Available online at www.sciencedirect.com
ScienceDirect
Behavior Therapy 46 (2015) 699–716
Behavior Therapy
www.elsevier.com/locate/bt

Generalization of Pain-Related Fear Using a Left–Right Hand Judgment Conditioning Task

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Recent research suggests that the *mere intention to perform a painful movement* can elicit pain-related fear. Based on these findings, the present study aimed to determine whether *imagining* a movement that is associated with pain (CS+) can start to elicit conditioned pain-related fear as well and whether pain-related fear elicited by imagining a painful movement can spread towards novel, similar but distinct imagined movements. We proposed a new experimental paradigm that integrates the left-right hand judgment task (HJT) with a differential fear conditioning procedure. During Acquisition, one hand posture (CS+) was consistently followed by a painful electrocutaneous stimulus (pain-US) and another hand posture (CS-) was not. Participants were instructed to make left-right judgments, which involve mentally rotating their own hand to match the displayed hand postures (i.e., motor imagery). During Generalization, participants were presented with a series of novel hand postures with six grades of perceptual similarity to the CS+ (generalization stimuli; GSs). Finally, during Extinction, the CS+ hand posture was no longer reinforced. The results showed that (1) a painful hand posture triggers fear and increased US-expectancy as compared to a nonpainful hand posture, (2) this pain-related fear spreads to similar but distinct hand postures following a generalization gradient, and subsequently, (3) it can be successfully reduced during extinction. These effects were apparent in the verbal ratings, but not in the startle measures. Because of the lack of effect in the startle measures, we cannot draw firm conclusions about whether the "imagined movements" (i.e., motor imagery of the hand postures) gained associative strength rather than the hand posture pictures itself. From a clinical perspective, basic research into generalization of pain-related fear triggered by covert CSs such as intentions, imagined movements and movement-related cognitions might further our understanding of how pain and fear avoidance spread and persevere.

Ann Meulders is supported by a Postdoctoral Research Grant of the Research Foundation-Flanders, Belgium (FWO-Vlaanderen) – ID: 12E3714N, and an EFIC-Grünenthal Research Grant – E-G-G ID: 169518451. G. Lorimer Moseley is supported by an NHMRC Principal Research Fellowship – ID: 1045322. Johan W.S. Vlaeyen is supported by an Odysseus Grant "*The Psychology of Pain and Disability Research Program*" of the Research Foundation-Flanders, Belgium, (FWO-Vlaanderen) – ID: G090208N. This study was also supported by an NHMRC Grant – ID: 1047317. The authors would like to thank Jeroen Clarysse for his technical assistance.

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Keywords: pain-related fear; fear conditioning; fear generalization; motor imagery; laterality judgment

According to contemporary fear-avoidance models, pain-related fear plays a pivotal role in the development and maintenance of chronic pain and disability (Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012; Vlaeyen & Linton, 2000, 2012). Accumulating evidence, mostly from studies in patients with musculoskeletal pain, demonstrates that fear of movement-related pain is associated with restricted physical performance, more functional disability, sickness absence, and work loss, and that pain-related fear is often more disabling than the pain itself (Crombez, Vlaeyen, Heuts & Lysens, 1999; Zale, Lange, Fields & Ditre, 2013). In addition, systematic reviews of the literature suggest that avoidance of feared movements and activities is involved in the maintenance of chronic pain rather than it is linked to poor prognosis in early stages of musculoskeletal pain (Pincus, Burton, Vogel & Field, 2002; Pincus, Vogel, Burton, Santos & Field, 2006). Recent evidence suggests that pain-related fear can be acquired through associative learning (Meulders, Vansteenwegen & Vlaeyen, 2011). That is, by virtue of the acquired propositional knowledge between initially neutral stimuli (conditioned stimulus; CS) and pain (unconditioned stimulus; US) (Rescorla & Wagner, 1972), these stimuli may start to elicit defensive responses such as fear and avoidance (conditioned response; CR). For example, movements associated with (increased) pain tend to be avoided, leading to increasing disability in the long run.

Interestingly, a recent study has shown that even the *mere intention to perform a painful movement* can elicit pain-related fear (Meulders & Vlaeyen, 2013b). The intention to move (i.e., motor intent) and imagined movement (i.e., motor imagery) share common cortical neural mechanisms (i.e., premotor and prefrontal activation) and measurable physiological responses (i.e., changes in heart rate) (Decety, 1996; Jeannerod, 1994). It seems reasonable to predict, then, that imagining a painful movement might evoke pain-related fear. Support for this idea comes from research in patients with complex regional pain syndrome (CRPS), showing that imagined movements increased pain and swelling in the painful limb, even though there was no measurable movement or muscle activity (Moseley, 2004b; Moseley et al., 2008). We contend that such an observation implies that pain-related fear may become conditioned to imagined movements, just as it does to the intention to move.

The idea that Pavlovian conditioning may contribute to the development and maintenance of chronic pain is not new. Fordyce (1976) was the first to propose its role; however, the focus quickly shifted to the effect of reinforcement on pain behavior (operant conditioning). That is, successful escape or avoidance of situations, movements, and activities that induce fear and possibly pain can be instrumentally reinforced, and as a consequence the occurrence of these behaviors will be intensified and maintained (Fordyce et al., 1973; Fordyce, Shelton, & Dundore, 1982; McCracken & Samuel, 2007; Philips, 1987).

Under normal circumstances pain-related fear would extinguish after healing, when individuals learn that the CS is no longer followed by the painful US. The power of operant conditioning and learned non-use/avoidance, however, may prevent this extinction from occurring (Philips, 1987; Taub, Uswatte, Mark, & Morris, 2006). That is, when avoidance/non-use is established, spontaneous exposure to the CS, which might disconfirm the CS-US association, is prevented.

Furthermore, it is clinically apparent that highly fearful chronic pain patients avoid not only movements and activities that were associated with (increased) pain, through *direct experience,* but also movements and activities that have not been associated with an initial pain episode. Contemporary models of classical fear conditioning offer a possible explanation for this observation. That is, under certain circumstances, novel stimuli that have features in common with the original fear-eliciting CS may come to evoke a similar CR. By and large, this mechanism, referred to as *stimulus generalization* (Ghirlanda & Enquist, 2003; Honig & Urcuioli, 1981; Kalish, 1969), is highly adaptive because a healthy balance between discrimination and generalization may assist in avoiding harm in a dynamic environment. Yet, a disturbed balance may give rise to maladaptive defensive behaviors, which is consistent with the persistent and undesired avoidance behavior observed in chronic pain. In our opinion, research into generalization of pain-related fear triggered by covert CSs such as intentions, imagined movements, and movement-related cognitions might further our understanding of how pain and fear avoidance spread and persevere.

In order to investigate the acquisition and generalization of fear of imagined movements, we integrated the left-right hand judgment task (HJT) with a differential fear conditioning procedure. During the acquisition phase, one hand posture picture (CS+) was consistently followed by a painful electrocutaneous stimulus (pain-US) and another hand posture picture (CS-) was not. Participants were instructed to judge whether the hand was a left or a right hand. This task involves mentally moving one's own hand to match the posture of the hand shown in the image (Parsons, 2001). CS hand posture pictures were presented in four different orientations to maximize the chances that the imagined hand postures, and not the geometric features of the picture, would be associated with the painful outcome. During the generalization phase, participants were presented with a series of novel hand