I think it's going to hurt: the effects of cognition on pain perception (Prepared for anonymous review.)

Abstract. The aim of this paper is to investigate whether, or to what extent, cognitive states (such as beliefs or intentions) influence pain perception. We begin with an examination of the notion of cognitive penetration, followed by a detailed description of the neurophysiological underpinnings of pain perception. We then argue that some studies on placebo effects suggest that there are cases in which our beliefs can penetrate our experience of pain.

Keywords: pain, music therapy, gate-control theory, cognitive penetration, top-down modularity, perceptual learning, placebo effect

1. Introduction

Consider the experience of eating wasabi. When you put wasabi on your food because you believe that spicy foods are tasty, the stimulation of pain receptors in your mouth can result in a pleasant experience. In this case, your belief seems to influence your perceptual experience. However, when you put wasabi on your food because you incorrectly believe that the green paste is mint, the stimulation of pain receptors in your mouth can result in a painful experience rather than a pleasant one. In this case, your belief that the green paste is mint does not seem to influence your perceptual experience.

The aim of this paper is to investigate whether, or to what extent, cognitive states (such as beliefs) influence pain perception. We begin with an examination of the notion of cognitive penetration and its theoretical implications using studies in visual perception. We then turn our attention to the perception of pain by considering its neurophysiological underpinnings. Lastly, we argue that some empirical findings suggest that there are cases in which our beliefs can penetrate our experience of pain.

2. Clarifying the debate of cognitive Penetration

Cognitive penetration refers to the influence of our beliefs, desires, intentions, and other cognitive states on perceptual experience. It concerns questions such as: Can our beliefs or desires influence how things appear to us? Can one's belief that a person is angry influence the way one perceives that person's voice? Can the desire to eat something sweet influence how something tastes? These questions have important implications for philosophy and cognitive science. In philosophy, the possibility of cognition having an influence on perception has serious implications with regard to the epistemic role of perception: if our cognitive states influence our perceptual experiences (in the way suggested in the examples above), then perception cannot be seen as an objective source of knowledge (Siegel, 2011). In cognitive science, the possibility of cognition having an influence on perception has serious implications with regard to the neurophysiological mechanisms underlying perception and cognition (Fodor, 1983). If our cognitive states influence our perceptual experiences, then (contrary to the prevalent view in cognitive science) perceptual mechanisms cannot be functionally independent from the mechanisms underlying cognition and language.

With respect to visual perception, the dominant view in philosophy and cognitive science is that cognitive states cannot influence the perceptual character or content of experience—call this view the *Cognitive Impenetrability Thesis* (CIT). For example, your desire for the unripe (green) banana in front of you to appear yellow (say, when you are looking forward to eating it) seems to have no effect on your visual experience of the banana: regardless of your desire, the banana continues to look green.[1] Philosophers have recently challenged CIT with respect to visual perception (Cecchi, 2014; Macpherson, 2012; Wu, 2013). The dialectic surrounding the problem of cognitive penetration goes something like this:

(1) Differences in the content (or phenomenology) of perceptual experience are observed.
(2) These differences cannot be attributed to shifts in the subject's attention, changes in distal stimuli, or changes to the state of the perceptual system.
(3) These differences can only be explained in terms of cognitive penetration.

If these three claims are true, then the CIT cannot be true. To see this, consider visual perception. Various studies on color perception seem to suggest that (1) is true (Delk and Fillenbaum, 1965; Hansen et al., 2006; Olkkonen, Hansen, and Gengenfurtner, 2008). For example, in one study participants were asked to match the color of figures with the color of their background (Delk and Fillenbaum, 1965). All of the figures were constructed using the same sheet of orange-red cardboard. Some of them depicted objects that are characteristically red such as a heart, a pair of lips, an apple, and so forth. Others depicted objects that either neutral such as a square or a circle or not characteristically red such as a mushroom or a bell. One at the time, these figures were placed against a background whose color could be changed from a light red to a dark red and vice-versa. A differential color-mixer was used, which permitted the experimenter to mix two colors to produce continuously varying intermediate shades at the participant's request.[2] Participants instructed the experimenters to make the background color darker or lighter until the figure could no longer be distinguished from the background. They found that red-associated figures (such as lips or heart) required more red in the ground for the match than neutral or non-

[1] Perceptual experience, by contrast, can bring about changes to one's cognitive states. For example, one's perceptual experience of a red traffic light can generate the belief that one must bring the car into a full stop.

