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Review

Behavioral neuroscience of psychological pain

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ABSTRACT

Pain is a common word used to refer to a wide range of physical and mental states sharing hedonic aversive value. Three types of pain are distinguished in this article: Physical pain, an aversive state related to actual or potential injury and disease; social pain, an aversive emotion associated to social exclusion; and psychological pain, a negative emotion induced by incentive loss. This review centers on psychological pain as studied in nonhuman animals. After covering issues of terminology, the article briefly discusses the daily-life significance of psychological pain and then centers on a discussion of the results originating from two procedures involving incentive loss: successive negative contrast—the unexpected devaluation of a reward—and appetitive extinction—the unexpected omission of a reward. The evidence reviewed points to substantial commonalities, but also some differences and interactions between physical and psychological pains. This evidence is discussed in relation to behavioral, pharmacological, neurobiological, and genetic factors that contribute to the multidimensional experience of psychological pain.

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1. Introduction: problem and terminology

In English and other languages, "pain" has both a physical dimension (e.g., discomfort caused by injury or disease) and a psychological dimension (e.g., suffering caused by grief or disappointment; Eisenberger and Lieberman, 2004). The identification of these two sources of aversive emotion with the same word, "pain," suggests that there might be important underlying commonalities in the brain mechanisms underlying these two dimensions of pain. In this article, we will argue that there is evidence of an extensive common ground, but also that important differences are starting to emerge.

This paper centers on psychological pain, but relations to both physical and social pains are pointed out as required by the argument. This review sets out to achieve three goals. First, to identify common themes, concepts, and outcomes among lines of research that have proceeded largely independently. This also requires a relatively homogeneous terminology to avoid unwanted semantic confusion. Second, to show the substantial overlap in the neurobiological basis of these types of pain despite the seemingly different procedures used to induce them. Although not phrased in terms of "pain," functional and neurobiological connections between physical and psychological pains have been recognized since the 1960s in terms of common outcomes in situations involving fear conditioning and frustrative nonreward (Gray, 1975, 1987; Wagner, 1966, 1969). Finally, the last aim of this review is to identify areas in which systematic research could have a significant impact in our understanding of psychological pain.

As in any emergent area of research, bringing together domains that have been treated separately in the past creates terminological confusion. To complicate matters further, many of the technical words used in descriptions of this type of research are also of common usage and therefore have less precise semantic limits. It is also important to recognize that many of the relevant concepts can be characterized either as intervening variables (Tolman, 1938) or hypothetical constructs (MacCorquodale and Meehl, 1948), that is, *unobservable variables* postulated theoretically to account for empirical evidence, but with the implication of mapping to a lower level of analysis (e.g., brain circuitry). Table 1 provides a list of the key concepts used in this article and their definition.

Three types of pain have been distinguished in the recent literature. Research described by the word "pain" that is connected to physical injury, disease, or intense discomfort is referred to as physical pain. *Physical pain* is a multidimensional experience that incorporates the sensory and emotional consequences that follow the administration of nociceptive stimuli (Pace et al., 2006). Laboratory studies have induced physical pain with a variety of procedures, including electric shock delivered peripherally (to the animal's feet, cheeks, legs, etc.), gastric discomfort induced by toxins (e.g., lithium chloride), peripheral nerve ligation (e.g., sciatic nerve), subcutaneous administration of chemical substances causing irritation or inflammation (e.g., formalin), and similar procedures. Organisms come to anticipate such aversive internal states, even with minimal exposure, by associating them with preceding stimuli (i.e., signals or conditioned stimuli, CSs). CSs of physical pain induce a variety of conditioned responses such as freezing, escape, rejection, and avoidance, assumed to reflect internal states usually referred to as *fear* (Whalen and Phelps, 2009) or *disgust* (Reilly and Schachtman, 2009), depending on the type of pain that induced the association (e.g., intense discomfort, sickness).

A second type of pain has been called social pain. *Social pain* is triggered by rejection, exclusion, separation, or loss events involving conspecifics (Eisenberger and Lieberman, 2004; MacDonald and Jensen-Campbell, 2011). A distinction between actual and anticipated states can also be drawn in the case of social pain.

Table 1
Definitions of key terms used in this article.

Psychological concept	Definition
Fear	Aversive state induced by *anticipated* physical pain
Incentive	An organism's expectation of an appetitive outcome
Reward devaluation	Presentation of an appetitive outcome of lower incentive value (in quality or magnitude) than that predicted by current stimuli (e.g., successive negative contrast)
Reward loss	A negative discrepancy between expected and obtained rewards. Two major instances are reviewed in this article: reward devaluation and reward omission
Reward omission	Absence of an appetitive outcome in the presence of stimuli previously associated with its presentation (e.g., appetitive extinction)
Physical pain	A multidimensional aversive state induced by *actual* disease or body injury, or by sensory signals associated to injury (e.g., electric shock)
Primary frustration	Aversive state induced by *actual* reward omission or devaluation in quality or magnitude
Psychological pain	Aversive state induced by *actual* or *anticipated* reward omission or devaluation in a nonsocial context
Secondary frustration	Aversive state induced by *anticipated* reward omission or devaluation in quality or magnitude
Social pain	Aversive state induced by *actual* exclusion or separation in a social context

Note: Some of these definitions may be more restrictive than in the common usage; they are intended to reflect how these terms are defined in the research reviewed in this article. Some key references: Amsel (1992), Logan (1960), MacDonald and Jensen-Campbell (2011), Pace et al. (2006) and Papini et al. (2006).

The terminology is complicated because social life, especially in humans, distinguishes many types of situations that might induce such an aversive state. This could be illustrated using social rejection. Whereas the actual emotion may be described in terms of feelings of *personal rejection*, the anticipated form may be described in terms of *social threat* (MacDonald and Leary, 2005). Thus, it seems plausible that a person who has felt rejected in a certain type of situation (e.g., a party with a specific group of friends) may later avoid confronting a similar situation. Much of the recent research on social pain with human participants is based on traditional methods of experimental social psychology occasionally combined with brain imaging techniques. A close analog in nonhuman animals would be research on mother–infant separation as studied in nonhuman primates and other animals (Maestripieri, 2003). Such studies have provided important information on the impact of rejection, exclusion, separation, and incentive loss. The research on mother–infant separation usually focuses on the immediate consequences and the long-term effects of early experience (Suomi, 2006), rather than the anticipatory effects.

A third type of pain, the one central to the present review article, can be called psychological. *Psychological pain* refers to the aversive emotional consequences of exposure to a reward loss event, relative to what was expected (Papini et al., 2006). Three types of reward loss events are distinguished: reward devaluation (reduced, but non-zero outcome), reward omission (complete outcome removal), and response-reward barrier (obstruction). This review centers on the first two since little research has been done with the obstruction procedure (for an example with human babies, see Kramer and Rosenblum, 1970). A major distinction between physical and psychological pains is the lack of a sensory component to psychological pain. The detection of a significant negative discrepancy between expected and actual rewards triggering a reaction of psychological pain is not a singular sensory event, but a comparison between actual and anticipated (i.e., retrieved from memory) incentive values. The distinction between psychological and social pain is less precise. Psychological pain has been typically studied in nonsocial