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ORIGINAL RESEARCH

Expecting pain

Frederique de Vignemont[1]

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Abstract
There is a large amount of evidence of placebo and nocebo effects showing that one's expectation of a forthcoming pain can influence the subsequent experience of pain. Here I shall not discuss the implications of these findings for the nature of pain, but focus instead on the nature of pain anticipation itself. This notion indeed remains poorly analysed and it is unclear what type of anticipatory state it involves. I shall argue that there is more to pain anticipation than a mere combination of anticipatory beliefs and fears. When the impending damage is imminent, pain anticipation involves a distinctive sui generis mental state, which I call nociceptive prediction. One then anticipates the forthcoming event under the pain mode. After analysing its points of similarities and differences with pain, I shall argue that nociceptive prediction is best understood in imperative defensive terms.

Keywords Peripersonal space · Imperativism · Fear · Danger · Protective behaviour · Nocebo · Motivational state · Belief

1 Introduction

In 2020, the pandemic situation revealed how bodily awareness could be easily influenced by expectations. After repeatedly hearing about COVID-19 symptoms in the mass media, many of us were under the impression of experiencing them, though we tested negative. One then talks of nocebo, or nocebo-like, effects. Whereas placebo effects involve the positive expectation that one's well-being will improve, nocebo effects involve the negative expectation that it will worsen (Shih et al., 2019). It is specifically with pain that the role of negative expectation has been the most care-

✉ Frederique de Vignemont
frederique.de.vignemont@ens.fr

[1] Institut Jean Nicod, CNRS—EHESS—ENS—PSL University, 29 rue d'Ulm, Paris 75005, France

fully studied. It has been found that anticipating pain to increase can be at the origin of hyperalgesia (increase in pain sensitivity), and even of allodynia (pain response to non-painful stimulation). It can also contribute to chronic pain (Vlaeyen & Linton, 2000). Pain can thus be altered, or even induced, by one's anticipating it (e.g. Benedetti et al., 2020; Atlas & Wager, 2012; Koyama et al., 2005). What interests me here, however, is not the fact that pain can be modulated as such, but rather what is doing the modulation. The notion of pain expectation itself remains poorly analysed and it is unclear which type of anticipatory state it involves.

Let us start with a simple example. A child is told that she must go to the dentist the day after. She remembers how much pain last visit caused her and she is convinced that it will be the same this time. She dreads the dentist and she is afraid of the pain that he will inflict her. On the basis of such an example, one might conclude that pain anticipation only includes anticipatory beliefs, often associated with fear, both about a pain that one is likely to experience in a more or less close future. On this deflationist view, there is nothing special about pain anticipation. One might as well anticipate that it will rain tomorrow: one believes that it will be the case and fears it because it will ruin one's plans. But is pain anticipation similar to a simple weather forecast? Or is there a notion of pain anticipation that corresponds to a distinctive type of mental state?

In this paper, I shall argue that there is more to pain anticipation than a mere combination of anticipatory beliefs and fears. More precisely, I shall propose that one's anticipation can be under a pain-like mode. One may then talk of *nociceptive prediction*. I shall then analyse its points of similarities, but also of differences, with pain. To do so, I shall not restrict my analysis to nocebo studies, which have the peculiarity that the participants have no control over the future pain, but also include more ecological dangerous situations in which pain expectation can directly translate into action to prevent the predicted bodily damage to occur. [1] I shall finally propose that at the very last minute, when danger is imminent, pain anticipation has an imperative defensive content (Martinez, 2015; Klein, 2015a; Barlassina & Hayward, 2019).

2 Believing that one will be in pain

Most discussions on pain anticipation can be found in the study of placebo and nocebo effects. For obvious clinical reasons, many studies have focused on the beneficial effects of positive expectations, but anticipating pain can have a detrimental effect, when one expects that it will worsen. Take the example of nitrous oxide, also known as laughing gas. It is normally used in anaesthesiology, thus leading to analgesia. Surprisingly, however, it can also lead to hyperalgesia following verbal suggestions (Dworkin et al., 1983). Hence, the same substance can decrease or increase pain, depending on what is said beforehand to the participants. This is one of the

[1] There is a wide variety of pains and one may wonder whether it is the same to expect the pain of a vaccine injection, the pain of a heavy handbook falling on your foot, and the monthly pain of your menstruation cramps. Here I leave aside the anticipation of certain types of pain, such as visceral pains, and focus only on the pain caused by external threats and in principle avoidable from the subject's viewpoint.

many results that show the influence of prior information on the intensity of pain. The hypothesis is that on the basis of what they are told, participants generate expectations about what is awaiting them and that the greater the certainty, the more impact it has on their subsequent experience (e.g., Brown et al., 2008). Nocebo (or nocebo-like) effects do not require the use of any specific substance. Consider, for instance, the following suggestion during hypnotic induction given before participants put their hand into hot water:

(i) When you feel your hand enter the water bath, you may be surprised to notice how much more intense the sensation is than you might have expected it to be. (Rainville et al., 1999, p. 170)
(ii) Although you will continue to experience normal sensation, your experience will seem surprisingly more unpleasant… surprisingly more uncomfortable… surprisingly more disturbing than you might have expected. (idem)