[2] These shades could be varied from 360^{o} red, resembling Munsell chip R/3/8, and 0^{o} yellow-orange, resembling Munsell chip YR/6/10, to 0^{o} red and 360^{o} yellow-orange.

red associated figures (such as square or mushroom). According to Delk and Fillenbaum, these findings suggest that past associations of color and form influence perceived color.[3]

A more recent study, conducted by Hansen et al. (2006), produced similar results. In this study, participants were presented with digitized photographs of natural fruit such as bananas as well as neutral patch such as a square against a gray background. Participants were asked to adjust the color of the object (a banana or a neutral patch) on the screen until it appeared gray. It was found that participants adjusted the color of the banana (but not the neutral patches) to a slightly bluish hue, which is the opponent of yellow, in order to make it appear gray. This suggests that the banana continued to appear yellow to participants even when it was actually achromatic (i.e., gray). According to Hansen et al. (2006), these results suggest that color memory influences perceived color.

These findings give credence to (1). Objects that have characteristic colors and neutral objects or patches seem to be experienced as having different colors—that is, differences in the content (or phenomenology) of the color experiences of participants are observed. The setting of the experiments rules out the possibility that these differences can be attributed to shifts in the participant's attention, changes in distal stimuli, or changes to the state of the perceptual system. In light of these observations, some philosophers have argued that these findings also give credence to (2) (Macpherson, 2012). But if findings support (1) and (2), then they also support (3). It follows that CIT cannot be true.

A typical strategy for blocking the conclusion that perceptual experience is cognitively penetrable relates to the view that perceptual systems are modular (Fodor, 1983; Marr, 1982). In Fodor's view, a perceptual system is modular just in case it is domain specific, informationally encapsulated, and hard-wired. A perceptual system is domain specific in the sense that it is specialized; it only operates on certain kinds of inputs. For example, vision operates on visual inputs, audition on auditory inputs, and pain on tissue damage inputs. However, perceptual systems are domain specific only in the weak sense of being used to process information underlying our aptitude for that domain, not in the strong sense of being exclusively dedicated to a specific domain (Prinz, 2006). Studies show that when a perceptual system, say, vision, is damaged, cortical areas housing that perceptual system can be used by another perceptual system, say, touch (Bates, 1994; Bates et al., 2000; Bishop, 1992; Tallal et al., 1996; Vargha-Khadem et al., 1995).

A perceptual system is informationally encapsulated in the sense that it has no access to information stored externally to it; its internal operations are not influenced by information stored in other systems. Fodor (2000) treats informational encapsulation as the hallmark of modularity. Indeed, most of the arguments in defense of the CIT as it pertains to vision can be summed up as an attempt to show that there is no top-down modulation of early visual areas (Pylyshyn, 1999; Raftopoulos, 2001). The notions of *top-down modularity* and *early visual areas* have been part of the predominant view in cognitive science, according to which perceptual

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[3] The term typically used to describe past associations of color is "color memory." Color memory is the ability to remember the colors of familiar objects.

systems process information in a hierarchical manner. When inputs enter the visual system, relevant information is first sent to the relevant subcortical areas, then to lower-level (non-cognitive) and, finally, to higher-level (cognitive) areas. (A detailed explanation of the hierarchical processing of pain inputs is provided in the next section). If a perceptual system is indeed informationally encapsulated, then one would expect that there would be no top-down modulation of earlier sensory areas. Studies, however, show that a participant's focus of attention influences perception, including pain perception (see Legrain and Torta, 2015; Durnez and Van Damme, 2015).

Cognitive scientists treat the focus of attention as a cognitive process. So why aren't differences in the focus of attention count as evidence against the CIT? In other words, why are such differences excluded in (2)? In the case of color vision, the answer is that the effects of attention on perceptual experience involve either pre- or post-perceptual top-down modulation of early visual areas (Pylyshyn, 1999). The influence of attention on perceptual experience involves top-down (and hence cognitive) modulation of earlier visual areas. However, this sort of top-down modulation does not count as evidence against the CIT because it occurs either before perceptual processing commences or after it has ended (Pylyshyn, 1999). To show, therefore, that the CIT is not true, we must show that top-down modulation of earlier visual areas takes place *during* perceptual processing.

