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Abstract

While Pavlovian conditioning is a widely recognized form of learning, the nature of this learned association continues to be debated and has significant implications for human and animal behavior. This paper will first address the basic structure of Pavlovian conditioning as well as the two major historical hypotheses—Stimulus-Stimulus (S-S) learning and Stimulus-Response (S-R) learning—regarding the underlying neural representation of first-order conditioning. Next, the revaluation procedure, an experimental method used to distinguish between these two hypotheses, will be discussed. Furthermore, the history of revaluation studies on rats will be analyzed, with an emphasis on the specificity of the learned association formed, the use of multiple observational methods to document revaluation, and the role of context in this procedure. In addition, revaluation will be discussed as it applies to humans, specifically its role in the formation of learned preferences, its role in preventing and treating phobias, and its role in the treatment of fear of movement-related pain.

Keywords: Pavlovian conditioning, S-S, S-R, devaluation, inflation, revaluation, evaluative conditioning, pain

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Introduction

Pavlovian conditioning, also known as classical conditioning, describes a learning process in which a biologically neutral stimulus, or a conditional stimulus (CS), comes to be associated with a biologically relevant stimulus, or an unconditional stimulus (US). Prior to conditioning, if the CS is presented alone, it will not elicit a response on its own; the US, on the other hand, will naturally elicit a biological response known as the unconditional response (UR). After repeated pairings of the CS and US, the CS will come to elicit a response, known as the conditional response (CR), which is often similar or identical to the UR (Pavlov, 1928).

Pavlovian conditioning is well-documented in both human and animal studies. It is often seen as an important learning tool in the natural world that allows organisms to increase their chance of survival through aiding them in the identification of significant causal relationships in the environment. However, much remains unclear, including the underlying neural representation of the learned association. Two prominent theories attempt to explain the association that forms during Pavlovian conditioning: stimulus-stimulus theory (S-S) and stimulus response (S-R) theory. S-S theory assumes that during conditioning, a direct association is formed between the neural representations of the CS and US. Presentation of the CS activates the neural centers coding the CS and, through the development of conditioning, induces connections to the centers processing the US. As the US centers are innately connected to centers governing response production (URs), activation of the US center by the CS also activates the response center producing the CR. In this model, there is no direct link between the CS and CR; the CS is only able to elicit the CR through the activation of the US center. On the other hand, S-R theory assumes conditioning involves development of a direct link between the

CS and response centers. During conditioning, the function of the US is to elicit a response (UR) at the proper time relative to presentation of the CS. In this model, after an association is learned, the CS forms a direct link to the response center thereby producing the CR. That is, production of the CR is not mediated by the CS activating the response center indirectly via the US center.

One method of testing between the theories is through a revaluation procedure, which includes both inflation and devaluation procedures. The typical revaluation experiment involves classically conditioning a subject to asymptote—where the CS is a perfect predictor of the US—then decreasing (devaluing) or increasing (inflating) the value of the US. For example, if the US is a shock, its value can be changed by increasing or decreasing the intensity of the shock. Next, the CS is tested alone to see if the predictive value of the associated CS is altered despite no explicit manipulation of the CS itself. If the magnitude of the CR changes to reflect the altered value of the US, then a direct link between the CS and US is implied, and S-S theory is supported. If the magnitude of the CR is unchanged after the US is manipulated, evidence for S-R theory is found (Holland & Straub, 1979).

Currently, the emphasis of the research is not on proving or disproving one theory, as there is evidence for both under different circumstances. Rather, the focus is on understanding the underlying association as well as the conditions which elicit S-S or S-R learning. In this paper, the history of the revaluation procedure on first-order conditioning in rats will be discussed with an emphasis on the specificity of the learned associations formed, the implications for learning, and the role of context in these procedures. Finally, revaluation will be applied to humans with an emphasis on its role in learned preferences, its application to learned fears and their treatments, and its role as a potential treatment for fear of movement-related pain.

Revaluation in Rats

In rats, revaluation effects have been consistently observed over a variety of devaluation methods, observational methods, and conditioning procedures. These studies have largely supported S-S theory of learning and provide important implications for the human application of revaluation.