After receiving these suggestions, participants rated significantly higher the intensity and the unpleasantness of the pain caused by the water, and this was correlated with stimulus-evoked heart rate increase. Furthermore, the effect was specific to the type of suggestion that was given, selectively influencing the participants' rating of the sensory (i) or the affective (ii) component of pain. It is not only the rating of the sensation that is affected in nocebo effects, but the sensation itself, as shown by the modulation of the neural activity in brain regions associated with pain, including in the insula, the thalamus, and in the anterior cingulate (Ploghaus et al., 1999; Wager et al., 2004). This is so even when pain is only hypnotically suggested, but not when it is simply imagined (Derbyshire et al., 2004). This neural activity is taken as evidence that it is not only the judgment that participants make that is influenced by their expectation, but the pain itself that they experience. Pain can even be induced in the complete absence of painful stimulation. In one study, participants were presented with red or green lights and they were given beforehand verbal instructions associating the coloured lights either with painful stimulation or with non-painful tactile stimulation. If the participants were presented with the colour associated with pain, they significantly reported a more intense pain when they received a small mildly painful electrical shock, but also when they only received a non-painful tactile stimulus (Colloca el al., 2008). Pain expectation then became pain.

I have reviewed here only a few results but they are consistent with the gate control theory proposed by Melzack and Casey (1968), according to which pain can be modulated not only at the level of the spinal cord, but also at the level of what they call the central control system, which allows for top-down influences. They raise fundamental questions about the penetrability of pain to higher influences. Though some of the effects may be explained by mere conditioning effects or sensory learning, it has been argued that others meet the conditions taken to be crucial to *cognitive penetration* (Gligorov, 2017; Shevlin & Friesen, 2021; Jacobson, 2017; for a different analysis, see Casser & Clarke, 2022). The question I address here, however, is not about pain itself, but about the nature of the anticipatory state that drives the modulatory effect on pain. According to what we may call a doxastic account, pain anticipation simply consists in a belief or belief-like state. Shevlin and Friesen (2021), for instance, summarize the placebo studies as follows:

> In the experiments described above, it seems that the *belief* that one has received an analgesic can be *sufficient* to reduce the intensity of pain experience (Shevlin & Friesen, 2021, p. 781, my underline).

Likewise, within the predictive coding approach, pain anticipation in placebo and nocebo effects has been defined as "conscious and unconscious *thoughts and beliefs* that people have about imminent pain" (Hoskin and coll., 2019, p. 127, my underline). In this framework, pain results from the comparison of nociceptive signals with predictions and their respective weights are pondered depending on their respective reliability (e.g. Hoskin et al., 2019; Büchel et al., 2014; Geuter et al., 2017). Predictive coding theories rarely qualify in details what they mean by predictions and it is not even clear that there is a general agreement. Nonetheless, since there can be predictions *errors*, predictions must be truth-apt. One can then describe them in terms of beliefs or belief-like states (i.e. endorsement of a proposition). [2] One may further claim that they are specifically about pain, rather than about something generically unpleasant that one will experience soon. They represent something like "This will hurt", and not only "This will be bad", as shown by the following study (Sharvit et al., 2018). Participants were showed images predicting either a painful heat or a disgusting odour before experiencing one of the two aversive events. It was found that pain anticipation did not alter disgust and disgust anticipation did not alter pain. The anticipatory belief was specific to the type of unpleasantness.

It thus seems to be hardly controversial that in nocebo studies participants generate the belief that their pain will increase but the crucial issue is whether this type of anticipatory belief exhausts the notion of pain anticipation. As we shall now see, the purely doxastic account has its limits. In particular, one may question whether it is the anticipatory belief that drives the modulatory effect and whether it can account for the role of pain anticipation for protective behaviours in more ecological settings.

3 Fearing that one will be in pain

So far, we have focused on pain-related anticipatory beliefs but the peculiarity of nocebo effects compared to placebo effects is that such beliefs can be the source of fear and anxiety. Consider the following study by Colloca and Benedetti (2007), who are among the leading experts on placebo and nocebo effects. Participants were informed in advance that they would receive a painful stimulation. Beforehand, some took an anxiolytic (proglumide or diazepam), known to relieve anxiety but with no direct effect on pain; others did not. Then they all received the noxious stimulation.

[2] For instance, Friston, who is at the origin of the predictive coding framework, sometimes appears to take prediction to be synonymous to beliefs, as shown here: "This surprise depends upon (prior) expectations, but where do these prior beliefs come from?" (2013, 213). The objective of this paper, however, is not to offer a detailed analysis of the predictive coding approach.

The participants in both groups believed that they will be soon in pain. Without anxiolytics, this thought triggered anxiety, while it did not with anxiolytics. If the nocebo effect were driven by anticipatory beliefs, this should have made no difference. Yet it was found that the participants that were anxiolytic-free rated the intensity of the pain significantly higher than those with anxiolytics. Nocebo effects, when they occurred, were thus driven by the participants' fear toward what was awaiting them and its relief could prevent nocebo effects. The anticipatory belief had only an indirect impact via anxiety, and it was not sufficient on its own to trigger pain modulation. Colloca and Benedetti (2007) thus conclude in favour an affective model of nocebo effects.