Top-down influences on visual processing are, of course, not limited to attention. The aforementioned studies on color perception suggest that color memory influences perceived color. More recently, Wu (2013) extended this argument to spatial perception claiming that stored memories constituting an action database (which Wu misleadingly calls "intentions") penetrate visual experience, specifically visual spatial constancy.[4] Wu observes that changes in the retinal image produced by objects moving in our visual field give rise to the experience of movement (a phenomenon known as spatial inconstancy). These same changes in the retinal image, however, can also be induced in the absence of a distal stimulus (i.e., through saccadic eye movements). The difference between changes in the retinal image produced by movement and changes induced in the absence of a distal stimulus is that, in the latter case, we are not experiencing objects as moving (a phenomenon known as spatial constancy). Thus, the same retinal image is consistent with both spatial constancy and spatial inconstancy. On the basis of these observations, Wu argues that spatial constancy rests on information exchange between the cognitive, motor, and visual modules. In particular, stored memories constituting an action database affect basic visual computations that underlie our visual experience. Since the visual system is penetrated by these stored memories, it is not informationally encapsulated.

One line of defense against the charge that perceptual systems are not informationally encapsulated is to accept that top-down influences are exerted in later stages but deny that they are exerted in earlier stages of visual processing (Pylyshyn, 1999). For example, Raftopoulos

[4] Vision is a special case, not akin to the perception of pain. The problem of vision is to explain how the visual system resolves the ambiguity resulting from the fact that the same retinal image is consistent with various distal stimuli; the correlation between the retinal image and distal stimuli is one-to-many, not one-to-one.

(2001) argues that although late vision is cognitively penetrated, early vision is informationally encapsulated. This line of defense is, however, problematic because top-down influences are exerted throughout the visual system (Gilbert and Li, 2013; Pourtois et al., 2008).[5]

One line of argument against the CIT relates to Fodor's claim that perceptual systems are hard-wired. A perceptual system is hard-wired in the sense that it cannot be subject to top-down influences or modifications of its neural architecture. Studies, however, show that gradual changes in brain connectivity can result from training consisting of repeated exposure to particular stimuli—a phenomenon known as perceptual learning (Bruce and Burton, 2002; Gilbert and Li, 2012; Roelfsema et al., 2010; Wallis and Bülthoff, 2002). Churchland (1988), for example, uses a study on perceptual learning involving subjects wearing inverse lenses (Kottenhoff, 1957) to argue that, pace Fodor, the visual system is not hard-wired since diachronic changes in its neural architecture have been observed as it adapts to new realities. More recently, Cecchi (2014) used a more current study on perceptual learning (Pourtois et al., 2008) to argue that changes to the neural architecture of the visual system extend to early visual areas.

The effects of top-down modularity of sensory systems (whether it is understood in terms of informational encapsulation or hard-wiring) can hardly be denied. The question, however, is whether these effects threaten the CIT. Fodor (1988) rejects Churchland's (1988) argument on ecological grounds: he argues that these changes can be attributed to the recalibration of the perceptual/motor mechanisms (such as hand/eye) that correlate bodily gestures with perceived spatial positions and which are required for an organism to grow. In other words, these changes are developmental or adaptational; they are not changes brought about by the perceiver's cognitive states. (The same can be said about Wu's argument since the relevant changes are developmental or adaptational and are not changes brought about by the perceiver's intentions; indeed "intention" is a technical term defined as "stored memories constituting an action database.") According to Fodor (1988: 194), "What Churchland needs to show—and doesn't—is that you *also* find perceptual plasticity where you *wouldn't* expect it on specific ecological grounds; for example, that you can somehow reshape the perceptual field by learning physics."

Fodor's observation is relevant to our discussion of cognitive penetration. To show that the CIT is false, it is not enough to show that top-down influences are exerted on a perceptual system. What must be shown is that the changes a perceptual system undergoes are somehow tied to the *perceiver's* beliefs or other cognitive states. In particular, it must shown that the information a perceptual system computes is sensitive (in a semantically-coherent way) to the *perceiver's* beliefs or other cognitive states and it can be altered in a way that bears a logical relation to the *perceiver's* knowledge or reasons (Brogaard and Gatzia, 2015; Pylyshyn, 1984, 1999; Raftopoulos 2009). Two states are said to be semantically coherent when they have the same content. For example, when you have the belief that the taste of wasabi is pleasant and that gives rise to a pleasant gustatory experience when you eat it, your belief (that the taste of wasabi

[5] With respect to audition, top-down modulation extends to subcortical areas (see Suga, 2008; Lee, 2003; Maison et al., 2001; Lee et al., 1998).