One of the earliest applications of the revaluation procedure was on conditioned fear experiments in rats. A typical conditioned fear experiment involves training a rat to associate a light or tone CS with a shock US until the CR reaches asymptote. Post-training, the shock is presented alone but at a higher intensity. The CS is then re-presented in the absence of shock, and the magnitude of the fear CR (typically suppression of operant bar-pressing for food reinforcement) is measured. Multiple findings demonstrate that the stronger the shock during inflation, the greater the suppression observed to the CS alone (Randich & Haggard, 1983; Rescorla, 1974; Sherman, 1978). In other words, when the value of the shock is increased, the rat exhibits a greater fear CR to the CS despite no explicit manipulation of the CS itself or the pairing of the CS with the shock of higher intensity. Correspondingly, if the shock is devalued by reducing its intensity, exposure to the CS alone will result in a less pronounced fear CR (Randich & Haggard, 1983). These results indicate that the current value of the US plays a significant role in the expression of the CR, implying a direct link between the neural representations of the CS and US in the production of the CR.

Other studies examined revaluation following appetitive conditioning and found similar support for S-S theory. These studies used a variety of devaluation procedures and drew attention to the specificity of its effects. Holland and Rescorla (1975) paired light (CS) with food (US) until their rats predictably approached a food magazine (CR) in anticipation of a food US whenever the light CS was presented. Next, they devalued the food alone either by satiation, intended to decrease the motivation to approach food, or by a high-speed rotation intended to make the rats feel dizzy and nauseous. Post-conditioning, when the light was presented alone, magazine-directed activity was reduced for both devaluation methods. Holland (1981) replicated these findings for satiety but used different CRs to assess devaluation—including startle, rearing, and head-jerk behaviors—in addition to magazine-directed behavior. Presentation of the CS alone post-devaluation resulted in a reduction in all observed responses. Holland and Straub (1979) conducted a similar experiment but chose to devalue the food US with LiCl injections or high-speed rotations, both of which result in a feeling of nausea. Both methods produced successful devaluation, as measured by general activity, magazine-directed activity, startle, and head-jerk responses. Kerfoot, Agarwal, Lee, and Holland (2007) reported similar results, but demonstrated them through taste reactivity (TR) responses which reflect rats' evaluation of food. Prior to devaluation, rats in this study received pairings of a tone (CS) and sucrose (US). During this process, the rats only displayed appetitive TR responses, including fast, rhythmic licking movements and movements where the tongue stuck out of the mouth. Following devaluation with LiCl, presentation of the CS alone reduced appetitive TR responses and resulted in the sudden emergence of aversive TR responses, including movements such as slow licking, shaking of the head, and gaping. These findings collectively suggest that multiple experimental methods can be utilized to demonstrate devaluation effects on a variety of behavioral responses.

Variations of these procedures have been used to garner a more comprehensive understanding of the underlying nature of conditioned associations. Decola and Fanselow (1995) tested the effects of delay in devaluation. They paired a saccharin CS with a LiCl US for both a short and long-delay group. In the short-delay group, they followed the saccharine immediately with LiCl during conditioning, and in the long-delay group, they presented the LiCl three hours after the rats tasted the saccharine. Post-conditioning, they inflated the US by giving rats a three times stronger dose of LiCl than was initially used. Next, they tested if the rats displayed a preference between either a water or saccharin bottle. Inflation affected only the short-delay group as they demonstrated enhanced preference for the water bottle (greater avoidance of the saccharin bottle). In another experiment, Decola and Fanselow (1995) followed the same method, except they varied the initial intensity of the CS to result in lower or higher initial associative CS-US strength. It was found that inflation was not dependent upon the strength of initial association; in both experiments, the short-delay group displayed greater inflation effects regardless of the strength of initial association. The authors concluded that temporal contiguity plays a crucial role in revaluation while associative strength does not.

