trace conditioning (Clark & Squire, 1998). However, he did not examine whether there was a statistical interaction between type of conditioning and the awareness-conditioning relation, a finding that would provide stronger evidence that different learning mechanisms underlie delay and trace conditioning. As a result, Experiment 2 was designed as an attempt to replicate and extend Squire's results by exploring whether there is an interaction between type of conditioning task, awareness and conditioning. Because neither post-conditioning instructions nor questionnaire order were influential in Experiment 1, Experiment 2 did not manipulate these two factors so that Squire's original procedures (administering the long questionnaire first and giving the Movie post-conditioning instructions; Clark & Squire, 1998) could be matched as closely as possible.

If the single-process model is correct, the type of conditioning (delay or trace) may affect rates of awareness or amounts of conditioning, but not the awareness-conditioning relations. That is, the single-process model predicts that only aware participants should show differential conditioning in both delay and trace conditioning; the awareness-conditioning relation would not change as a function of the interval between CS offset and US onset.

Alternatively if the dual-process model is correct, the awareness-conditioning relation should be different in delay and trace conditioning tasks. That is, the dual-process model hypothesises that both aware and unaware participants would show differential conditioning in delay conditioning tasks, but that only aware participants would show differential conditioning in trace conditioning tasks. At the very least, there should be some evidence that the awareness-conditioning relation is stronger in a trace conditioning task than in a delay conditioning task.

Method

Design

The second experiment examined whether conclusions regarding the ability of unaware participants to condition would differ depending on the type of conditioning task. The design matched Squire's delay and trace conditioning procedures (Clark and Squire, 1998) in order to explore any possible differences in the aware-conditioning relation when a delay versus a trace conditioning task were used. Hence, there were two levels of the independent variable Conditioning Type (delay vs. trace) and a further independent variable Awareness (aware vs. unaware) created based on participants' responses on the Long or Short Questionnaire. Analysis of variance (ANOVA) was used to test these effects, with differential conditioning performance as the dependent variable.

Participants

Sixty first year psychology students from the University of New South Wales participated in this experiment in partial fulfilment of course requirements. One participant was excluded because of computer errors midway through testing. Another withdrew after experiencing discomfort associated with the airpuffs. The remaining 58 participants were randomly allocated to two groups. The first group (*M* age = 20 years, *SD* = 2.60 years), comprising of 13 men and 17 women, were given a delay conditioning task; the second group (*M* age = 21.03 years, *SD* = 5.05 years), comprising of 11 men and 17 women, were given a trace conditioning task.

Materials

The materials in Experiment 2 were identical to those of Experiment 1, except that an additional programming code was created in Med-PC (version 1; Med Associates Inc. & Tatham, 1991) for the trace conditioning task. As with the delay conditioning task, 120 trials or six blocks of 20 trials were programmed: CS+ trials comprised half of the trials and CS- trials comprised the other half, and the allocation of the tone and white noise to CS+ was counter-balanced across participants. The interval between trials was 10-15 s, with trial type (CS+ or CS-) being randomised within the restrictions that no one trial type could occur more than twice in a row. However, the CS in the trace conditioning task had a shorter CS duration (250 ms) than that in the delay conditioning task; the ISI (1250 ms) and US duration (100 ms) were matched across both tasks. (Figure 3 shows how the CS and US are temporally related for the delay and trace conditioning tasks.)

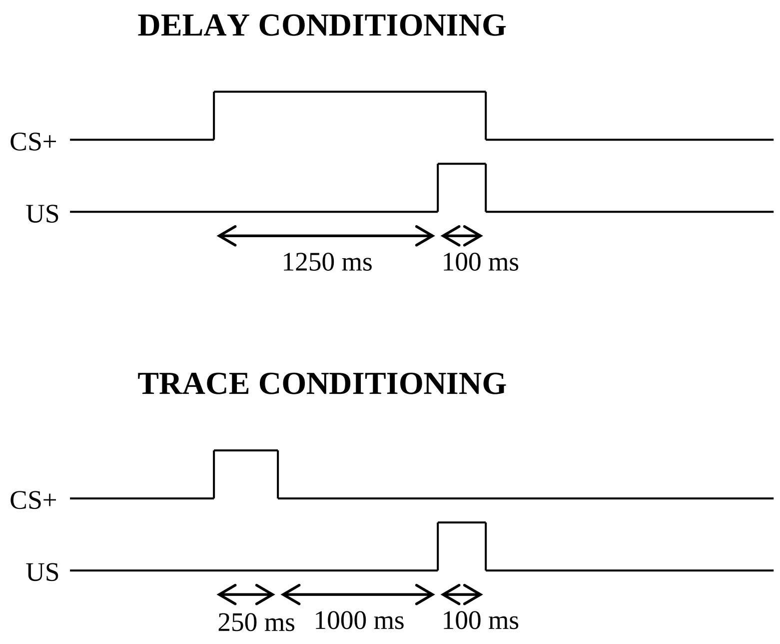

Figure 3. Time sequence of events within a CS+ trial in Experiment 2, for each type of conditioning task.

Procedure

All participants underwent an experimental procedure identical to that of the Movie Instructions-Long Questionnaire first group of Experiment 1 (i.e., the movie cover story continued after conditioning and all participants filled in the Long Questionnaire before the Short Questionnaire), except that half of the participants were given a delay conditioning task and half were given a trace conditioning task.

Data Analyses

Data analyses were conducted using Squire's CR definitions (% CR for a 500 ms window; Smith et al., 2005). As in Experiment 1, an Awareness group variable was created based on participants' awareness status. Hence, the final analysis involved planned orthogonal contrasts in a (2) x (6) x 2 x 2 ANOVA analysis with Trial Type (CS+ or CS-), Trial Blocks (1 to 6), Awareness Status (Aware or Unaware) and Conditioning Task (Delay or Trace) as the factors. The dependent variable was % CR per block, and the Type 1 Decision Wise Error Rate (DWER) was controlled at α=0.05. ANOVA analyses were repeated with the application of Squire's criterion to exclude "voluntary" eyeblinks.

Results and Discussion

Awareness Questionnaires

As shown in Table 3, the Long Questionnaire (Long Questionnaire 13/17 criterion) classified a smaller proportion of participants as unaware for the Delay group than for the Trace group. This finding is consistent with the notion that trace conditioning may be a more difficult task than delay conditioning is (e.g., Baer & Fuhrer, 1968). However, the effect of conditioning task on awareness was not significant, Chi-Square(1, N = 58) = 1.79, p = 0.18 (see Appendix H for details of this analysis).

Table 3
Number of Delay and Trace Participants Classified as Aware or Unaware by the Long Questionnaire in Experiment 2

Long Questionnaire (13/17 criterion)	Conditioning Task	
	Delay	Trace
Aware	24	18
Unaware	6	10

Awareness and Conditioning

Long Questionnaire Awareness Definition

Figure 4 shows aware and unaware participants' eyeblink responses as a function of blocks of 20 trials, wherein awareness was defined by Squire's questionnaire (Long Questionnaire 13/17 criterion). With this definition, there were a total of 24 aware and 6 unaware participants in the Delay group, and a total of 18 aware and 10 unaware participants in the Trace group.

