Conditioning

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The word conditioning has two different meanings, only one of which is uncontroversial. In common usage, even in the psychological literature, the word is used to refer to a *kind* (or *kinds*) of learning, but formally it refers only to two basic *procedures* that have been used to study learning; instrumental and Pavlovian conditioning. The question of what exactly is learnt under these procedures is very much a matter of ongoing debate. As will become apparent, this question is particularly important when we are considering the role that conscious awareness might play in "conditioning".

Instrumental, or operant, conditioning is a procedure in which behaviours increase or decrease in frequency as a consequence of being followed by reinforcing (rewarding) or punishing outcomes. For example, Thorndike, who discovered instrumental conditioning, noticed that cats escaping from his "puzzle boxes" initially seemed to behave in a largely random manner until they inadvertently "solved" the puzzle, pushing a lever and releasing themselves from the box. He concluded that many sophisticated, apparently goal-directed behaviours may depend on an essentially blind mechanism that simply favours successful behaviours – those that happen to lead to reward. An implicit assumption was that the strengthening of successful behaviours was completely automatic and independent of conscious thought. Pavlovian, or classical, conditioning is a procedure in which a neutral stimulus (most famously, a bell) repeatedly predicts the arrival of a behaviourally important stimulus (like food), resulting in the previously neutral stimulus acquiring the ability to produce responses relevant to the behaviourally important stimulus (like preparatory salivation).

Both these procedures reliably produce learning in a very wide range of species – from ants to elephants (and humans) - which is usually taken to mean that the learning mechanisms engaged under these procedures are in some sense fundamental properties of neural activity and that they have been conserved over evolutionary time. Indeed a major rationale for studying learning in rats and pigeons – still the main experimental subjects for such research – is that the conditioning mechanisms themselves are thought to be essentially identical, at least across the vertebrates, and so choice of species is largely a matter of convenience. If this view is valid, it implies that the learning in such circumstances should be very simple, automatic and independent of conscious control or interference. Interestingly, in the case of human learning, exactly the opposite view now dominates – that is, that conditioning does not occur in humans in the absence of awareness of the stimulus contingencies.

It had been almost universally assumed that conscious awareness was unnecessary (indeed irrelevant) for any kind of conditioning until three separate reviews of the evidence for conditioning in the absence of awareness each concluded that the accumulated evidence was, in fact, unconvincing (Brewer, 1974; Dawson & Schell, 1985; Shanks & St John, 1994). This conclusion was recently reinforced by two more critical reviews (Lovibond & Shanks, 2002; Shanks, 2005). The reviews differ in their details, and are directed at different bodies of empirical data, since they span nearly 30 years, but the main thrust of the arguments have remained the same. In common with most of the research conducted in this area, the reviews concentrated on the possible role played by awareness of the *relationship* to be learnt in a conditioning situation, *while* that learning is taking place. There are clearly other things that learners may or may not be aware of (the stimuli being learned *about*, for example), but these have been considered less critical or less interesting questions (Boakes, 1989). As might be imagined, the difficult part of demonstrating conditioning without awareness is in devising a measure of awareness that captures all of the learner's relevant conscious knowledge without *providing* them with explicit information about the contingency they had been exposed to. The main criticisms of the awareness tests that have been used is that they were either too insensitive, and so simply failed to detect conscious knowledge possessed by the learners, or that they asked the wrong questions, failing to detect the conscious knowledge that actually helped in the learning task. As will be discussed below, these criticisms are important and frequently valid, but unless our default assumption is that conditioning does depend on awareness, it is equally important to be sure that awareness tests *only* measure conscious knowledge, without any contamination from unconsciously acquired information, and that claims of strong links between awareness and conditioned responding are held to the same high standards of evidence as alleged dissociations. In other words, reasons for doubting the evidence purporting to show conditioning without awareness are not, themselves, reasons for believing that conditioning *depends* on awareness. This is a separate claim, in need of independent empirical support.

Starting with Thorndike himself, a number of researchers have investigated whether instrumental conditioning can occur in the absence of awareness of the relationship between responding and its consequences. Many of those studies were criticised in Brewer's (1974) review, mostly on the grounds that the awareness tests used were too insensitive, and in many early cases they clearly were, but there are at least a few studies that have produced reasonably compelling evidence of instrumental responding without awareness. For example, Hefferline, Keenan & Harford (1959) showed that when termination of a loud, unpleasant noise was made contingent on a small movement of the subject's thumb (detected by an electrode) thumb twitches increased in frequency. Similarly, Liebermann Sunnucks & Kirk (1998) constructed a fake ESP task, in which feedback that the subject had selected the card the experimenter was "thinking of" was actually contingent on the subject's voice volume, and produced both conditioned increases and decreases in volume, without subjects becoming aware of the contingency. In both these tasks the intention of the experiment was disguised by a convincing cover story that participants seem to have believed.