Other researchers tested the effects of minimal and extensive training on devaluation as well as the differential effects of devaluation on various behavioral responses. One researcher conditioned rats to two CS-US combinations and varied the amount of CS-US training between groups of rats. Each group received 16, 40, or 160 paired trials for each CS-US. The experimenter then devalued only one US for each rat. It was found that the rats showed greater food aversion to the specific CS-US that was devalued, regardless of the amount of initial CS-US training (Holland, 1998). However, other research suggests that not all responses are as easily altered by devaluation. Holland, Lasseter, and Agarwal (2008) varied the amount of CS-US training prior to devaluation and used two methods, either a food cup or intraoral sucrose injection, to deliver the US. They measured TR responses and found similar results to Kerfoot et al. (2007). However, they observed that rats showed more TR responses to minimal training than extensive training, but rats showed consistent sensitivity to devaluation regarding magazine-directed behavior and licking responses. Other research highlights the differential effects of devaluation on various aspects of behavior. Holland and Straub (1979) observed that startle and head jerk responses were more affected by high-speed rotation devaluation compared to LiCl devaluation, and magazine-directed behavior and food consumption were more affected by LiCl devaluation. These results imply that devaluation may be subject to an associative bias that renders certain USs more subject to devaluation than others depending on the devaluation method used. They may also indicate that certain methods of devaluation require more comprehensive techniques in order to successfully document.

Revaluation procedures have not only been observed in multiple conditioning procedures, they have also been observed to be highly specific in regards to the CS-US pairing that is affected. In addition to the experiment by Holland (1998), several researchers have found that, upon conditioning two different CS-US pairs and devaluing one US, reduced responding is evident only for the CS that was associated with the devalued US (Cleland & Davey, 1982; Colwill & Motzkin, 1994; Galarce, Crombag, & Holland, 2007). The specificity of revaluation has been demonstrated in simple as well as compound stimuli. Holland (1990) conditioned rats to two different tone (CS) and food (US) combinations. He then devalued a compound stimulus (US1+US2) with a toxin and left the individual USs intact. Upon re-testing, the rats were exposed to the first tone (CS1), the second tone (CS2), or a combination of both (CS1+CS2). The rats displayed an avoidance response to the compound stimulus but did not alter their responding to the individual CSs; they did not associate the individual CSs with the devalued outcome. Holland performed a similar procedure in another experiment but left the compound stimulus intact and devalued the individual USs. Once again, rats differentiated between the stimuli and only avoided the specific stimulus that was devalued. In all three of Holland's (1990) experiments, more aversive responses were observed to the devalued stimulus than the non-devalued one.

One potential confounding variable in revaluation research is the role of context. Subjects' behavior may be a reaction to different contextual cues rather than an indicator of changes in the neural representation of the US. However, this hypothesis has not been supported; evidence indicates that revaluation effects cannot simply be attributed to contextual effects. In multiple experiments, training was done in one context and devaluation was done in another. Upon return to the original training context for testing, devaluation effects were still observed, reflecting their ability to generalize across contexts (Cleland & Davey, 1982; Holland, 1981; Holland, 1990; Holland, 1998; Holland et al., 2008; Holland & Straub, 1979; Kerfoot et al., 2007). Another possibility that has been tested is whether inflation effects are due to CS-context summation, which occurs when a subject's fear of the context summates with its fear of the CS to produce a fear response of greater magnitude. Bouton (1984) tested these findings in a series of three experiments. In his first experiment, he conditioned two groups of rats to a CS-US pair. Post-conditioning, the first group received an inflated shock in the same context it received conditioning, and the second group received an inflated shock in a different context. If CS-context summation was at work, the first group of rats should have a fear response of a greater magnitude than the second group. However, this was not the case. Regardless of context, stronger shocks resulted in a more pronounced fear response in both groups. In the second experiment, rats were once again conditioned. Post-conditioning, rats received an inflated shock. However, rats in one group received an extinction trial to reduce their fear response to the context. Upon testing of the CS alone, it was found that reduced fear of context did not affect the magnitude of the response to the CS. In the third experiment, contextual fears were increased to see if the fear response to the CS alone would change. If CS-context summation accounts for inflation effects, then increasing the fear of the context should increase the inflation effect. However, even with increased contextual fear, the response to the CS was not significantly affected. All three of Bouton's (1984) experiments reject the CS-context summation hypothesis and suggest that the inflation effect is obtained regardless of whether inflation occurs in the same context as conditioning.

Revaluation in Human Subjects

Application of revaluation to the human experience is considered in three areas: evaluative conditioning, the development and treatment of learned fears, and in the treatment of fear of movement-related pain in physical therapy. Implications from research on rats and suggestions for further research and application will also be discussed.