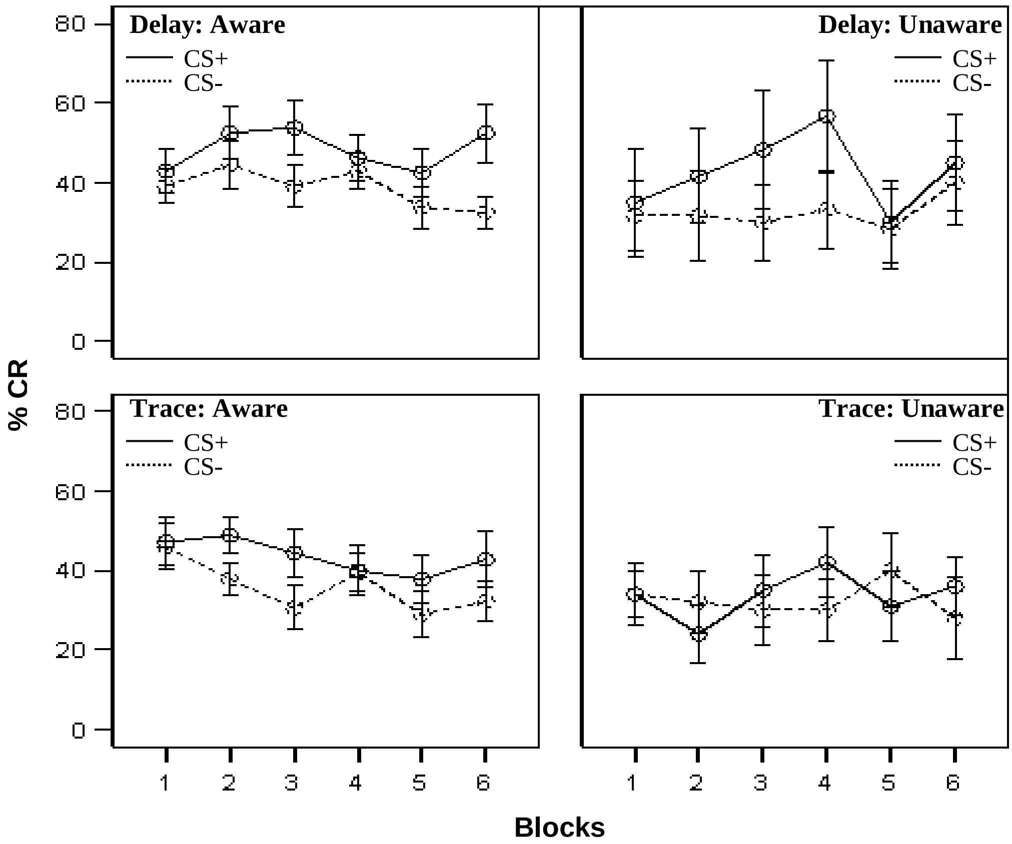

Figure 4. Experiment 2. Percentage of eyeblink conditioned responses (CRs) for aware and unaware participants (defined by a cut-off of 13 on the Long Questionnaire) in delay and trace conditioning, across 6 blocks of 20 trials. CS+ = stimulus signalling the presence of the unconditioned stimulus; CS- = stimulus signalling the absence of the unconditioned stimulus. Points represent the mean percentage of trials per block in which the CR magnitude was at least 20% of the unconditioned response (UR) magnitude; vertical lines represent standard errors of the means.

As can be seen in Figure 4, participants did not show any consistent linear increase or decrease in CRs across blocks of trials. Accordingly, when all participants were included, ANOVA analyses found no significant main or interaction effects involving the linear trend across blocks (largest $F(1,54) = 2.61$, $p = 0.11$). The only exception arose when the aware participants in the Trace group were analysed separately: averaged across CS Type, these participants showed a significant linear decrease in CRs across the six blocks of trials, $F(1,17) = 4.43$, $p = 0.05$. This suggests that the aware Trace participants may have habituated to the US over blocks of trials. Because there were no significant effects involving the interaction between CS Type and the linear trend across blocks (largest $F(1,54) = 3.40$, $p = 0.07$), subsequent analyses involving the CS Type factor collapsed across the six blocks.

Averaged across conditioning task and awareness status, participants showed significantly more responding to the CS+ than to the CS-, $F(1,54) = 9.09$, $p < 0.01$. Figure 4 suggests that both aware and unaware participants in the Delay group showed CS+ and CS- discrimination, as did aware participants in the Trace group (albeit to a lesser degree than did participants in the Delay group). There was no evidence that unaware participants in the Trace group acquired differential conditioning. ANOVA analyses revealed that unlike in Experiment 1, the interaction between CS Type and Awareness status was not significant (averaged across Conditioning Task, $F(1,54) = 0.36$, $p = 0.55$). Although there was a trend in the data suggesting that the relation between awareness and differential conditioning was stronger in trace conditioning than in delay conditioning, this difference was not significant, $F(1,54) = 0.52$, $p = 0.48$. Further, there was no significant effect of type of task (trace vs. delay) on differential conditioning, averaged across participants' awareness status, $F(1,54) = 1.30$, $p = 0.26$.

To explore this pattern further, separate analyses were conducted for the Delay and Trace groups. Amongst Delay participants alone, there was no significant interaction between CS Type and Awareness status, $F(1,28) = 0.01$, $p = 0.92$. When the Delay group was further analysed separately based on awareness status, aware participants showed significantly more responses to CS+ than to CS-, $F(1,23) = 8.91$, $p < 0.01$, whereas unaware participants did not significantly differ in their responses to CS+ and CS-, $F(1,5) = 2.49$, $p = 0.18$. Amongst Trace participants alone, there was again no significant interaction between CS Type and Awareness status, $F(1,26) = 1.02$, $p = 0.32$. When analysed separately, aware Trace participants showed significantly greater responding to CS+ than to CS-, $F(1,17) = 4.18$, $p = 0.05$; unaware participants did not, $F(1,9) = 0.07$, $p = 0.80$. Deleting voluntary responses according to Squire's criterion (Smith et al., 2005) made no impact on the general pattern of results.

Taken together, the results from Experiment 2 suggest that when awareness was defined by the Long Questionnaire (13/17 criterion), awareness of CS-US contingencies was not strongly associated with differential conditioning in either the delay or trace conditioning tasks. At the same time, the evidence that unaware participants were able to acquire differential conditioning was not very convincing regardless of conditioning task. However, the data suggest that had there been more unaware participants (there were only six), the analysis would have had more power and the unaware participants in the delay conditioning group may have been able to show differential conditioning. This pattern of results was unexpected, given the clear association between awareness and conditioning in Experiment 1.