Fear can be conceived as intrinsically anticipatory in nature. As noted by Aristotle, "Fear is pain arising from the anticipation of evil" (Aristotle, *Rhetorics*, 2.5, 1382a21-25). Consider the following example. Johnny faces a bully looking angrily at him. Davis (1987, p. 303, my underline) proposes the following analysis: "Johnny is afraid of the bully because his experiential fear results from his propositional fear that the bully *will* harm him!". Likewise, Bordini and Torrengo (2022) argue that fear involves "an awareness of the possible harm that the bully is likely to cause in the (near) future". Pain anticipation might be conceived here as one facet of fear, which is future-directed, whereas the other facet, which can be present-directed, is turned towards the bully. One can then attentionally switch from one to the other. Interestingly, fearing the forthcoming pain induces hyperalgesia, whereas fearing external threats induces analgesia (Colloca & Benedetti, 2007).[3]

We have just seen that pain-related anticipatory beliefs on their own do not suffice to account for nocebo effects. Nor do they suffice to trigger protective behaviours. Predictive states are generally conceived as an asset in our cognitive architecture because they allow us to prepare our reactions to whatever awaits us. A standard example comes from the computational model of motor control. One generates sensorimotor predictions, also known as the forward model, on the basis of one's motor command in order to better calibrate one's movement even before it being performed (Wolpert & Flanagan, 2001). This is also true in the sensory domain. When a cricket player sees the ball looming toward her, she must anticipate the path of its trajectory to compute what is known as the time to collision in order to be able to intercept the ball (Tresilian, 1999). In nocebo studies, however, prediction is completely cut off from action: participants have no opportunity to react to prevent the forthcoming pain. However, this purely passive role should not be generalized outside well-controlled laboratories. Arguably, pain anticipation is a mechanism widely spread in animal kingdom in a world full of dangers for which one must be ready. One may then propose that pain anticipation partly shares the same functional role as pain, that is, to keep the subject from harm. More precisely, they both qualify as intrinsic motivating states and motivating reasons for protective behaviours. Consider first pain. When in pain, one does not need to have a desire to not-be-in-pain in addition to pain itself for one to try to stop the pain (Bain, 2013; Martinez, 2015). Likewise, one does not need this extra desire in addition to one's anticipating pain for one to

[3] One can explain the analgesic effect in the latter case by the fact that attention is then focused on the environment, and thus, away from one's body. By contrast, one can predict fear of bodily damage (which is not tested here) to induce hyperalgesia.

try to prevent the pain. Independently of further desires, pain anticipation defeasibly motivates and rationalises avoidance behaviours. Nonetheless, the role of pain anticipation is not strictly identical to the role of pain. Pain anticipation has only a preventive role, to avoid bodily damage, whereas pain has also a restorative role, to allow the organism to heal.

There have been extensive discussions on the motivating role of pain, but one might argue that the role of pain anticipation is even more important because the damage, and its associated pain, have not yet occurred. In brief, it is not too late. The content of pain anticipation can then be said to be self-defeating: it represents that one will soon be in pain so that if it successfully fulfils its function, it turns out to be false. It does so by triggering protective behaviours to prevent the expected harm. Such a motivational role can hardly be played by a mere pain-related belief on its own.[4] According to a Humean conception, beliefs and judgments are motivationally inert. Unless one defends motivational internalism, beliefs and thoughts about the impending pain have no motivational force on their own. They are not sufficient to push one to act. Pain-related fears, on the other hand, are not motivationally inert. One is then affectively engaged instead of being doxastically detached. If you are afraid of the impending pain, then you try to avoid what may cause the pain. One may then claim that the motivational role of pain anticipation is fulfilled by fear, and not by anticipatory pain belief.

At this point, one may question whether anticipatory pain belief is even necessary. For instance, after years of receiving flu shots, I am fully aware that it is painless and yet, each time that the needle approaches my arm, I feel tensed and hold my breath, anticipating the pain. My anticipating pain is not rationally defeated by the contradictory knowledge that the injection does not hurt. Hence, one can believe that one will not be in pain and yet still anticipate pain. Put it another way, one can believe that one will not be in pain and yet still fear that one will be in pain, as vividly described in *The Demons* by Dostoyevsky who imagines how we could fearfully anticipate pain, even though we believe that we would be killed on the spot:

> "Imagine"—he stopped before me— "imagine a stone as big as a great house; it hangs and you are under it; if it falls on you, on your head, will it hurt you?" (…) "The most learned man, the greatest doctor, all, all will be very much frightened. Everyone will know that it won't hurt, and everyone will be afraid that it will hurt (…) In the stone there is no pain, but in the fear of the stone is the pain." (Dostoyevsky, 1872, Chapter III, VIII).