Evaluative Conditioning

Evaluative conditioning (EC) describes a learned association that can be viewed as a form of Pavlovian conditioning. It is the process by which preferences are learned. In a typical example, a neutral stimulus (CS) is paired with an affective stimulus (US) that naturally elicits an emotional response (UR). The affective stimulus is often described as having a valence, or emotional response, that is positive or negative. Upon pairing the CS and US together, the valence of the CS shifts to reflect that of the US. In other words, the CS comes to elicit the same emotional response as the US. This form of conditioning has a few distinct features that will later play a role when the revaluation procedure is applied to it. These key features include its lack of need for a CS-US contingency and the effects of awareness on contingency.

Unlike in conditioned Pavlovian fear or appetitive responses, evaluative conditioning does not require a CS-US contingency in which a CS accurately and consistently predicts a US.

Evaluative conditioning depends more upon temporal contiguity than it does on contingency. Baeyens, Hermans, and Eelen (1993) paired a CS and US only once before testing for evaluative conditioning effects and found no substantial effect on the observation of evaluative learning. In addition, even if a contingency is present, lack of awareness of this contingency does not affect evaluative learning. Even if participants are unaware of a contingency, they still displayed evaluative learning (Baeyens et al., 1992; De Houwer et al., 2001; Kattner, 2014; Olson & Fazio, 2001).

Some researchers experimentally reduced awareness to observe its results on evaluative learning. Fulcher and Hammerl (2001) split participants into an aware and unaware group. The unaware group was given a distracter task that served to reduce their awareness of the CS-US contingency. This group successfully displayed EC effects despite no explicit awareness of the contingency. Similar results were found in a study that did not offer information to manipulate awareness but divided participants into groups based on their own sense of awareness of the CS-US contingency (Hammerl & Grabitz, 2000). These results indicate the lack of dependence evaluative conditioning has on the presence or awareness of a CS-US contingency.

Other researchers took the opposite approach and experimentally induced awareness of the CS-US contingency in their subjects. Their results suggest that awareness may actually dampen the effects of evaluative conditioning or reverse it completely, the latter of which is referred to as the contrast effect. Fulcher and Hammerl (2001) explained to one group of research participants that a CS-US contingency would be present. To another group, they described evaluative conditioning and its effects. Other groups of participants were left unaware. Participants who were aware of the contingency displayed a contrast effect; the change in valence they displayed in response to the CS was in the opposite direction of the change in valence of the US. Hammerl and Grabitz (2000) reported consistent results in their group of subjects who were classified as aware. Collectively, these results indicate that subjects can compensate for or potentially overcorrect the influence of the affective stimulus (US) through awareness of a CS-US contingency.

Revaluation Applied to Evaluative Conditioning

In the first revaluation study on EC, Baeyens, Eelen, Van den Bergh, and Crombez (1992) paired neutral images with faces that naturally elicited a positive or negative response. Post-conditioning, the faces were revalued; positive faces were paired with negative adjectives and negative faces were paired with positive adjectives. This led to a reversal in the valence of the US. Subsequently, when the CSs were tested alone to test for revaluation effects, their valence reflected the current value of the US they were associated with. Walther, Gawronski, Blank, and Langer (2009) replicated this experiment but controlled for the potential confounding factor of biased self-reports by adding a priming task to test the implicit valence of the stimuli. They also included a test of memory to account for the possibility that participants were relying on memory to answer questions about the US instead of reflecting upon the affect it elicited. Their results reflected those of Baeyens et al. (1992) both for the subjective and implicit measure of valence. In addition, after retesting one week later, they found that revaluation did not decrease with time, as would be expected if it were dependent upon explicit memory. One unique aspect of revaluation in humans is that it does not require direct contact with the US. Multiple methods of revaluation, including providing verbal information, can be used to successfully devalue a US (Davey, 1992).