Short Questionnaire Awareness Definition

In Experiment 1, the Short Questionnaire had been introduced as a potentially more psychometrically sound measure of detecting participants' contingency awareness than was the Long Questionnaire. The results of Experiment 1 provided little support for this hypothesis because both questionnaires were able to capture an awareness-conditioning relation. However, because in Experiment 2 both aware and unaware participants classified by the Long Questionnaire (13/17 criterion) showed similar conditioning performances (regardless of conditioning task), the possibility remained that for Experiment 2, the Long Questionnaire was not sufficiently sensitive to detect participants' knowledge of CS-US relations. Unfortunately, Experiment 2 had not been maximally designed to test this possibility: for every participant, the Short Questionnaire was administered after the Long Questionnaire such that the interval between conditioning trials and completion of the Short Questionnaire was long, possibly diminishing the sensitivity of the Short Questionnaire. Nonetheless, analyses were repeated with an awareness definition based on the Short

Questionnaire. When the Short Questionnaire 50% Difference Criterion was used (as in Experiment 1), the relation between awareness and differential conditioning was weak; however, when a 75% Difference Criterion was used, a strong awareness-conditioning relation was apparent. With this definition, there were a total of 17 aware and 13 unaware participants in the Delay group, and a total of 10 aware and 18 unaware participants in the Trace group. Figure 5 shows aware and unaware participants' eyeblink responses as a function of blocks of 20 trials.

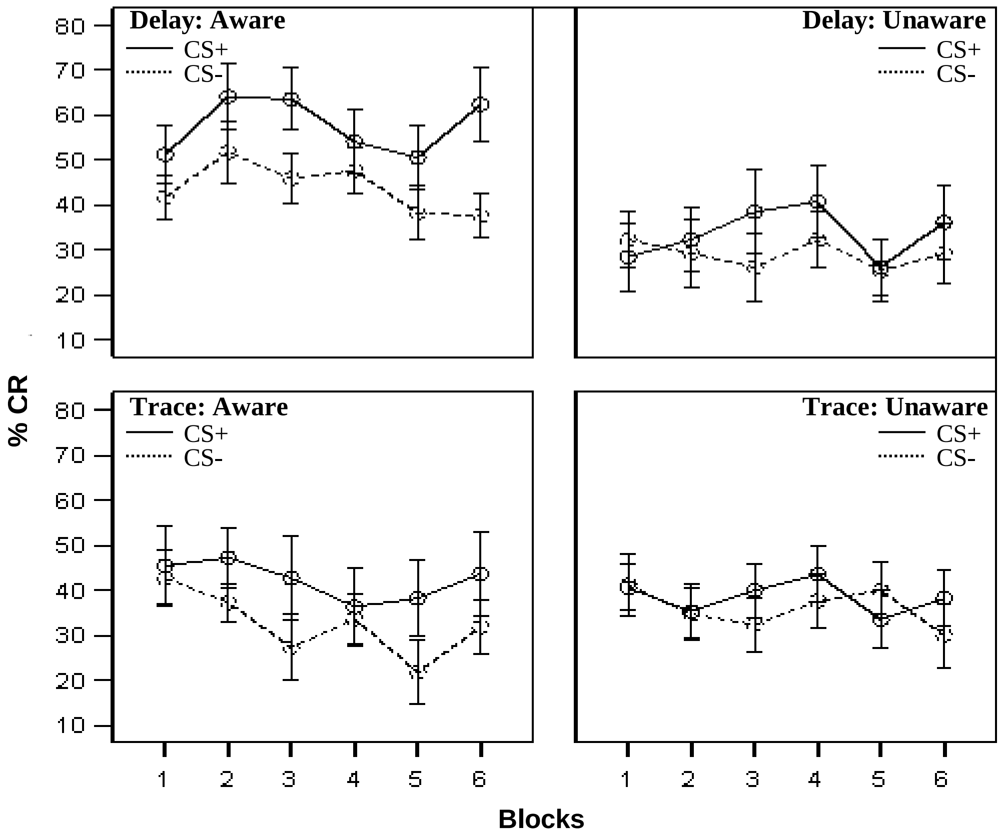

Figure 5. Experiment 2. Percentage of eyeblink conditioned responses (CRs) for aware and unaware participants (defined by a cut-off of 75% difference of greater rated predictability of the reinforced stimulus than the stimulus presented alone, on the Short Questionnaire) in delay and trace conditioning, across 6 blocks of 20 trials. CS+ = stimulus signalling the presence of the unconditioned stimulus; CS- = stimulus signalling the absence of the unconditioned stimulus. Points represent the mean percentage of trials per block in which the CR magnitude was at least 20% of the unconditioned response (UR) magnitude; vertical lines represent standard errors of the means.

As seen in Figure 5, there was no reliable linear increase or decrease in conditioned responses across blocks. ANOVA analyses found no significant main or interaction effects involving the Block factor (largest $F(1,54) = 2.54$, $p = 0.12$); hence, subsequent analyses collapsed across the six trial blocks.

Overall, averaged across awareness status (Short Questionnaire 75% Difference Criterion) and type of conditioning task, participants showed more CRs to the CS+ than to the CS-, $F(1,54) = 14.80$, $p < 0.01$. However, a comparison between Figures 4 and 5 suggests that the aware participants as defined by the Short Questionnaire showed more differential conditioning than did the aware participants as defined by the Long Questionnaire; simultaneously, the unaware participants classified by the Short Questionnaire showed less differential conditioning than did the unaware participants classified by the Long Questionnaire. Consistent with this, statistical analyses revealed that averaged across type of conditioning task, the aware participants showed a significantly greater difference in responding to CS+ and CS- than did the unaware participants, $F(1,54) = 5.05$, $p = 0.03$. Participants allocated to Delay versus Trace groups did not differ in differential conditioning performance shown (averaged across awareness status), $F(1,54) = 0.35$, $p = 0.56$; nor did they differ in terms of the awareness-conditioning relation found, $F(1,54) < 0.01$, $p = 0.98$.

Follow-up tests analysed the Delay and Trace groups separately. Amongst Delay participants as a group, there was no significant effect of awareness, $F(1,28) = 2.63$, $p = 0.12$. However, when participants were further divided in terms of their awareness status, aware participants showed significantly more responses to CS+ than to CS-, $F(1,16) = 13.70$, $p < 0.01$, whereas unaware participants did not, $F(1,12) = 1.17$, $p = 0.30$. Similarly, amongst Trace participants as a group there was no significant effect of awareness, $F(1,26) = 2.43$, $p = 0.13$. However, when analysed alone the aware Trace participants showed significantly more CRs to CS+ than to CS-, $F(1,9) = 5.58$, $p = 0.04$, whereas unaware Trace participants did not,

$F(1,17) = 0.315$, $p = 0.58$. Deleting voluntary responses according to Squire's criterion (Smith et al., 2005) made no impact on the general pattern of results.