[4] More generally, Klein (2018) argues against the predictive coding theories that the mind cannot be only a predictive machine if predictions are belief-like because there need also to be desires, preferences, and motivational states in general for the organism to act: "Try to get by with only prediction, and you'll end up just sitting there" (Klein, 2018, p. 2542). See also Arpaly and Schroeder (2013). Advocates of predictive coding, however, want to collapse the distinction between beliefs and desires with the help of the notion of active inference (e.g. Clark, 2020; Hohwy, 2018). To summarize, Klein claims that predicting that you will be hungry will not suffice to make you eat, but Clark replies that it will in association with the prediction that you will no longer be hungry if you eat. It is not clear, however, that one can fully explain away conative states. For the sake of this paper, I shall not go further into the debate, since the notion of pain anticipation exists independently of the predictive coding framework.

There seems to be a primacy of fear over one's beliefs. [5] Let us take stock for a moment. I first considered a doxastic view, according to which pain anticipation simply involves anticipatory beliefs (or belief-like states), which take the forthcoming pain for their intentional object. I have shown that these beliefs suffice to account neither for nocebo effects, nor for the motivational role of pain anticipation. I have then proposed to supplement them with pain-related fears, since they seem to play most of the explanatory role. We thus end up with the following account:

$$Anticipation\,of\,pain = Belief\ (future\,pain) + Fear\,(future\,pain)$$

On this account, there is no distinctive *sui generis* mental state to which pain anticipation corresponds. It can be reduced to other primitives. In this sense, this account may be said to be deflationist: there is nothing special about pain anticipation. We have many anticipatory beliefs and many fears, and it is simply that some of them concern future pains. The question then arises: does this deflationist account fully exhaust what happens when one expects pain? Do we only have anticipation *of pain*, or can we also have something like *painful* anticipation? More precisely, since we do not want to assume that the act of anticipation itself feels painful, can we anticipate under a pain-like mode?

4 Anticipating under the pain mode

Let us make a small detour here via sensory predictions. When seeing a object passing behind another, the motion being partially occluded, infants as early as four-month old are able to track it behind the occluder and to correctly anticipate its reappearance on the other side on the basis of its speed and path (Rosander & von Hofsten, 2004). The content of the anticipatory representation is then typically about the moving object. One *visually expects* the object to reappear. One does not expect having *a visual experience* of the object reappearing. The predictive content is world-directed, and not mind-directed. It is the vehicle of the anticipatory representation that can be conceived as visual (Munton, 2022). The question is: is there a notion of pain anticipation that can be understood on the model of visual prediction? Let us call it *nociceptive prediction*. I deliberately choose the term *nociceptive* prediction here to avoid making any assumption about the affective phenomenal character of this type of prediction.

If we apply the visual model in its strictest sense, then nociceptive prediction should display two distinctive features. First, it should be world-directed, instead of being mind-directed. In brief, it should be about bodily damage or disturbance, and not about pain itself. Secondly, the vehicle of the representation should be pain-like. The difficulty here is that the parallel between vision and pain is highly problematic. There is an ambiguity frequently encountered in the literature between pain as a state (one is in pain) and pain as an object (one feels pain) (Aydede, 2009). Furthermore,

[5] One may reply that such a case of emotional recalcitrance does not suffice to prove that there is no anticipatory pain belief insofar as one can entertain contradictory beliefs (Pendoley, 2023).

unlike visual experiences that are transitive, pains are said to be intransitive (Armstrong, 1962). Solving these issues goes beyond the scope of this paper, but there is no need to defend a perceptualist account of pain to argue that there could be something akin to nociceptive prediction. The model of visual prediction needs not be taken literally. Instead, I shall assume that it suffices for an anticipatory state to qualify as nociceptive prediction if it shares some of the distinctive features of pain, though not all of them. Nociceptive prediction indeed does not pretend to be strictly similar to pain. There needs to be only a certain degree of isomorphism between the two.

One can find some prima facie plausibility to the notion of nociceptive prediction in the neuroscientific literature. It has been shown that anticipating pain partly activates the same regions as pain, including the thalamus, prefrontal cortex, secondary somatosensory cortex, anterior cingulate cortex, and anterior insula (Ploghaus et al., 1999). These shared regions constitute what has been described as the core affective component of pain. These results are difficult to account for if expecting pain involved nothing more than belief and fear. They rather point in the direction of a distinct type of mental state that bears some similarities with pain. Nanay (2017) concludes that pain anticipation involves *pain imagery*. On his view indeed, “if there is pain processing in these regions that is not triggered by nociceptors, we have to talk about mental imagery” (Nanay, 2017, p. 490). The evidence, however, is less straightforward. The so-called “pain matrix” is also activated by a range of aversive non-painful events, such as seeing a sudden flash or hearing a loud bang close to one’s body (Legrain et al., 2011). This is so even in two patients with congenital insensitivity to pain: the presentation of salient stimuli close to their body activates the so-called pain matrix (Salomons et al., 2016). If neural activity in these regions did correspond to pain imagery, then these patients that do not feel pain would still be imagining pain, which seems relatively unlikely. Furthermore, one should not neglect neural differences between pain and nociceptive prediction. Cell recordings in monkeys show that though there are neurons common to both pain and pain anticipation, there are also some that are specific to pain and others specific to pain anticipation (Koyama et al., 2005; Urien et al., 2018). This is not an objection against the notion of nociceptive prediction. As said earlier, the proposal is that pain and nociceptive prediction are only partially isomorphic. Neural similarities are interesting because they show that expecting pain involves a distinctive mental state that is pain-like, but neural differences are also relevant because they show that it should not be confused with the pain state itself.