Revaluation studies in evaluative conditioning support S-S learning. Some authors argued that these studies were biased in favor of S-S learning since they often involved stimuli from the same categories which encouraged subjects to associate them. Jensen-Fielding, Luck, and Lipp (2017) hypothesized that if these factors were removed, evidence would indicate S-R learning. In their experiments, they made their USs more salient, using happy or angry faces to elicit a stronger positive or negative response, and they tested the CSs in implicit priming tasks to control for the effects of demand characteristics. In addition, they used CSs and USs from different categories that didn't resemble each other; the USs were individuals, and the CSs were shapes. Despite their efforts to favor S-R learning, S-S learning was observed, as measured by both explicit and implicit measures.

Implications of US Revaluation Effects on Evaluative Conditioning

EC is an evolutionarily useful form of learning, allowing for a quick method by which new information can be learned to influence emotions and behaviors without conscious awareness or effort. However, it poses harm to social functioning in the world today by allowing for the propagation of prejudice and negative attitudes. Since evaluative conditioning does not seem to require repeated presentations between a neutral CS and affective US, it can be acquired rapidly and operate along a range of situations in the daily lives of all people. People no longer need to have direct contact with an aversive out-group (US) for that to influence their perception of neutral others (CS). Understanding how evaluative conditioning effects may spread as well as the role revaluation may play in controlling them are important in finding solutions to the detrimental aspects of this form of learning.

Revaluation plays a significant role in countering the adverse effects of learned attitudes. It indicates that, due to the association between the CS and US, if the US is changed, the response to the CS will change as well. When applied to stereotypes, if positive aspects of a community in question are highlighted, the meaning associated with them is more likely to change to reflect a more positive valence. Consequently, the perception of neutral others who are associated with this community would change to reflect the same valence.

In addition, awareness of association has the potential to alter the CR so that it does not follow the change in valence that the US does. This suggests that awareness during evaluative conditioning may favor S-R learning rather than S-S learning, which may help reduce the spread of negative attitudes. For example, if people are consciously aware that media portrayals may influence how they react to neutral others, their awareness can help them act in the opposite of what is expected, in line with the contrast effect. This offers a way to control for the negative aspects of evaluative conditioning.

Revaluation Applied to Phobias and Their Treatments

Revaluation has been consistently documented in fear conditioning in rats, and researchers have extended these finding to humans as well. White and Davey (1989) tested the inflation of a US after fear conditioning in humans and confirmed its occurrence through both a subjective measure of aversiveness as well as physical measures such as skin conductance responses. The literature on conditioned fears and phobias are similar to those of evaluative conditioning; both reflect S-S learning in the majority of situations (for a review of fear and phobic conditioning research, see Davey 1992). One researcher hypothesized that, unless subjects are aware of the CS-US contingency, they demonstrate S-S learning in the majority of situations (Davey, 1992). Hosoba, Iwanaga, and Seiwa (2001) tested this hypothesis. In their study, subjects were either tested under an inflation, devaluation, or control condition. Skin conductance responses and a subjective aversion scale were used to measure fear. They used triangles as the CSs and loud white noise as the US. An inflation effect was observed for the inflation group and a devaluation effect was observed for the devaluation group based on skin conductance. However, subjective measures of aversiveness were not influenced by revaluation for either group. Schultz, Balderston, Geiger, and Helmstetter (2013) found a similar disparity in their implicit and explicit revaluation results. They also demonstrated that revaluation could not be explained by differences in participants' expectations or explicit knowledge that the US had been altered. Although research results indicate the prevalence of S-S learning in first-order conditioning, there remain unanswered questions as to why certain variables experience revaluation more readily than others.

Revaluation has significant effects on learned fears and, as a result, can be applied to learned phobias and anxieties. Some people with phobias report no recollection of trauma being explicitly paired with the stimulus that elicits them. Since learned fears reflect S-S learning in the majority of situations, phobic responses in the absence of paired trauma can be explained through revaluation. Davey (1992) described this through the example of a person who witnessed someone die of a heart attack on a train. The train (CS) and heart attack (US) became associated in the person's mind but did not produce a phobic response. However, at a later date, the person may witness a close friend die of a heart attack and, as a result, develop a phobia of trains. In this situation, the heart attack was inflated due to the traumatic death of a friend, and the response to the train was subsequently altered. Field (2006) supported Davey (1992)'s hypothesis, and suggested that, in order to prevent anxiety or phobias in response to traumatic events, the traumatic events should be devalued shortly after their occurrence.