As a whole then, the Short Questionnaire (75% Difference Criterion) appears to have been more sensitive in capturing the awareness-conditioning relation than was the Long Questionnaire: when the Short Questionnaire was used, the interaction between awareness and differential responses to CS+ and CS- was significant when all participants were analysed (averaged over of Conditioning Task). When Delay and Trace groups were analysed separately, there was no significant interaction of Awareness and CS Type; however, the F ratios for these contrasts were larger when the Short Questionnaire was used than when the Long Questionnaire was used, further supporting the conclusion that the Short Questionnaire was more sensitive to detecting a relation between awareness and conditioning. Similarly, the F ratios for the CS Type main effect were larger amongst Delay and Trace groups' aware participants and smaller amongst Delay and Trace groups' unaware participants (analysed separately) when the Short Questionnaire was used than when the Long Questionnaire was used. (For details of these analyses, see Appendix I.)

Trial Sequence Awareness

Nonetheless, Figure 5 suggests that even when the Short Questionnaire (75% Difference criterion) was used to define awareness, the Delay unaware participants were still able to show some differential conditioning. Hence, these participants were further examined for evidence that they may have used trial sequence knowledge to show this apparent differential conditioning.

Of the 13 participants classified as unaware by the Short Questionnaire (75% Difference criterion), 9 were classified as aware by one of the trial sequence questions on the Short Questionnaire (Short Trial Sequence Criterion) and 1 was classified as aware by both questions. The conditioning data for the one participant classified as contingency unaware but trial sequence aware was examined as a function of predictability of the particular trial. Consistent with the hypothesis that this participant may have been using trial sequence knowledge on the conditioning task, she showed more CRs to CS+ trials that could be predicted by trial sequence than to CS+ trials which could not be predicted by trial sequence. Correspondingly, this participant also showed fewer CRs to predicted CS- trials than to the unpredicted CS- trials. When ANOVA analyses using the Short Questionnaire (75% Difference Criterion) were repeated excluding this participant, amongst the unaware Delay participants alone there was no longer any suggestion that these participants showed more responses to CS+ than to CS- (averaged across blocks), $F(1,12) = 0.20$, $p = 0.66$. Further, the interaction between differential conditioning and awareness was now significant: the aware Delay participants now showed a significantly greater difference in responding to CS+ and CS- than did the unaware Delay participants, $F(1,28) = 4.42$, $p = 0.05$. (See Appendix I for details of these analyses.)

Summary

Thus, Experiment 2 found that when the Long Questionnaire (13/17 criterion) was used to classify participants' awareness status, the data were partially reminiscent of Squire's data (Clark & Squire, 1998; Smith et al., 2005). With the Delay group, there was no significant relation between awareness and conditioning: the pattern of results was compatible with the possibility that both Delay aware and unaware participants can acquire differential conditioning. However, the evidence that Delay unaware participants were showing differential responses to CS+ and CS- was not conclusive because it was not statistically significant. With the Trace group, although the relation between awareness and differential conditioning was not significant, only the aware participants appeared to have shown differential conditioning. There was no suggestion in the data that Trace unaware participants may have acquired differential conditioning.

On the other hand, when the Short Questionnaire (75% Difference criterion) was used to classify participants as aware or unaware, an association between awareness and conditioning was found in the combined group of Delay and Trace participants. These results suggest that the Short Questionnaire was more sensitive than the Long Questionnaire in detecting participants' true awareness status. Nonetheless, even when the Short Questionnaire was used to define awareness there continued to be a suggestion that some unaware participants may have acquired differential conditioning. That is, the poor sensitivity of the Long Questionnaire (relative to the Short Questionnaire) explains some but not all of the observed lack of relation between awareness and conditioning when the Long Questionnaire was used. A second explanation that may be appealed to is the poor content validity of the Long Questionnaire in capturing all possible rules that participants may have used to solve the conditioning task: although trial sequence knowledge alone may have permitted the "unaware" participants to show a pattern of conditioned responses akin to that of differential conditioning, participants had no opportunity to show this knowledge on the Long Questionnaire. Experiment 2 found some evidence to suggest that some participants classified as unaware of CS-US contingencies could have used knowledge of trial sequencing to perform the conditioning task.

Finally, in contradiction to Squire's theory (e.g., Clark & Squire, 1999), when the Short Questionnaire was used there was no evidence that the relation between awareness and conditioning differed depending on whether a delay or trace procedure was used. Although there was a non-significant trend suggesting that trace conditioning was harder than delay conditioning in terms of rates of awareness and rates of differential conditioning, there was no evidence that trace conditioning differed from delay conditioning in terms of the awareness-conditioning relation participants showed.

GENERAL DISCUSSION

The focus of this research had been to compare the single- and dual-process accounts of learning. To this end, the present research explored why previous literature has yielded conflicting results regarding the involvement of conscious awareness in human eyeblink conditioning. Specifically, Experiments 1 and 2 were designed to investigate why Squire had previously found evidence for unaware delay conditioning (supporting a dual-process model; Clark & Squire, 1998; Smith et al., 2005), whereas other researchers had found no such evidence (supporting a single-process model; e.g., Bellebaum & Daum, 2004; Knuttinen et al., 2001; Nelson & Ross, 1974).

Principle Findings

Experiment 1

The first experiment examined whether discrepancies in the conditioning literature could have been due to differences in the sensitivity and validity of different awareness classification methods. It was hypothesised that because Squire's awareness classification methods were not in line with best practices from the psychometric literature, they may not have been as sensitive or valid as those used in other delay conditioning studies. Hence, different questionnaires and post-conditioning instructions were explored to see if these could alter conclusions made about the awareness-conditioning relation.

Experiment 1 found that, regardless of the questionnaire or post-conditioning instruction used, performance on a differential delay conditioning task was closely linked to awareness of CS-US contingency: only aware participants acquired differential conditioning; unaware participants failed to discriminate between CS+ and CS- even after 120 conditioning trials. This pattern of results is similar to that of Knuttinen et al. (2001), who also found no evidence for unconscious delay conditioning despite using Squire's experimental procedures and awareness questionnaire. Thus, Experiment 1 represents a second empirical failure to replicate Squire's delay conditioning results (Clark & Squire, 1998; Smith et al., 2005). Further, Experiment 1 extended Knuttinen et al.'s (2001) study by demonstrating that this failure to replicate was not specific to one CR definition nor due to the inclusion of voluntary eyeblinks. Additionally, the observation that only aware participants showed conditioning was not an artefact of Knuttinen et al.'s (2001) eyeblink recording equipment, which Squire suggested may have been selectively sensitive to aware participants' voluntarily-emitted eyeblinks but not to unaware participants' involuntarily-emitted conditioned responses (Manns et al., 2002; Smith et al., 2005).

Experiment 1's failure to find unconscious conditioning with Squire's questionnaire and post-conditioning instructions precluded further analyses about the impact of using different awareness classification methods. That is, because Squire's awareness classification methods were found to be sufficiently sensitive and valid to detect an awareness-conditioning relation in Experiment 1, the use of another awareness questionnaire and/or post-conditioning instruction did not alter conclusions made about the association between contingency awareness and performance of CRs.

Experiment 2

The second experiment was designed to extend and replicate the results of Experiment 1 through a direct comparison of learning on delay and trace conditioning tasks. This comparison permitted an exploration of whether delay and trace conditioning were governed by different learning mechanisms, as Squire had theorised (e.g., Clark & Squire, 1999).