These results primarily highlight the affective dimension of pain, but pain is also characterized by its somatosensory dimension, and in particular by its bodily location. Whether one’s back hurts, one has a toothache, or one feels muscle pain, the sensation is typically experienced as of being located in a region of the body. The question is: does one expect pain in a specific part of one’s body? I shall now argue that the embodied dimension of pain anticipation depends on the imminence of the forthcoming pain. In brief, the closer the impending harm, the more embodied, and thus, the more pain-like, the anticipatory state. In situations of real-life danger, there can remain for a long time a certain amount of uncertainty about the bodily details of the forthcoming harm. When Johnny is afraid of the bully, he cannot predict whether the bully will hit his head or twist his arm. He fears the forthcoming pain, but his fear needs not include any bodily details. The situation is different when the threat enters the immediate surrounding of his body. Johnny no longer anticipates *that* he will be in pain. He also anticipates *where*. A deflationist may then claim that the fear content gains in spatial precision, but recent evidence shows that when harm is imminent, specific mechanisms get into play.

It has been found that the immediate surrounding of one's body, also known as peripersonal space, is processed differently from far space (Vignemont et al., 2021). According to the neuroscientist Graziano (2018), who was among the first to investigate it, peripersonal space works as a margin of safety encoded in a specific way to quickly elicit protective behaviours if necessary. Crucially, it has been shown in monkeys that the same neurons that respond to noxious stimuli can also fire when the monkey is merely seeing objects moving towards a part of its body (Dong et al., 1994). This is so only when the visual stimuli are close. Furthermore, these visuo-nociceptive neurons are body part specific. Those that react for noxious stimulation of the face fire only when the looming stimulus approaches the face; those that react for the hand fire only when it approaches the hand. What is seen is automatically remapped onto the reference frame of the bodily surface, the same somatotopic frame of reference as pain (de Paepe et al., 2017). In my terms, visual experiences of approaching objects are translated into nociceptive predictions.

Similar results have been found in humans. The perception of objects perceived in one's immediate surroundings has a modulatory effect on pain. It is known that participants report significantly less pain when they receive an electric stimulus on both hands than when they receive it only on a single hand. This phenomenon, known as extinction, also occurs when participants see a small light close to one of their hands instead of receiving a shock (Filbrich et al., 2019). Hence, seeing the flash in peripersonal space has a similar effect on pain as actually receiving a noxious stimulation. Nociceptive prediction can also boost the processing of noxious stimuli if the part of the body expected to be hurt is congruent with the body part that is actually hurt. In one study, participants responded faster when asked to localize where they perceived a noxious stimulus if they saw at the same time a visual stimulus approaching the stimulated hand and entering peripersonal space (de Paepe et al., 2016; see also de Paepe et al., 2017). [6] Finally, it has been shown that seeing a needle approaching one's hand induced an increase of skin conductance response (SCR). The closer the needle (1 or 5 cm away from the hand compared to 40 cm away), the greater the SCR. The authors concluded that the increase in SCR revealed pain anticipatory responses specific to peripersonal space (Rossetti et al., 2015).

Peripersonal space has been described as a space of potential actions (Rizzolatti et al., 1997; Bufacchi & Iannetti, 2018). When the threat is close-by, perception cannot afford to be relatively detached from action. The reactions triggered by nociceptive predictions are similar to some extent to those associated with pain. For instance, it

[6] These effects cannot be explained exclusively in attentional terms. The processing of peripersonal space keeps its unique signature even when attention is shifted away from the hand that receives the somatosensory stimulus and when participants focus on the contralateral side (Zanini et al., 2021). Still, these effects can hardly qualify as cognitive penetration. The impact of nociceptive prediction on pain appears to be closer to multisensory interaction.

has been found that a 300 ms burst of white noise near the hand reduces corticospinal excitability, which resembles that found during the presentation of noxious stimuli (Avenanti et al., 2012). More generally, predictive mechanisms in peripersonal space allows for faster action selection (what one should do given that the rock looming towards one's shoulder) and more fine-grained action monitoring (remapping peripersonal space while the movement unfolds and the body moves). At the neural level, this is made possible by the fact that peripersonal space is mainly represented in brain regions that are dedicated to action guidance. We shall soon see that the best framework to interpret nociceptive prediction is in imperative terms.