The treatment and prevention of phobias may be addressed through revaluation. Typical treatments for reducing a conditioned fear response utilize an extinction procedure, which involves the post-associative presentation of a CS in the absence of a US over multiple trials until the magnitude of original fear response decreases. In extinction, the subject learns a new association that masks—but does not eliminate—the previous association. It learns that, in a given context, the CS predicts the absence of the US. This poses a problem for extinction, since it means that extinction learning is specific to the context it is learned in. When a subject goes to a different context, the fear response returns in a process known as renewal (Bouton & King, 1983). Revaluation offers a promising alternative, as it generalizes across contexts.

Dibbets, Poort, and Arntz (2012) tested whether renewal effects would be reduced using a devaluation procedure rather than extinction. The devaluation method they used was Imagery Rescripting (IR), which involves recalling an aversive event and consciously reimagining it so that it results in a more positive ending. This method has demonstrated success in past studies in the reduction of fear responses (Hunt & Fenton, 2007; Holmes, Arntz, & Smucker, 2007). In their study, Dibbets et al. (2012) divided participants into an ABAir, ABAcont, ABAno, or AAA group, and they were all taught to associate a car (CS) with a picture of a dead child (US) in context A. Post-conditioning, subjects in the ABAir were moved to context B and given an extinction trial with IR devaluation. The ABAcont group received an IR procedure that wasn't meant to devalue the US, and the ABAno group received no IR during extinction. The AAA group was a control that remained in the same context at all points. Next, subjects were moved back to context A and tested for their response to the CS alone. It was found that all subjects in the experimental groups extinguished the US in context B and differentiated between the two contexts. ABAir demonstrated less renewal then the ABAno group, reflecting the contribution of the devaluation procedure. When testing the value of the US alone, only the ABAir group reflected a devalued US; it had a less negative representation compared to both the start of the study and to the ABAno group. These results indicate the promising contribution revaluation procedures may have on reducing learned fear responses.

Other researchers conducted a similar study except they devalued the US by pairing the visualization of an aversive event with eye movements (EM). Previously, EM has been shown to decrease self-reports of aversiveness of a memory, in terms of both vividness and emotionality (see Gunter & Bodner, 2008; van den Hout, Muris, Salemink, & Kindt, 2001; Shapiro, 1989). Leer, Engelhard, Altink, van den Hout (2013) first conditioned a tone CS to a US that naturally evoked a disgusted reaction. They asked participants to fill out questionnaires to assess vividness, emotionality, and difficulty recalling the US. Next, they were asked to recall the US as vividly as they could. The EM group was asked to track a moving black dot on a screen while the control group was instructed to keep their eyes fixed on the center of a plain black screen. Finally, the CSs were presented alone and participants had to rate them in terms of pleasantness, fear, and expectancy of the US. Devaluation by EM reduced the vividness and emotionality of the recalled memory. It also reduced self-reports of conditioned fear. However, a reduction was not observed for skin conductance. In line with the discrepancy in previous research, implicit and explicit responses were not affected the same way by revaluation. This may suggest that certain responses are more readily devalued than others. The authors suggest including more trials and multiple methods of assessing implicit fear, such as including a fear-potentiated startle, in order to obtain more accurate results.

Understanding aspects of the underlying neural representation of first-order conditioning as well as the revaluation procedure promotes significant progress in preventing or reducing the intensity of learned phobic responses. Although the discrepancy between implicit and explicit responses remains a topic that must be addressed, multiple methods have been used to successfully devalue aversive USs. Future studies should focus on evaluating new methods and comparing existing methods in an effort to find the best mode of devaluation for the goal of treating and preventing anxious and phobic responses.