Experiment 2 found that when Squire's Long Questionnaire (13/17 Criterion) was used, awareness was not significantly associated to delay conditioning performance. Further, there was some evidence (a non-significant trend) that the Delay unaware participants had acquired differential conditioning. These results differed from those of Experiment 1 and previous delay conditioning studies which found awareness to be closely linked to conditioning (e.g., Bellebaum & Daum, 2004; Knuttinen et al., 2001; Nelson & Ross, 1974); instead, Experiment 2's delay conditioning results were comparable to those of Squire's (Clark & Squire, 1998; Smith et al., 2005). Similarly, Experiment 2's trace conditioning results were consistent with Squire's contention that awareness is necessary for trace conditioning (Clark & Squire, 1998): although the difference between aware and unaware participants' differential conditioned responses was not significant, only aware participants showed differential conditioning. There was no trend in the data suggesting that unaware participants had acquired any differential conditioning.

That is, when Squire's Long Questionnaire was used, Experiment 2 showed some support for Squire's theory that awareness can be dissociated from performance in delay but not trace conditioning. However, this evidence was weak for three reasons. First, to make a convincing case that delay and trace conditioning are governed by different learning mechanisms, one should be able to show a statistically significant interaction between the type of conditioning task and the awareness-conditioning relation found. This interaction was not significant in Experiment 2. Second, for evidence of unconscious delay conditioning to be persuasive, unaware participants in the delay group should show significantly more conditioned responses to the CS+ than to the CS-. This differential conditioning effect did not reach significance amongst Experiment 2's unaware participants. Last, to show that any effects are robust, the effects should not be specific to a particular awareness questionnaire used; instead, the same pattern of results should be found using different awareness questionnaires. In Experiment 2, the lack of any significant interaction between awareness and conditioning was only found when Squire's Long Questionnaire (13/17 Criterion) was used. When the Short Questionnaire (75% Difference Criterion) was used, awareness was found to be significantly related to conditioning, collapsed across delay and trace conditioning groups. Further, there was no evidence that the awareness-conditioning relation differed depending on the type of conditioning task (delay versus trace). Because the Short Questionnaire was designed to maximise questionnaire sensitivity by following recommendations from the psychometric literature, the Short Questionnaire's finding of an awareness-conditioning relation undermines the conclusion, based on the Long Questionnaire, that awareness can be dissociated from delay conditioning. Any suggestion that unaware participants in the delay group may have been conditioning could be further explained by unaware participants' usage of trial sequence rules to emit conditioned responses in a manner resembling differential conditioning.

On the whole, then, Experiment 2 supports the single-process model's hypotheses that findings of unaware conditioning may be an artefact of the poor sensitivity and content validity of an awareness questionnaire. This suggests that the conflicting findings regarding the awareness-conditioning relation in previous eyeblink conditioning literature could have been due to differences in the psychometric properties of awareness questionnaires used.

Factors Influencing the Long Questionnaire's Performance

Although Squire's Long Questionnaire was found to be unsuitable for assessing awareness-conditioning relations in Experiment 2, the same questionnaire was able to detect awareness-conditioning relations in other delay conditioning studies (Experiment 1; Knuttinen et al., 2002) as well as in Squire's own trace conditioning studies (e.g., Clark & Squire, 1998). That is, within one experimental design – differential eyeblink conditioning using a movie masking task – Squire's Long Questionnaire has been found to be able sometimes and unable at other times to classify participants accurately enough that an awareness-conditioning relation can be detected. This is not because of different learning mechanisms underlying different task structures (delay versus trace conditioning): even with the same task – delay conditioning – the Long Questionnaire sometimes yielded a pattern of results suggesting an awareness-conditioning *dissociation* (Experiment 2; Clark & Squire, 1998; Smith et al., 2005) and other times yielded a pattern of results suggesting an awareness-conditioning *relation* (Experiment 1; Knuttinen et al., 2001). Thus, it appears that the psychometric properties of the Long Questionnaire may change depending on the exact conditions in which it is used. That is, there may be factors outside the questionnaire which determines how well it can perform in a conditioning experiment. One such extra-questionnaire factor could be the likelihood that participants would remember the CS-US relations by the time they reach the critical questions on the Long Questionnaire. Alternatively, another extra-questionnaire factor could be the total number of unaware participants found within a conditioning experiment.

Likelihood of Remembering CS-US Relations

Subject Sophistication

In terms of how likely participants are able to remember the CS-US relations when the Long Questionnaire asks about them, *subject sophistication* or participants' familiarity with psychology may play a role (Page, 1970; Page & Lumia, 1968). For example, Experiment 1 was conducted at the tail-end of the academic year when participants were nearing completion of their second psychology course; that is, most participants would have learnt about classical conditioning by the time they participated in the experiment. On the other hand, Experiment 2 was conducted at the beginning of the academic year when participants had just enrolled in their first psychology course; most participants were unfamiliar with classical conditioning at the time of the experiment. Thus, the greater subject sophistication in Experiment 1 than in Experiment 2 may have moderated the ease at which participants forgot conditioning contingencies. In turn, this could have influenced the Long Questionnaire's ability to detect participants' awareness status during conditioning and hence, determined whether an awareness-conditioning relation could be found. In support of this, a substantial number of participants in Experiment 1 guessed during debriefing that the study had been about conditioning. Further, no participants reported that they had forgotten or gotten confused about the CS-US relations by the time they had gotten to the key questions in the Long Questionnaire. In contrast, no participant in Experiment 2 suggested at debriefing that the study may have been about conditioning. In addition, several participants in Experiment 2 claimed that throughout the conditioning trials, they had known that one sound (CS) was always presented with the airpuff (US) and the other sound was not. However, these participants claimed that by the time they had filled in five pages of the Long Questionnaire asking them about knowledge unrelated to CS-US relations, they had forgotten or gotten confused over which sound was which. Hence, when they reached the critical questions on the Long Questionnaire, they were unable to report how each sound was related to the airpuff.

One reason why general knowledge about classical conditioning may have been important is that it could have caused participants to actively search for a relation between the conditioning stimuli, which could have resulted in participants processing the CS-US relations more deeply than if they had not undergone such an active search. Previous research has shown that deeper processing during encoding of information facilitates subsequent recall of the information (Craik & Tulving, 1975). Hence, it could be that Experiment 1's aware participants had good memory for the CS-US relations at test because they had actively searched for it. On the other hand, some participants in Experiment 2 may have forgotten the CS-US relations they had consciously learnt during conditioning because they had not actively searched for these relations and hence, had not processed this information deeply. Consequentially, the Long Questionnaire was more sensitive in Experiment 1 than in Experiment 2 at detecting participants' true awareness status during learning.