is pleasant) and your gustatory experience (of the wasabi tasting pleasant) have the same content. Cognitive penetration, on this view, requires a semantically coherent connection between the penetrating cognitive state and the penetrated perceptual experience understood in terms of an inference-supporting relation between the perceiver's belief—the penetrating state—and her perceptual experience—the penetrated state (Brogaard and Gatzia, 2015; in press). It follows that if top-down modularity is to be taken as evidence against the CIT, what must be shown is that the perceiver's cognitive states can penetrate her perceptual experience. We believe that this claim can be made with respect to pain perception. Prior to defending this claim, however, an explanation of the physical underpinnings of pain is in order.

3. The physical underpinnings of pain

The goal of the above discussion was not to defend or refute the CIT in general but to clarify the debate in order to explore the question of whether the perception of pain can be said to be cognitively penetrated. Unlike vision, pain may constitute a simpler case in which to examine cognitive penetrability because the stimuli may be less varied, and the representation less complex. Moreover, there are ample data to suggest that top-down influences are important in the experience of pain. Thus, we may find stronger arguments that pain perception can be cognitively penetrated by a perceiver's cognitive states. Let us then begin by discussing the neurophysiological processes behind the experience of pain.

Pain is typically defined as follows: the perceptual experience of real and threatened tissue damage. Pain arises from stimulation of nociceptors or free nerve endings, which one can find throughout the skin as well as in muscle, bone, and in the digestive system (Schwartz and Krantz, 2016). Although the acute pain of a pin prick may feel different than the dull ache of arthritis, they both begin by stimulation of nociceptors, in the first case, in the skin, in the second case, in the muscles and joints. Although pain is usually quantified by asking participants to rate it by intensity, there are also subjectively different varieties of pain, starting with the difference between acute versus chronic pain (Williams and Purves, 2001).

Nociceptors are sensory receptors embedded in the skin and other parts of the body. When stimulated, they cause us to feel pain. Nociceptive pain is the pain that results from tissue damage that cause these nociceptors to fire. Thus, when your fingers accidentally (or intentionally, for that matter) touch a hot stove, the heat from the stove causes nociceptors to fire. This bottom-up process in pain is presumably a system that evolved to make us move our fingers away from the source of the heat as quickly as possible. There are two distinct types of nociceptors: A-delta fibers and C-fibers. A-delta fibers respond rapidly to tissue damage, responding to both heat and pressure. It is these fibers that cause the stinging pain that we experience when we touch the stove and are probably involved in the rapid movements we make away from the source of pain. C-fibers are slower to respond and are therefore more associated with throbbing pain and chronic pain (Williams and Purves, 2001). It is for this reason that C-fibers are associated more with pain caused by inflammation and other internal forms of pain (Scholz and Woolf, 2002).

The pain signal travels up the axons of the spinothalamic tract of the spinal cord. After leaving the spinal cord, the axons carrying the pain signal synapse in the medulla and the thalamus before entering the somatosensory cortex in the parietal lobe. In particular, areas 3A and 3B of the somatosensory cortex receive input from the nociceptors (Hsiao, 2008). Areas 3A and 3B are both considered part of primary somatosensory cortex. From there, the pain signal goes to secondary somatosensory cortex in the parietal lobe and then to the insula and the anterior cingulate cortex, both in the frontal lobes (Hutchinson et al, 1999). It is to these areas that we look for evidence of top-down modulation of areas associated with the perception of pain. Indeed, when the anterior cingulate is damaged, a condition called akinetic mutism may arise. People with akinetic mutism show little inclination to move or speak, though they can when pressed to do so. With respect to pain, they report experiencing pain, but tend to not be bothered by it and may not respond to it (Nagaratnam, Nagaratnam, Ng, and Diu, (2004).

Critical to any model of pain perception is the gate control theory of pain, a model that accounts for the top-down regulation of the pain signal. Gate control theory posits that signals emanating from the cortex, in particular, the anterior cingulate, control the pain signal that comes up from the spinal column to the brain. Information from the cortex can enhance the signal coming from the nociceptors, leading to greater experience of pain, or it can dampen the signal, lessening the experience of pain (Melzack and Wall, 1988). This leaves open a wide range of cognitive and emotional factors that can influence the sensory experience of pain. For example, Salomons et al. (2015) found that people given more control over the source of pain showed less pain and less activity in the anterior cingulate. Activity in the anterior cingulate has been correlated with the emotional components of pain (Rainville et al.,1997) as well as pain intensity (Coghill et al., 1999; Sawamoto et al., 2000).