Revaluations and Fear of Movement-Related Pain

Fear of movement-related pain (FMRP), a major hindrance in the recovery process of injuries, can be learned through Pavlovian conditioning. This typically involves a condition or injury which leads to a certain musculoskeletal movement eliciting pain when performed. Over time, the movement alone comes to elicit fear of the pain it is associated with. This leads patients to hesitate before performing movements or to avoid them altogether. In various therapies, this is detrimental to the healing process, as movements are required to facilitate the healing process. Meulders, Vansteenwegen, Vlaeyen (2011) tested the effects of FMRP by having subjects engage in two movements, one that was associated with pain (CS+) and one that was not (CS-), in order to mimic musculoskeletal pain. The US used in this study was a painful shock. They measured fear with various physiological and behavioral measures such as an eye blink startle response, the latency to initiate a pain-related movement (CS+), and the response duration. They also included subjective measures such as verbal ratings of expectancy, valence of the CS, unpleasantness of the CS, and the level of fear experienced. Participants reported more distress when performing the CS+ compared to the CS-, a result that was supported by the physiological and subjective measures. The latency to respond was longer for the CS+ than the CS-, reflecting a reluctance to engage in the movement associated with pain. All three measures supported the hypothesis that FMRP is learned through Pavlovian conditioning.

Other researchers expanded upon these results by testing whether the mere intention to engage in a fear-related movement would elicit a fear response. Meulders and Vlaeyen (2013) conditioned participants to associated one movement (CS+) with pain and not the other (CS-).

They measured levels of fear through participant self-reports and eye blink startle responses. Their results indicated that the mere intention to perform a movement associated with pain resulted in a higher eye-blink startle as well as higher self-reports of fear compared to movements that were not associated with pain. These results indicate that both the intention to move and the movement itself became associated with the pain. Collectively, the results of the previous two studies offer more knowledge regarding the underlying process that contributes to FMRP. In addition, they offer insight as to what treatments may be added to traditional therapies in order to lessen patients' fear and ease them through the process of recovery.

As a result of the Pavlovian process that contributes to FMRP, a common approach to treatment is an extinction procedure. Researchers have applied this procedure to reduce FMRP in an experimental setting successfully (Meulders & Vlaeyen, 2012). However, as with any extinction procedure, it is context specific. Upon return to a different context, renewal occurs and the fear response returns. As a result, this would not be a practical approach in a clinical setting with real patients. Reducing pain in one setting offers a minor improvement, but it is not practical as a long-term approach for patients who are constantly moving between environments. As previous researchers established, revaluation generalizes across contexts, so facilitating the extinction procedure with a devaluation procedure should provide a better method of reducing FMRP across multiple contexts.

Applying Revaluation to Fear of Movement-Related Pain

One common method of reducing pain in a clinical physical therapy setting is through graded exposure in vivo therapy (GEXP). This is a way to gradually expose a patient to movements that previously evoked fear, which allows fear to decrease. It is often used to address FMRP in chronic pain patients (Blickenstaff & Pearson, 2016; Meulder & Vlaeyen, 2012;

Vlaeyen, de Jong, Geilen, Heuts, & van Breukelen, 2001). GEXP differs from the traditional extinction procedure in that it does not avoid the pain US. It can be interpreted as a revaluation procedure since it involves exposing the patient to pain but at a lower intensity in order to diminish the threat value associated with it. De Jong, Vlaeyen, Eijsden, Loo, and Onghena (2012) gradually exposed patients with pain in the upper extremities to movements and activities that elicit pain in order to reduce the expectation of fear and threat associated with those movements. In addition, they informed patients that the consequences of their condition were catastrophized, and, contrary to common patient belief, engaging in movements aids the recovery process rather than hinders it. This study resulted in reduced pain catastrophizing and pain-related fear, and these changes persisted upon testing six months later. Similar methods have been used for chronic back pain and complex regional pain syndrome (Leeuw et al., 2008; Linton et al., 2008; Vlaeyen, de Jong, Geilen, Heuts, & van Breukelen, 2002; de Jong et al., 2005).

Other treatments for FMRP may also be understood through revaluation. Blickenstaff and Pearson (2016) offer guidelines for physical therapists on how to incorporate cognitive techniques in order to better address patient pain. They mention techniques such as GEXP as well as others, including methods such as asking patients to work on reducing body tension and maintaining a constant breathing rate during movements. One of their suggested procedures involves moving a patient to the threshold of pain and stopping before the pain is intense. Next, therapists are instructed to ask patients if they feel safe and if they believe they will be okay later. Movements are altered until a patient feels minor pain, but does not perceive it as threatening to their well-being. During this process, therapists are instructed to help the patient reduce muscle tension and maintain a regular breathing pattern. In addition, therapists are told to avoid distracting the patient, as patients must be consciously aware of the pain as well as the perception of safety in a given position. This allows patients to experience a certain amount of movement that they learn is safe and, over multiple sessions, this boundary is gradually pushed so the perception of safety increases over a wider range of motion. Although the authors did not interpret these techniques through the lens of revaluation, they can be interpreted as such. These procedures involve direct contact with the pain US and the control of the behavioral responses that accompany it in order to successfully devalue it. Since these successful procedures lend support to S-S theory, it can be inferred that any alteration to the value of the US can affect the value of the CS. This information can be further used to explore the efficacy of other methods of devaluation.