However, if knowing about conditioning paradigms led participants to actively search for CS-US relations, then one should find a higher proportion of aware participants in

Experiment 1 than in Experiment 2. That the rates of awareness were similar in Experiment 1 and Experiment 2 suggests that general knowledge about conditioning may have had effects *after* rather than *before* participants were cognisant of how the conditioning stimuli were related. Perhaps the Long Questionnaire was able to detect an awareness-conditioning relation in Experiment 1 because participants who became aware of CS-US relations were able to link these relations to their prior knowledge about classical conditioning. That is, the CS-US relations were sufficiently salient or memorable for Experiment 1's aware participants, enabling these participants to report the CS-US relations mid-way through the Long Questionnaire. In contrast, in Experiment 2 the Long Questionnaire may have been insensitive to participants' true awareness status because the CS-US relations were not salient for participants who became aware of these relations. That is, because participants who became aware of the CS-US relations continued to believe that the study was about the movie, they did not place much importance on the CS-US relations observed. Hence, by the time the Long Questionnaire asked participants about their contingency knowledge, some aware participants may have forgotten which CS had been reinforced in the conditioning trials. As a result, these participants had to guess which CS was related to the US: if they had guessed this incorrectly, they would have been wrongly classified as having had no knowledge of CS-US relations during learning. Thus, this account suggests that demand characteristics or participants' views on what was important in the experiment may have influenced the accuracy of the Long Questionnaire in classifying them. Unfortunately, Experiment 2 had not been designed to explore this possibility. First, all participants completed the Long Questionnaire based on instructions that the questions about the movie were the focus of the questionnaire. Second, amongst participants who wrongly reported that the CS- (rather than the CS+) was related to the US and who also showed differential conditioning, it was difficult to distinguish between those who had been aware during conditioning but who had forgotten which sound was the CS+, from those who had guessed a wrong hypothesis but whose conditioned responses were nonetheless independent of their conscious knowledge. The possibility remains that although demand characteristics did not influence the awareness-conditioning relations found when participants were familiar with psychology (as in Experiment 1), demand characteristics may have an impact when participants are unfamiliar with psychology. Hence, future research should examine the effects of different post-conditioning instructions amongst a group of participants unfamiliar with psychology.

Task Difficulty

Although subject sophistication may account for the differences between Experiment 1's and Experiment 2's delay conditioning results, it is not a convincing explanation for the differences between Squire's delay and trace conditioning results (Clark & Squire, 1998). That is, because participants in Squire's delay and trace conditioning groups were drawn from the same population, it seems unlikely that subject sophistication explains why the Long Questionnaire performed differently in Squire's delay and trace conditioning groups. Nonetheless, possible differences in the salience of CS-US relations may have arisen because of differences in task difficulties. It may be that because trace conditioning was a harder task than delay conditioning to acquire (in terms of conscious awareness or conditioning performance; Baer & Fuhrer, 1968; Kehoe & Schreurs, 1986), the CS-US relations in trace conditioning had to be more salient for participants than they were in delay conditioning before participants in the trace group could become aware of the relations. As a result, by the time the Long Questionnaire addressed the conditioning contingencies six pages into the questionnaire, trace conditioning participants who had become aware of CS-US relations were more likely than delay conditioning participants to still remember the CS-US relations. To test this possibility, future studies should manipulate task difficulty (e.g., by putting a greater load on participants' working memory during conditioning) to see if a more difficult task could result in stronger awareness-conditioning relations found with the Long Questionnaire.

However, if the Long Questionnaire failed to show an awareness-conditioning relation because at test participants had forgotten the CS-US relations they had learnt during conditioning, then it is unclear why the Short Questionnaire was able to detect this awareness-conditioning relation in Experiment 2. In Experiment 2, the Short Questionnaire always followed the Long Questionnaire: if participants' forgetting of the CS-US relations limited the sensitivity of the Long Questionnaire, then the Short Questionnaire should have been similarly affected. If anything, one would expect even more participants to have forgotten the CS-US relations by the time they filled in the Short Questionnaire, because the interval between conditioning trials and the Short Questionnaire was even longer than that between conditioning trials and the Long Questionnaire's key questions on the CS-US relations.

It could still be the case that the Short Questionnaire was better able to classify participants' true awareness status because of its simplicity: perhaps, participants were able to "start afresh," ignoring all that they had written on the Long Questionnaire. The Short Questionnaire may have encouraged them to cast their minds back to the conditioning trials such that they were able to recall the CS-US relations and report these relations accurately. However, this explanation suggests that the Long Questionnaire had misclassified aware participants as unaware, and that the Short Questionnaire re-classified these misclassified unaware participants as aware. In fact, the disagreements in classifications occurred in the opposite direction (see Table 4). That is, although there was a moderately strong agreement between the awareness classifications of the two questionnaires (Phi = 0.58, which was statistically significant, Chi-Square(1, $N = 58$) = 19.24, $p < 0.01$; see Appendix J for details), where there was disagreement in classifications it was because the Short Questionnaire classified the Long Questionnaire's aware participants as unaware. None of the Long Questionnaire's unaware participants were classified as aware by the Short Questionnaire.

Table 4

Number of Participants Classified as Aware or Unaware by the Long and Short Questionnaires in Experiment 2 (Collapsed Across Groups)

Long Questionnaire (13/17 criterion)	Short Questionnaire (75% Difference criterion)	
	Aware	Unaware
Aware	27	15
Unaware	0	16

Number of Unaware Participants

In other words, the ability of the Short Questionnaire (75% Difference Criterion) to detect an awareness-conditioning relation in Experiment 2 was not because it had classified as aware participants whom the Long Questionnaire (13/17 Criterion) had wrongly classified as unaware. Instead, the advantage of the Short Questionnaire appears to have been because it produced a greater number of unaware participants than did the Long Questionnaire. That is, using the Short Questionnaire did not explain away the differential conditioning performance of the Long Questionnaire's unaware participants as an artefact of the Long Questionnaire's poor sensitivity. Rather, the Short Questionnaire amalgamated the small group of the Long Questionnaire's unaware participants with a larger number of unaware participants who did not show conditioning. With this larger group of unaware participants, any evidence of unaware differential conditioning collapsed.

The hitherto analysis suggests that the differential conditioning performance of the participants classified as unaware by both questionnaires is still unaccounted for by a single-process model. That is, these participants' performance appears to support the dual-process model. However, the evidence for unconscious conditioning comes into question by the finding that unaware participants in Experiment 2 may have been aware of the experiment's trial sequences. For example, amongst the unaware participants in Experiment 2's delay conditioning group, most participants reported partial knowledge of the two trial sequence rules. Although only one participant showed knowledge of both trial sequence rules, this participant also appeared to show CRs consistent with these rules. Further, her conditioning performance alone was able to account for much of the apparent differential conditioning found in the group of unaware participants.

Together, Experiment 2's pattern of results suggests that the Long Questionnaire may be valid for assessing awareness as long as participants do not use knowledge about trial sequences to show conditioned responses, as is the case with most participants. However, the Long Questionnaire has poor content validity when used with a very small proportion of participants who do not show contingency awareness but who are fully aware of the two trial sequence rules: because the Long Questionnaire does not acknowledge that these participants may be using trial sequence knowledge to perform the conditioning task, the Long Questionnaire would misclassify these participants as unaware. If the number of participants who are misclassified is large relative to the total number of unaware participants, then the use of the Long Questionnaire could lead to the erroneous conclusion that awareness and conditioning is unrelated. In general, this may mean that the larger the unaware group, the more likely it would be that the Long Questionnaire can detect an awareness-conditioning relation if there is one.