I have argued so far that pain-related beliefs and fears do not suffice to account for pain anticipation and that there is a point at which one also makes nociceptive predictions, which can influence the experience of pain and which can trigger protective behaviours. We can now specify in which sense nociceptive prediction may be related to pain. First, it partly shares the same neural resources. Secondly, it shares the same bodily frame of reference. Finally, it shares the same motivational role, by being in direct connection with action selection. There is, however, a striking difference. Nociceptive prediction is typically not painful. In most situations, it operates independently from any conscious feeling of painfulness, and possibly also of unpleasantness. Roughly speaking, it does not hurt to see the needle ready to be inserted in your flesh. It may be only in some rare pathological cases in which nociceptive prediction turns into *anticipatory pain* (painful sensation elicited by pain anticipation). [7] Yet even when it is not painful, this does not entail a complete lack of affectivity. Nociceptive predictions have been shown to involve early appraisal of what is beneficial or harmful to the organism in the amygdala (Clery & Ben Hamed, 2021). Numerous findings show that such evaluative processing can remain non-conscious and that valence can be represented unconsciously (Berridge & Kringelbach, 2008; Ledoux, 2015; Carruthers, 2018). In one study, for instance, subliminal presentation of threatening stimuli activated the amygdala and elicited physiological responses, though the participants reported no feeling of fear (Tamietto & de Gelder, 2010). One may then propose that nociceptive prediction is negatively valenced, even though it does not necessarily give rise to a feeling of painfulness.

We now have a better grasp of the notion of nociceptive prediction. It is (i) partly based on the same neural resources as pain, (ii) encoded in a somatotopic frame of reference, (iii) action-oriented, and (iv) negatively valenced. It is not pain, but neither is it only a combination of anticipatory beliefs and fears. It may be conceived as *a sui generis* anticipatory state. We shall now see what kind of content nociceptive prediction has. Discussions on pain shall pave the way for our analysis, even though we shall not have to face the difficulty here to account for the phenomenal character of painfulness. We shall focus on three families of theories: perceptualism, evaluativism, and imperativism.

[7] Grahek (2001) describes what he calls threat hypersymbolia: as soon as something or someone approaches his arm, a patient made brisk withdrawal movements and reports experiencing a burning pain (Hoogenraad et al., 1994). Similar behaviours can be found in patients with chronic pain (Moseley & Vlaeyen, 2015).

5 An imperative approach

Armstrong (1962) describes pain as the perception of bodily disruption. It has a descriptive content that represents the damage as being located in a specific body part. One can then apply his account to nociceptive prediction:

> Perceptualism: Nociceptive prediction represents impending damage to be located in a specific part of the body.

Insofar as nociceptive prediction is grounded in sensory perception, perceptualism may seem to be the most promising option. However, it fails to account for the motivational force of nociceptive prediction. This objection was already raised for perceptualist accounts of pain: feeling pain and seeing the associated bodily injury do not play the same motivational role (Bain, 2013). Hence, the content of pain cannot represent only bodily damage. Likewise, anticipating pain and seeing injuries do not have the same motivational force. Though it involves vision in both cases, it does not have the same effect on you to see a knife falling on your finger and to see the cut. Only the former pushes you to immediately react.

To overcome this problem, it has been proposed that pain content is not only descriptive, but also evaluative (Cutter and Tye, 2014; Bain, 2013). It represents the bodily damage *as being bad*, which explains why pain feels unpleasant, and thus, why we react. This account can then be generalized to nociceptive prediction as follows:

> Evaluativism: Nociceptive prediction represents impending damage to be located in a specific part of the body and it represents it as being bad for the subject.

A classic objection against evaluativism is that it cannot explain why one takes painkillers. If pain simply informs us about something bad happening, then getting rid of it seems as irrational as killing the messenger who carries bad news (Jacobson, 2013). The fact that a state represents something as being bad does not make the state itself intrinsically bad and if pain itself is not intrinsically bad, it cannot be an intrinsic motivating reason to take painkillers. Bain (2019) replies that when in pain, one does not merely represent the disturbance as bad; one perceptually encounters its badness and this perceptuality is a crucial ingredient to explain why pain feels bad and why it can be an intrinsic motivating reason for pain-directed behaviour.

Whether this reply is satisfying or not for pain, one may argue that the debate is not relevant for nociceptive prediction. It is taken to be irrational to bury one's head in the sand like the ostrich to prevent oneself from seeing a threat. The fact is that one typically does not feel the urge to stop one's anticipating something bad about to happen (unless one is aware that this anticipation is mistaken). And why kill the messenger anyway in this case? Nociceptive prediction does not feel painful. The evaluative account of nociceptive prediction thus does not encounter the same problem as the evaluative account of pain. However, it faces another difficulty. How can anticipatory evaluative content explain the direct link between nociceptive prediction and action? For instance, it has been found that artificially stimulating the neurons responsible for the processing of peripersonal space in monkeys suffices to automatically elicit defensive movements, such as squinting, shifting the head away, or rapidly lifting the hand into the space near the side of the head as if to block an impending impact (Cooke & Graziano, 2004). It is not clear how the evaluative account could explain such findings. One may adopt Bain's (2011, p. 179) suggestion about pain that it can "inform us of what behaviour is such that, if it is not performed, injury will ensue". But does this leave the anticipatory content with only a mind-to-world direction of fit? According to Millikan (1995, p. 191), there is no need for information about motor possibilities if it is not for the motor system to exploit this information at one point and ultimately the function of this type of representation is to guide actions. If so, the content has a world-to-mind direction of fit.