4. Evidence for the possibility of cognitive penetration of pain perception

There are a variety of other factors that can influence the experienced intensity of pain emanating from the same action of nociceptors. One of the interesting and relevant observations from the point of view of cognitive penetrability is that listening to music can reduce the experience of pain, in at least some situations. Studies overwhelmingly suggest that music influences pain perception (Dobek et al., 2014; Garza-Villarreal et al., 2014; Lee, 2015). In particular, studies show that music therapy reduces chronic pain (Korhan et al., 2013; Roy et al., 2012). A meta-analysis of ninety-seven trials on the effects music has on pain perception suggests that participants in music therapy and music medicine required fewer anesthetics as well as both opioid and non-opioid medications (Lee, 2015). Music medicine means that patients listen to specific pieces of music in order to reduce the amount of pain they feel, usually in hospital settings (Shultis, 2012). Music therapy involves both listening to and playing music in a social context of interacting with a therapist with the goal of moving the patient beyond the pain rather than simply distracting him or her (Shultis, 2012).

Lee (2015) found that music therapy was the more effective than music medicine in reducing chronic pain associated with cancer, whereas music medicine was found to be more effective in managing procedural pain than music therapy (Lee, 2015). In some cases, the patients were dealing with chronic pain associated with quite severe illness, and yet, the music reduced pain. Across music medicine studies and music therapy, pain was reduced by about 1 unit on a 1 to 10 scale relative to control conditions. Moreover, these patients required less medication to control their pain, and this was true across the age of the patients. This is not surprising given that listening to music has been related to dopamine release (Salimpoor et al., 2011), which is known to have a role in analgesia (Wood, 2008).

However, these studies do not provide evidence for the falsity of the CIT as the analgesic effect of music are typically attributed to engaged attention (Bradshaw et al., 2011; Brown, El-Deredy and Jones, 2014; Durnez and Van Damme, 2015), change in mood (Villemure and Bushnell, 2009) or relaxation (Garza Villarreal et al., 2012; Finlay and Rogers, 2015). It follows that there seems to be a no semantically coherent connection between penetrating cognitive states, i.e., the belief that music will reduce pain, and the penetrated experience of pain, meaning that there is no inference-supporting relation between the perceiver's belief (the penetrating state) and her experience of pain (the penetrated state). The analgesic effects of pain associated with these studies, therefore, cannot be attributed to the beliefs (or other cognitive states) of the perceivers.

There are, however, other studies that seem to provide evidence against the CIT as it pertains to pain perception. One of the more striking demonstrations of the effects of a perceiver's cognitive states on pain perception comes from the famous placebo effect (Pollo et al., 2001; Price et al, 2008). Placebo effects with respect to pain mean that when participants expect a treatment to be effective at reducing pain, they feel less pain even when the treatment is objectively no different from a condition in which participants are told the same treatment will have no effect. Thus, in the placebo effect, the belief that a medication can provide pain relief is enough to create pain relief. Consider a recent demonstration of this effect. Freeman and colleagues (2015) administered three creams (which were all identical) before presenting a moderately painful stimulus. In one condition, the cream was labeled "lidocaine" and was introduced as an analgesic. In a second condition, the cream was labeled "capsaicin" and was introduced as a substance that might increase the pain from the stimulus (hyperalgesia). In the third condition, the cream was labeled "neutral," and the participants were not told of any pain-decreasing or pain-increasing tendencies. Consistent with the placebo effect, the belief that the cream was an analgesic led to subjectively less pain experienced relative to the control condition whereas the belief that the cream was a hyperalgesic led to subjectively more reported pain relative to the control. The pain stimuli were administered while participants were being monitored by fMRI. When participants were expecting an increase in pain—that is, when they believed that the cream will act as an hyperalgesic—there was greater activity in the insula, as well as orbitofrontal cortex. When participants were expecting pain relief—that is, when they believed that the cream will act as an analgesic—there was greater activity in the striatum, a subcortical part of the brain associated with reward (Freeman et al, 2015).