Consistent with this hypothesis, studies that have found an awareness-conditioning relation using Squire's Long Questionnaire (e.g., Experiment 1; Knuttinen et al., 2001) have generally involved a larger group of unaware participants than studies that have found no such relation (e.g., Experiment 2; Smith et al., 2005). Future research should examine the ability of the Long Questionnaire to detect awareness-conditioning relations as a function of the total number of participants classified as unaware, wherein conditioning involves Squire's

(Smith et al., 2005) trial sequences. Also, further studies should attempt to replicate Squire's results of unconscious delay conditioning with a randomised trial sequence, wherein the restriction on runs is not limited to two trials of the same type.

However, the size of the unaware group does not explain why Squire's Long Questionnaire was able to detect an awareness-conditioning relation in his trace conditioning tasks but not his delay conditioning tasks (Clark & Squire, 1998), because the unaware delay groups were similar in size to the unaware trace groups in his study.

Combination of Factors

In other words, no single factor identified has been able to account for all previous findings relating to the use of the Long Questionnaire. It appears that a *combination* of extra-questionnaire factors determines how the Long Questionnaire would perform in a particular experiment. Because the Long Questionnaire has now been used in several conditioning studies, the present paper calls for research to determine the exact circumstances under which it is appropriate to use the Long Questionnaire. It is tentatively suggested that the Long Questionnaire may be sufficiently sensitive and valid for assessing contingency awareness when: participants are familiar with psychology, the conditioning task is difficult, the total number of unaware participants is large, and/or trial sequences are random. If further research supported the use of the Long Questionnaire under these circumstances, then studies showing a lack of an awareness-conditioning relation in these circumstances may be considered as evidence that awareness can be dissociated from conditioning. On the other hand, findings of awareness-conditioning dissociations would provide little information about the true relations between awareness and conditioning if the Long Questionnaire was used in circumstances known to limit its sensitivity and validity (e.g., when participants are unfamiliar with psychology, the conditioning task is simple, the total number of unaware participants is small, and/or trial sequences are restricted to runs of two or less).

Integration of Results with the Theoretical Background

Taken together, Experiments 1 and 2 suggest that Squire’s findings of unaware participants acquiring delay conditioning (Clark & Squire, 1998; Smith et al., 2005) was not convincing evidence for unconscious learning. The first experiment failed to replicate Squire’s delay conditioning results, questioning the robustness of his findings. Although the second experiment partially replicated Squire’s findings with his Long Questionnaire, the second experiment found a significant awareness-conditioning relation when a different awareness questionnaire was used; this suggested that Squire’s findings of unaware delay conditioning (Clark & Squire, 1998; Smith et al., 2005) could be an artefact of his Long Questionnaire having poor psychometric properties.

Further, the present research found little support for Squire’s theory (e.g., Clark & Squire, 1999) that conditioned responses in delay conditioning are governed by a different learning process from that which governs contingency awareness. Instead, the results suggest that a single learning process underlies conditioning performance and awareness in *both* delay and trace conditioning tasks.

Dual- or Single-Process?

More broadly, the findings of the present research are consistent with a single-process model of associative learning. This is in line with the preponderance of evidence from other studies on classical conditioning as well as from studies on other forms of learning which converge on the conclusion that there is no convincing evidence for learning apart of awareness (Lovibond & Shanks, 2002; Shanks & St. John, 1994). An earlier review of the literature had identified Squire’s findings of unaware delay conditioning as a possible exception to this conclusion (Lovibond & Shanks, 2002). However, the present research suggests that, because of the poor reliability of these findings (Experiment 1 and Knuttinen et al., 2002 failed to replicate these results) or because of the poor psychometric properties of the questionnaire used to classify participants' awareness status (Experiment 2), Squire's results do not provide strong support for the dual-process model of learning. In other words, the bulk of the learning literature continues to support a single-process model of learning in which awareness is closely linked to task acquisition.

Suggestions for Future Research

A Case for the Dual-Process Model

Although the present research suggests that the evidence for a single-process model of learning is stronger than that for a dual-process model, several alternative explanations limit this conclusion. That is, the dual-process model may still be appealed to by: (i) declassifying the task used as being too complicated for awareness to be dissociated from task performance, and/or (ii) suggesting that whether a single- or dual-process model governs learning depends on an individual difference characteristic.

Declassifying the Task as Being Too Complicated

Inter-stimulus interval. A first way in which the task used in the present research may be seen as being too complicated is in terms of the inter-stimulus interval (ISI) used, or the interval between CS and US onsets. Squire (e.g., Clark & Squire, 2004; Manns et al., 2000; Squire & Kandel, 1999) has suggested that one can differentiate tasks which require awareness from those which do not in terms of task simplicity, wherein simplicity is defined as a task not requiring the use of the hippocampus. In both Experiments 1 and 2, there was no evidence that a task often cited as being independent of hippocampus activation (e.g., Kirsch et al., 2003) – delay differential conditioning – could be acquired unconsciously. However, there is research suggesting that even in delay conditioning, the hippocampus may come to be involved if the ISI was long (Beylin et al., 2001). One may argue that the ISI used in the present experiments was extended, making the delay conditioning task demanding enough to necessitate hippocampal activation. As a result, conditioning performance had to be governed by the hippocampal learning mechanism associated with conscious awareness. The possibility remains that evidence for a dual-process model would be found if a delay conditioning task with a shorter ISI was used. Future studies should examine how manipulating the ISI in delay conditioning can affect the awareness-conditioning relations found.

Number of CSs. Alternatively, proponents of the dual-process theory of learning may contend that regardless of the conditioning parameters, the differential delay conditioning task is too difficult to be learnt unconsciously because it involves two cues. That is, even though differential delay conditioning does not typically require the hippocampus to be acquired, it may still be too complicated for implicit acquisition; instead, only single-cue delay conditioning tasks can be learnt unconsciously. Such an argument is difficult to test, because most participants become aware of the CS-US relation when there is only one CS (as an indication, almost all participants in Experiments 1 and 2 were aware that the two auditory stimuli CSs were related to the airpuff US); that is, it is very difficult to find unaware participants in such designs (Ross & Nelson, 1973). Furthermore, a single-cue delay conditioning task does not allow for control of non-associative factors involving the eyeblink response (Lovibond, 2004): one cannot establish the participants' base-line rate of blinking to sounds independent of the sound being a signal for the US.