This is then in line with the imperative theories of pain, which highlight the importance of directive content (Martinez, 2011; Klein, 2015a; Barlassina & Hayward, 2019; Klein & Martinez, 2018). On the imperative approach, pain content does not evaluate the bodily situation, but rather prescribes what to do about it. More specifically, the imperative content can be conceived as a form of bodily command that orders us to engage into protective behaviours. It is coercive: we must listen to pain, though we do not always do so. Its authority is benevolent: it normally – but not always – gives good advice. On this view, pain is not only a motivating reason that is part of the causal chain that leads to protective behaviours, but also a justifying one that a rational agent would count as adequate. But what orders exactly does pain give? One can distinguish two types of imperative content:

(i) Body-directed content: "Don't have this bodily disturbance!" (Martinez, 2011).
(ii) Pain-directed content: "Less of this pain!" (Barlassina & Hayward, 2019).

According to first-order imperative account, pain has body-directed content (Martinez, 2011). According to a reflexive imperative account, pain has pain-directed content (Barlassina & Hayward, 2019).[8] One may immediately object to the reflexive account that if pain represented "Less of this pain", then the brain would have evolved a system whose only biological function was to self-extinguish. Martinez (2022) compares this hypothesis to Minsky's absurd idea of the Ultimate machine: once turned on, it can only turn itself off. This objection, however, does not apply in the case of nociceptive prediction because the pain-related content would not be reflexive. It would be about the future pain ("Less of this future pain!"), and not about the predictive state itself. Nonetheless, it seems more plausible that nociceptive prediction has body-directed content. Nociceptive prediction is indeed closely related to tactile prediction that also occurs only within peripersonal space (Clery & Ben Hamed, 2021). Their respective mechanisms are based in the same brain regions and obey the same rules. In the tactile domain, one does not anticipate a future tactile sensation, but rather a future impact (Straka et al., 2022). Likewise, one may argue that

[8] Finally, one can also mention Klein's (2015a) two-layer account, which distinguishes between pain itself, and painfulness, or what he calls suffering. On his view, painfulness, is not constitutive of pain; it is a distinct attitude taken towards pain. Within this framework, he then defends a body-directed imperative account for pain (e.g. "Don't put weight on your ankle!"), and a higher-order imperative account for suffering ("Less of this pain!").

nociception prediction is world-oriented, and not mind-oriented. It could be phrased in the following way: “Don’t have this impending bodily disturbance!”.[9]

A further issue concerns the intentional nature of the imperative content. Pain imperativism has been declined into representationalist (Martinez, 2011; Barlassina & Hayward, 2019) and non-representationalist versions (Klein, 2015a). Pain content can also be exclusively imperative (Klein, 2015a), or both descriptive and imperative (Martinez, 2011; Barlassina & Hayward, 2019). In the case of nociceptive prediction, it might seem that the latter version has the most explanatory power. Prediction is useful not only for motor readiness, but also for sensory enhancement. It has been found that participants show improved performance in peripersonal space in purely sensory tasks, such as shape recognition (Blini et al., 2021). More specifically, it has been shown that nociceptive prediction reduces reaction times in a localization task of noxious stimuli (de Paepe et al., 2016). One may thus propose that the sensory effects of nociceptive prediction are explained by its descriptive content, and the motor effects are explained by its imperative content.[10] On this dual view, nociceptive prediction can be conceived as closely related to what Millikan (1995) calls pushmi-pullyu representations (PPRs) In PPRs, there is no need to translate descriptive information into directive information: the same representation has both directions of fit. It is because one is in a situation of emergency that the bodily command needs to be built in the expectation itself. We can then formulate the imperative view of nociceptive prediction as follows:

> Imperativism: Nociceptive prediction represents impending damage to be located in a specific part of the body and it prescribes to prevent this damage.

Is nociceptive prediction then similar to Anscombe’s (1957) example of the shopping list, a single content that tells you what to put in your caddy now and what will be in the caddy by the end? The shopping list has an overall pushmi-pullyu structure, with the directive component (what to take) predominating early and the descriptive component coming to the foreground later (what is now in the caddy). This analysis, however, does not work for nociceptive prediction. The indicative content of the shopping list is true in virtue of the satisfaction of the directive content. By contrast, the indicative content of nociceptive prediction is false in virtue of the satisfaction of the directive content. If one is successful in obeying the bodily command to prevent the damage, there will be no damage. Hence, there is no unique content that intervenes at two different stages. There are two contents, with different temporal orientations (what will happen *soon* and what to do *now*), playing different roles (indicative and directive), carried by the same representation. Nociceptive prediction should thus

[9] One may wonder whether the imperative content should be more detailed and contextually anchored, specifying exactly the kind of movements to perform given the exact threat. However, the imperative view does not assume that nociceptive prediction takes over motor planning and motor control. It simply claims that it directly provides to the motor system the end to achieve. The specific means to achieve this end are computed by the motor system, which anchors the bodily command to the situation and which organizes the information into action schemas hierarchically organized (Jeannerod, 1997).