Unfortunately, despite these apparent successes, it is difficult to evaluate the extent to which instrumental conditioning can occur without awareness because there is an essentially infinite number of ways in which a response can increase or decrease in frequency, and so no way to be sure that even a very sensitive awareness test actually measures awareness of the particular "response" reinforced in any given situation. For example, although Hefferline et al's subjects may, in fact have been completely unaware of the relationship between their thumb movement and the offset of the loud noise, they *may* have been aware of the relationship between some correlate of the thumb movement and noise offset, about which they were not asked a specific question. Presumably a general increase in muscular tension, certain kinds of gross bodily movements, or even thinking about flicking switches might each produce small, inadvertent or incidental movements of the thumb, and so it may have been any of these (or a host of others) that were actually reinforced - and no sensitive, specific measure of awareness could hope to capture all of them. Equally plausible correlated hypotheses can be postulated to underlie the voice level effects found by Liebermann et al. Of course this is not to say that instrumental conditioning does not happen without awareness – the fact that it occurs in headless cockroaches strongly suggests that it can – just that it is, in practice, difficult to be sure that it has. For this reason, most of the research designed to test whether conditioning can occur without awareness has focussed on classical or Pavlovian conditioning.

Pavlovian conditioning was discovered around the same time as instrumental conditioning when Pavlov, a digestive physiologist, noticed that the dogs he was using in his experiments started salivating prior to the delivery of food. His research led him to believe that the anticipatory salivation occurred because the close temporal proximity of some neutral stimulus and the food had given the neutral stimulus the power to produce the same reflex normally elicited by the food. More modern research (starting with Rescorla, 1967) has demonstrated that this kind of conditioning actually depends on the extent to which the previously neutral stimulus *predicts* the arrival of the behaviourally significant stimulus (the extent to which the predicted stimulus is *contingent* on the signal), although there is no reason to suspect that this more complex process is necessarily more likely to depend on conscious mechanisms. There are two main paradigms that have been used to study the role of awareness in classical conditioning - conditioning of psychophysiological responses (mainly eye-blinks and skin conductance) and evaluative conditioning.

In a typical human psychophysiological Pavlovian conditioning experiment, a participant is exposed to two or more neutral stimuli (usually sounds of different frequencies), one of which predicts the delivery of a puff of air to the eye (in some experiments) or a mild electric shock (in others). Puffs of air to the eyeball produce eyeblinks, measured by electrodes over the eye muscles, and electric shocks produce a range of physiological responses, but the most frequently measured is a change skin conductance level. These kinds of contingencies produce rapid conditioning, with changes in the psychophysiological measures usually detectable after just a few pairings, and reliably higher responding to the sound paired with the shock or airpuff than to the other sounds after tens of pairings. Because the relationship to be learnt is so straightforward, and because it is completely under the control of the experimenter, it is easy to exhaustively test for awareness of the contingency participants are exposed to, and so these kinds of paradigms have formed the major testing ground for the role of awareness in conditioning. Of course, the relationship is *so* straightforward, and the predicted stimulus sufficiently aversive, that it is not really particularly surprising that there is typically a tight relationship between awareness and conditioning in such studies, as long as awareness is measured sensitively. The most sensitive awareness test developed is to have subjects turn a dial to continuously indicate the extent to which they expect to receive an electric shock (or an airpuff), and the usual finding is that there is very little evidence of conditioning until there is also evidence of a conscious expectancy (although Perruchet, 1985, collected data in which these two measures, in fact, dissociated). The normally tight relationship between expectancy and conditioning has been widely interpreted to mean that conditioned responding *depends* on developing an awareness of the contingency, but it is, of course, only a demonstration that conscious awareness of the contingency is *sufficient* to produce a “conditioned” response. In order to demonstrate that conscious awareness is also *necessary* for conditioning it must be shown that there are no conditioning paradigms in which conditioned responding can occur in the absence of awareness of the contingency. Since this is logistically impossible (there will always be the possibility of an untested paradigm that would yield unconscious conditioning), it must at least be demonstrated that the evidence for a tight relationship between awareness and conditioning is equally strong in paradigms where the contingency is less obvious, and in which the learner's attention is not explicitly drawn to the contingency, as it almost certainly is when they are asked to continuously self-report their expectancy on a dial.