As was established through evaluative conditioning, direct contact with a US is not necessary for revaluation; other methods, such as the verbal transmission of information, can be used to revalue a US. Arntz and Claassens (2004) conducted a study in which participants were told a bar—which was described by experimenters as either very hot or very cold—was going to be pressed against their neck. Results showed that, although the bar was the same temperature throughout, participants were influenced by the verbal information they received. When told the bar was hot, participants reported feeling more pain. This study highlights the importance of verbal information in the perception of pain. Other researchers describe specific methods therapists can use to challenge pain perception and encourage confidence in patients. Nijs, Girbés, Lundberg, Malfliet, and Sterling (2015) recommended that therapists address the threat perceptions of patients and challenge them during treatment. The authors suggest asking questions to patients about the threat they associate with an exercise, their confidence in completing the exercise, and the usefulness of the movement. Therapists can decrease the threat associated with movement by reassuring patients of the safety of the movement they are performing as well as providing a sense of confidence in patients' abilities. This allows therapists to understand and change patients' fears and allows patients to engage in movements they once avoided.

Educational interventions are another method of devaluation that may be used to address FMRP. Moseley (2004) used an educational intervention to affect pain perception. In his study, patients had a history of chronic lower back pain. All subjects received one of two educational sessions. One presented information on the physiology of pain, and the other provided information regarding the anatomy and physiology of the spine. Before and after the educational intervention, assessments were given to document the change in how subjects felt about physical activity, including both cognitive and physical factors. They were also given a questionnaire on pain attitudes and pain catastrophizing, and they received two physical measures of performance. Results indicated a strong relationship between changes in attitudes about pain and physical measures. Since there was no opportunity for physical activity in this study, these changes could not be attributed to getting more practice with these movements. The authors of this study and the previous two did not explicitly describe their procedures through a revaluation paradigm, but the mechanism by which these procedures operate to reduce patient pain can be understood from this perspective. These studies provide a useful method for incorporating verbal information into a devaluation procedure for pain. Different methods of verbal feedback and their intensities may result in stronger or weaker revaluation effects.

Although revaluation offers promising results for the treatment of FMRP, there are some areas that must be explored with a greater depth. Some studies failed to document a revaluation effect. Den Hollander, Meulders, Jakobs, and Vlaeyen (2015) first conditioned subjects to associate a movement with pain. Post-conditioning, participants in the inflation group received threatening information about the pain. Participants in the devaluation group received safety information about the US, participants in the inflation group were told their skin was very vulnerable, and participants in the control group received no new information about the pain. Threat information was manipulated by providing feedback through a fake machine about participants' skin vulnerability. Following revaluation, participants were told to engage in the pain-related movement once again. However, the revaluation effect was not present for either revaluation group. This experiment highlights the specificity of revaluation that is common across all revaluation studies. Certain methods may revalue certain behaviors more so than others. In addition, certain observational measures may contribute to the failure to document revaluation effects. As such, this study draws attention to the need for more research on revaluation procedures using different methods of devaluation and modes of observation. Nonetheless, revaluation has proven to be a promising tool in the treatment of multiple conditions and should be further explored both experimentally and in the clinical setting.

Conclusion

Although Pavlovian conditioning was discovered nearly a century ago, the nature of the learned association remains a topic of great importance that must be better understood. This paper aimed to discuss the major theories concerning the nature of the underlying association formed during first-order Pavlovian conditioning, the role revaluation plays in testing between the two theories, and the contribution of revaluation in the treatments of various conditions. Future research should focus on untangling the conditions which elicit S-S or S-R learning and using this knowledge to structure interventions to increase the efficacy of various clinical treatments.

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