[10] However, we cannot fully rule out that the imperative content could explain both effects.

be conceived as what Bayne (2010) describes as a dyadic PPR. The vehicle of the representation is the same but the contents are different.

I have argued here that the best way to characterize nociceptive prediction is in imperative terms. When the risk of bodily damage is imminent, action must come at the forefront. It is when there is almost no time left that the strength of the motivational force of pain anticipation must be at its highest, that there must be a direct connection between perception and action. It is then that the body must send its imperative command. Though pain-related fear also motivates protective behaviours, it bears a different relation to action. According to Deonna and Teroni (2012), fear corresponds to a specific experiential mode characterized by a holistic pattern of action-readiness that expresses how the body is poised to neutralize what provokes the fear. Experiencing one's body ready to react, however, is not ordering the body to react. The relation to action must be direct and automatic in the case of nociceptive prediction because of the emergency. One might say that nociceptive prediction is the last resort, the plan B when all the other anticipatory mechanisms have failed. Then only is anticipating acting.

At this point, one may object against imperativism that there are threats towards which one does not react (Grahek, 2001). This is the case of the rare neurological disorder of pain asymbolia. Asymbolic patients say that they feel pain but they display no defensive responses or emotional expressions. For instance, when exposed to noxious stimulations such as electric shocks, they are able to judge the location and the intensity of the stimuli but they do not report what they experience as being unpleasant and they do not scream or withdraw their hand. But if they are in pain, then why do they display no response? Does it entail that pain does not intrinsically motivate protective behaviour, and thus that the imperative account of pain is false? Interestingly, pain asymbolia is associated with what we may call *threat asymbolia*. Patients show no reaction not only to noxious stimulation, but also to threats (Hemphill & Stengel, 1940). In his book *Vivre sans la douleur* (*To live without pain*), Danziger (2010) reports how he pretended to violently hit with a hammer the hand of a patient with pain asymbolia without eliciting in the patient's part any avoidance response. Danziger then asked:

- You do not withdraw your hand? I asked once it was done, relieved I did not hurt him.
- No, why? He replied.
- And if I had hit your fingers?
- Well, it would have been that it had to happen!
- You were not worried I would damage your fingers with the hammer?
- It has already been broken, so another time, it does not matter anymore. (Danziger, 2010, p. 20, my translation)

The question now is whether asymbolic patients anticipate the bodily damage but do not react, or whether they simply do not anticipate it. Let us consider the first option. According to Klein (2015b), even in asymbolic patients the body sends a command to stop the damage. The lack of actual response comes from the fact that they no longer care about the well-being of their organism. Consequently, the body has lost its authority and its orders are no longer obeyed. Bodily care is conceived here as an enabling condition for pain to play its motivational role, and one may suggest that it is also true of nociceptive prediction. As well summarized by Danziger's patient, it does not matter anymore what happens to his body. One can thus account for both pain and threat asymbolia with a single deficit of bodily care.

However, there may be a more parsimonious explanation that does not involve positing a supplementary dispositional affective attitude that raises a series of difficulties (Vignemont, 2015). It suffices to claim that there is simply no bodily command sent to prevent the impending damage. Put it another way, there may be a deficit of nociceptive prediction in pain asymbolia. This seems to be line with Grahek's (2001) own interpretation. He explains threat asymbolia by a lesion of visuo-nociceptive neurons in the parietal area and in the insula that are activated both by noxious stimuli and by visual stimuli in peripersonal space (Dong et al., 1994). This interpretation is further confirmed by the temporary inhibition of these peripersonal neurons. Monkeys then no longer blink or flinch when their body is under threat, thus reacting like asymbolic patients (Graziano, 2018). Hence, there is no need to appeal to an alleged disruption of bodily care. There is simply no nociceptive prediction.

To summarize, nociceptive predictions are best explained in terms of PPRs. They represent what is awaiting the subject while prescribing what to do. Compared to a performative act, as when the priest declared you married, however, the satisfaction of the directive content does not make the descriptive content true. It is the opposite: if one is successful in obeying the bodily command to prevent the damage, there will be no damage. The descriptive content of nociceptive prediction becomes false in virtue of the satisfaction of the directive content.

6 Conclusion

Although most literature uses the notion without further qualification, pain anticipation should be conceived as an umbrella term that covers several types of anticipatory representations. This is especially salient when one enlarges its analysis beyond nocebo studies to approach it from the perspective of a creature surrounded by potential threats. Here only can one fully grasp the evolutionary role of pain anticipation, which is to motivate protective behaviours. Spatio-temporal proximity then becomes a crucial factor. Early anticipation may appear as the most essential insofar as the earlier one anticipates a potentially harmful event, the more prepared one can be to protect oneself. At this early stage, anticipatory representations need not bear strong similarity with pain and they can be explained in terms of beliefs and fears. However, when bodily damage is imminent and its probability high, pain anticipation starts sharing some crucial features of pain itself, though not its painfulness. This affective phenomenal character is kept for when the damage is done, when one is in pain.

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