One way of making the contingency less obvious is to introduce a delay between the tone and the puff of air. Squire and colleagues (reviewed in Clark, Manns & Squire, 2002) have used exactly this strategy, comparing the role of awareness in traditional forward conditioning, in which the tone starts before the airpuff, but is still on when the airpuff arrives, and in trace conditioning, in which the tone is over before the airpuff arrives. As well as rendering the contingency less obvious, the trace conditioning procedure might be expected to draw on memory mechanisms, and the results of these studies are consistent with that expectation. The major findings are that in trace conditioning learning is apparent only in subjects classified as aware of the tone-airpuff contingency in a later questionnaire. Subjects who show no awareness of the contingency do not produce conditioned eyeblinks, and neither do amnesiac subjects, who have memory deficits resulting from damage to the hippocampus. All three groups show conditioned responding in normal, forward conditioning. While criticisms have been levelled at the adequacy of the awareness test used in these experiments (Lovibond & Shanks, 2002), the fact that the results map perfectly onto findings from rabbit eye-blink conditioning, in which rabbits with hippocampal lesions learn in forward, but not trace, conditioning situations (whereas intact rabbits learn in both situations), suggests that there is a genuine dissociation between these procedures, and that awareness (requiring at least an intact hippocampus) is necessary only in the trace conditioning procedure. This implies that awareness is not, therefore, necessary for basic Pavlovian conditioning.

An alternative way to make the contingency in a Pavlovian conditioning paradigm less obvious is to avoid the use of an aversive stimulus by burying the to-be-learnt contingency in an innocuous (cued) reaction time task. This was the approach used by Burke & Roodenrys (2000), and they also concluded that basic conditioning can proceed in the absence of awareness of the contingency. In this task, learners are simply asked to respond as quickly as possible to two target shapes which appear in a continuous sequence of shapes, replacing each other every 250 ms. The order of the shape sequence is random except that one of the targets is always preceded by a cue shape. All subjects come to respond more quickly to cued than to uncued targets, including those identified as unaware in a post-learning awareness test designed to be as sensitive and specific as is possible without providing the subjects with awareness of the cue-target contingency that they did not possess during the task.

The other major human conditioning procedure that has been used to study the role of awareness is evaluative conditioning. In this procedure affective responses are transferred from a liked or disliked stimulus to a neutral stimulus it is paired with (for a review see De Houwer, Baeyens & Field, 2005). For example, if a face rated as neutral (neither liked nor disliked) is presented in close temporal proximity before a disliked face, in a long string of faces, then the neutral face is subsequently rated as more disliked than it had been. The effect also works for liked stimuli. Since it is true that most people seem unable to account for many of the likes and dislikes they have, this kind of learning seemed particularly likely to proceed unconsciously, and, indeed, all of the early studies suggested that awareness was not involved in evaluative conditioning. More recently collected data, however (reviewed in Lipp & Purkis, 2005) has resulted in a controversy that almost exactly parallels the earlier debate about whether traditional, psychophysiological conditioning can occur in the absence of awareness. The current consensus seems to be that evaluative conditioning is a genuine, if experimentally fragile, conditioning phenomenon, but that the issue of whether it can occur in the absence of awareness has not yet been conclusively resolved. Learned synesthesia (Stevenson & Boakes, 2004), on the other hand, a conditioning phenomenon that shares many features with evaluative conditioning, has provided perhaps the clearest evidence yet collected of unconscious learning in a conditioning paradigm.

In a typical odour-taste learned synesthesia experiment, participants first rate the sweetness (for example) of various sniffed odours, and are then exposed to the odours paired with tastes (in a sucrose solution, for example). Just as in an evaluative conditioning experiment, some of the properties of the taste stimulus transfer to the odour, so that an odour that has been paired with sucrose is subsequently rated as sweeter than it had been before conditioning. The awareness test used in these studies involves, re-exposing subjects to the odours, immediately after the main experiment, and asking them to identify which taste each had been paired with. This is a very sensitive and specific technique, and it results in some subjects being classified as aware of (at least some of) the taste odour pairing(s), and some being classified as unaware. There is no relationship between the size of the conditioning effect and conscious knowledge of the stimulus pairing, suggesting that in this paradigm, at least, awareness is not only unnecessary for conditioning, it is irrelevant.

In evaluating the evidence for the role of awareness in conditioning it is important to remember that Pavlovian and instrumental conditioning are only *procedures* for studying learning. In both paradigms, there is ample opportunity to learn a wide range of things, including, of course, whatever it is that enables people to become consciously aware of the contingency they have been exposed to. But given the wide range of species that do learn in conditioning situations, and the accumulated evidence from human studies suggesting that behaviour can change in these paradigms in the absence of awareness of the contingencies, it is likely that some of the things learned in conditioning paradigms do depend on awareness and some do not. If we are to ever understand the functional role of consciousness in learning, then the simplicity of conditioning paradigms makes them particularly attractive avenues for research.

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