In terms of understanding this literature, the term "placebo" effects is typically used to describe an analgesic effect of an otherwise inert substance that participants expect to reduce pain. In addition, the term "nocebo" effect refers to the hyperalgesic effect brought about by an expectation of increased pain (Colloca, 2014). Thus, like placebo effects, nocebo effects are top-down in nature, but they involve a negative rather than a positive outcome. Some have argued that the mechanisms for placebo and nocebo effects are similar, whereas others have argued for different mechanisms (see Freeman et al., 2015). For our purposes here, the point is that a perceiver's beliefs about a medication can have a profound effect on perceived pain in both positive and negative directions.

The aforementioned studies suggests that beliefs that a medication will act as an analgesic causes direct changes in the brain, which then influence the experience of pain in a top-down manner. Here, there seems to be a semantically coherent connection between the penetrating cognitive state (i.e., the belief that a cream will reduce the pain experienced) and the penetrated experience of pain (a reduction of pain is experienced). In addition, there is an inference-supporting relation between a perceiver's belief (the penetrating state) and her experience of pain (the penetrated state). When perceivers believe that the cream administered will act as an analgesic, they tend to experience less pain than they experience when they believe that the cream will not act as an analgesic. The analgesic effects of pain associated with these studies, therefore, can be attributed to perceivers' cognitive states, viz. their beliefs about a medication. Similarly, when perceivers believe that the cream administered will act as an hyperalgesic, they tend to experience more pain than they experience when they believe that the cream will not act as an hyperalgesic. The hyperalgesic effects of pain associated with these studies, therefore, to perceivers' cognitive states, viz. their beliefs about a medication. It follows that these studies provide evidence against the CIT because they suggest that our beliefs can penetrate our experience of pain.

The participants in studies on pain perception are volunteers who undergo mild pain under controlled conditions. The studies cited above seem to indicate that beliefs tend to influence (or penetrate) pain perception. However, a study that examined torture victims after their release from captivity indicates that these individuals show a heightened sensitivity to pain, even under controlled situations (Defrin, Ginzburg, Mikulincer, and Solomon, 2014). These results seem to be contrary to our suggestion that one's beliefs can penetrated one's perception of pain; for, one would not expect to find heightened sensitivity to pain under controlled situations. It is worth noting, however, that the heightened sensitivity to pain in this experiment was directly associated with areas of the body that were affected during the torture sessions. Heightened sensitivity to pain was not found for unaffected areas during the ordeal. It is likely, therefore, that the heightened sensitivity to pain may be attributed to the belief of victims of torture that the areas of their bodies that had undergone torture are more sensitive than other areas. In this case, the content of their belief and the content of their experience lack semantic coherence; they believe that the affected body area is more sensitive although they do not experience more pain in the affected area than they experience in the unaffected area. Or it may be that such traumatic experiences somehow re-tune the physical pain system leading to heightened pain sensitivity in the affected areas. In this case, the content of their belief and the content of their experience are semantically coherent; they believe that the affected area is more sensitive and as a result they experience more pain in the affected area than they experience in the unaffected area. Either way, this study would not provide evidence that our suggestion is erroneous. The first case cannot be used as evidence against our suggestion since the requirement of semantic coherence is not satisfied. The second case cannot be used as evidence against our suggestion even though the requirement of semantic coherence is satisfied since it does not follow that their beliefs cannot influence their pain perception.

5. Conclusion

The aim of this paper was to investigate whether, or to what extent, beliefs influence pain perception. We began with an examination of the notion of cognitive penetration and its theoretical implications using studies from visual perception. We then argued that if cognitive penetration is understood as a semantic thesis, studies on the placebo effect seem to provide support for the possibility of cognitive penetration of pain perception. According to the semantic thesis, the information a perceptual system computes is sensitive (in a semantically-coherent way) to a perceiver's cognitive states and cannot be altered in a way that bears a logical relation to her knowledge or reasons (Brogaard and Gatzia, 2015; Pylyshyn, 1984, 1999; Raftopoulos 2009). Unlike the studies conducted on other modalities, such as vision, studies on the placebo effect seem to provide evidence for the possibility of the cognitive penetration of pain perception. The study on the placebo effect discussed above found that the intensity of pain depended, at least in part, on whether the participants believed that the cream would act as an analgesic or as an hyperalgesic. Both the analgesic and hyperalgesic effects of pain, therefore, can be attributed to the beliefs perceivers had about the medication. It follows that these studies provide evidence for the claim that pain perception is cognitively penetrated as they suggest that there is an inference-supporting relation between cognitive states of perceivers (the penetrating state) and their experience of pain (the penetrated state).

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