Individual Difference Account

Another way in which the dual-process may be appealed to is by suggesting that the ability or predisposition to learn unconsciously is an individual difference characteristic. Although the present research found no convincing evidence for unconscious conditioning amongst unaware participants as a group, there were individual cases of participants who were classified as unaware (by either questionnaire) but who also appeared to have acquired conditioning. This leaves the possibility that the dual-process model of learning may be accurate for describing a certain group of individuals but not all. The difficulty with such a "black sheep analysis" is that it is a post-hoc explanation violating the principle underlying statistical analysis, which accounts for random errors of experimentation: these individual cases could alternatively be explained by suggesting that neither the Long nor Short Questionnaire was perfect, resulting in these individuals being misclassified as unaware when they were in fact aware (Benish & Grant, 1980; for a discussion of the limitations of post-conditioning questionnaires in general, see Dawson & Schell, 1985). Nonetheless, the possibility remains that unconscious learning could exist in at least some individuals. That is, instead of the dual-process model being descriptive of learning for all individuals, it could be descriptive of learning for a select class of individuals with a unique trait-like ability to enable them to learn unconsciously. If so, further studies should seek to identify these "unconscious learning" individuals and examine the relation between their awareness and task acquisition across a variety of tasks. If this certain trait did in fact exist, researchers would then find more success in changing the focus of research from "which tasks permit unconscious learning?" to one of "how can we predict who will show unconscious learning on a certain task?"

Nonetheless, even if further research supported the dual-process model of learning in simpler tasks or in a select group of individuals, the present research still suggests that this model is less general and the phenomenon of unconscious learning less robust than had previously been believed to be.

Alternative Forms of Evidence

This paper has been concerned with searching for evidence supporting either a single- or dual-process model by using Squire's (Clark & Squire, 1998; Smith et al., 2005) definitions of what constitutes evidence supporting either model. That is, the present research was based on the premise that evidence coming from Squire's experimental designs and data analyses would be a legitimate way of teasing apart the two models of learning. If one accepted this premise, then Experiments 1 and 2 suggest that the evidence support a single-process model of learning. However, other researchers may disagree with these experiments' method of data analysis or with their criterion for distinguishing a single-process model from a dual-process model.

Disagreement with Data Analysis

In Experiments 1 and 2, awareness of CS-US relations was examined in terms of a binary concept. In general, the reduction of a continuous variable (e.g., awareness score) into a binary variable (e.g., aware versus unaware) is discouraged as this reduces the statistical power of analyses relating to the variable (e.g., Streiner, 2002). However, this paper used such a procedure for three reasons. First, it enabled the experiments' results to be directly compared with those of previous awareness-conditioning studies wherein awareness has been analysed as a binary concept. Second, it is difficult to conceive of someone being "partially" aware that the CS+ predicts the US will occur and the CS- predicts the US will not occur (either this individual knows the relations or does not). Third, in avoiding the use of correlations between conditioning scores and awareness questionnaire scores, the binary analysis of awareness acknowledged the single-process model's view that awareness may be necessary but not sufficient for learning (Lovibond & Shanks, 2002).

Nonetheless, one may still advocate that awareness would be better conceptualised as a continuous concept (e.g., LaBar & Disterhoft, 1998). One possible strategy for future research could involve the use of taxometric methods to determine whether contingency awareness is a categorical or continuous construct (Ruscio & Ruscio, 2004). Assessment of awareness could then match this structure, permitting a more sophisticated analysis of the data (Ruscio & Ruscio, 2002). Alternatively, one may choose to examine continuous awareness scores on the basis that although awareness of CS-US relations may be binary in structure, confidence of this awareness could be continuous.

Disagreement with Criterion for Distinguishing Models

On a different level of analysis, researchers may disagree with the criterion that has been used to distinguish the single-process model from the dual-process model. The present paper focused on a single dissociation – learning apart of conscious awareness – as evidence for whether a single- or dual-process model is supported. However, Dunn and Kirsner (1988; 1989) have advocated against the use of dissociations, suggesting that evidence based on dissociations could be incorporated into either model and thus sheds little light on the true number of processes governing learning. Instead, Dunn and Kirsner (1988) argued for the use of "reversed association" evidence, whereby one searches for a non-monotonic relation between tasks as evidence against a single-process model. Future studies could use this reversed association technique to examine the number of processes underlying acquisition of conditioning.

New Directions for Learning Theories

On a broader scale, the present research has implications for theories on learning in general. In particular, it suggests that learning theories should be reformulated with regards to the mapping of biology and awareness as well as to the mapping of animal learning to human learning.

Biological Mapping

Hitherto, much of the research involving the role of awareness in learning has been focused on locating awareness in a biological structure and seeing whether that structure is implicated in task acquisition (for a review, see Griffin & Speck, 2004). Typically, awareness has been mapped onto the hippocampus: some researchers have suggested that there is a one-on-one matching between awareness and hippocampal activation (e.g., Manns et al., 2000;

Squire, 1992), whereas others have suggested that although hippocampal activation need not indicate that awareness is involved in learning (Chun & Phelps, 1999), hippocampal activation is necessary for awareness in learning (Eichenbaum, 1999). However, the present research suggests that even in a task which has been shown to be acquired independently of the hippocampus (delay conditioning), awareness is necessary for task acquisition. Hence, current theories on the mechanisms underlying learning should move away from the assumption that there is a simple mapping relation between awareness and hippocampal function. Future research should either examine awareness as a psychological concept independent of a particular biological structure, or should search for new biological candidates for where awareness may be located in the brain.

Animal Learning

The present research also has implications for theories that have attempted to map the mechanisms underlying animal learning to those underlying human learning (for a discussion of these theories, see Schacter & Tulving, 1994). Because animals have traditionally been viewed as having no conscious awareness, tasks which animals can acquire have been said to be governed by unconscious learning mechanisms in both animals and humans (e.g., Razran, 1955; 1971). However, the present research suggests that there is still no convincing evidence that, even in tasks which animals can acquire (classical conditioning), learning can take place apart of conscious awareness in humans. This finding raises questions for theories that have assumed that there is a common unconscious reflexive learning mechanism in both humans and animals.

The lack of access to self-report data in animals makes the question of whether animals learn with consciousness or not a controversial issue (e.g., Dawson, 1973; Efron, 1966). Some psychologists have argued for animal consciousness on the basis that the characteristics of human learning that are associated with awareness are similar to the characteristics of animal learning (e.g., Clark et al., 2002; Griffin & Speck, 2004; Lovibond & Shanks, 2002), but this is correlational evidence that does not definitively shed light on whether animals were aware at learning or not. The issue of whether animals learn with conscious awareness is out of the scope of this paper; nonetheless, the present research suggests that theories attempting to *integrate* human and animal learning mechanisms (e.g., Davey, 1987) need to be reviewed.

Conclusions

In conclusion, the present research addressed the question of whether learning is governed by one or two learning processes. Squire (Clark & Squire, 1998; 1999) had suggested that two independent processes govern conscious awareness and task performance in simple forms of learning (e.g., delay classical conditioning), but that a single process governs awareness and performance in more complex forms of learning (e.g., trace classical conditioning). However, Experiments 1 and 2 found no evidence that awareness can be dissociated from task performance in either a simple (delay conditioning) or a complex task (trace conditioning). Integrated with the broader literature, these experiments suggest that there is still no strong evidence for unconscious acquisition of conditioning or of learning in general. Instead, the preponderance of evidence is consistent with the theory that a single-process of learning gives rise to both awareness and task performance.

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