How semantic priming modulates pain perception in an increasing or attenuating way.

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Abstract

Pain is a widely known phenomenon that everyone has experienced. The experience of pain is commonly thought to be a response to nociceptive stimuli. However, recent research has shown that the perception of pain is not only due to biological factors, but also sociological and psychological factors. This paper investigates how semantic priming can influence pain perception. We hypothesis that pain-related written stimulus will increase participants' subjective pain perception and that comfortable-related written stimulus has an attenuating effect. The semantic priming stimuli were designed from a pre study that found 13 words in three different categories, comfortable, neutral and painful. These 39 words were then used to make nine sentences, that was used to prime participants to either feel more or less pain, which was given from an electrical device. The study found that presenting participants with comfortable-related sentences compared to pain-related sentence decreased the subjective pain perception of the participants by 0.55 on an arbitrary scale from 0 to 10, this effect was also found when taking the valence of the sentences into account. These results show that semantic priming can have an effect on pain perception, and that there is something inherently different about pain and comfortable-relatedness compared to positive and negative valence.

Keywords: Pain ratings, Nociceptive stimulus, Semantic priming, Valence

Introduction (JFE, DEC)

Pain comes in many forms and has many names; Acute, chronic, nociceptive, psychological, neuropathic, muscular et cetera (‘Pain Classifications and Causes’, n.d.). Pain is a major problem with 19% of Europeans suffering from chronic pain, 21% of the patients suffers from additional psychological pain caused by their chronic pain, in the form of depression. 61% of Europeans suffering from chronic pain are less able to or unable to work outside the home (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006).

Pain is a major problem, but not all pain is in the form of nociceptive pain, which is pain produced, because of outside stimuli, this pain is produced to warn you about a potentially damaging stimuli. For instance placing your hand on a hot stove will cause nociceptive signals to travel from your hand to the brain, where this signal then will be interpreted and you would probably experience pain (‘Nociception—An overview | ScienceDirect Topics’, n.d.; Dubin & Patapoutian, 2010). One can see that not all pain is in the form of nociceptive pain, by the countless studies investigating chronic pain and pain caused by pathological or anatomical causes, these studies find that the correlation between people in pain and them having something structurally abnormal is weak and that practitioners should interpret the results from imaging techniques like MRI, x-rays et cetera with caution (Brinjikji et al., 2015; Tonosu et al., 2017; Bedson & Croft, 2008).

Pain is extremely subjective (Wilcox, 2015; Fillingim, 2017), and could therefore be prone to change and modulation. Since pain is a major problem, we find it interesting to do research within this area.

When consulting with doctors, reading about your condition on online databases or being informed in other ways about your symptoms or pain, it is always communicated via verbal or written stimuli. This gives rise to one problematic, though interesting, aspect of the human mind: To ease the cognitive load and to help quicken decisions we tend to make predictions. The brain predicts outcomes based on incoming sensory stimulus from specific modalities, in this case; the auditory and visual modality.

Predictive coding is the theory describing the idea of a brain constantly predicting outcomes (Spratling, 2017). This theory holds that sensory information is not the only thing that determines our perception; sensory information is just one part of the puzzle. The theory states that our prior knowledge and expectations plays a role in our perception of stimuli as well. This can be demonstrated with several kinds of visual or auditory illusions, or by what is referred to as the phoneme restoration effect (Samuel, 1996). This theory might therefore explain why pain is so subjective, if a lot of the perception of pain is based on prior experiences and expectations. Therefore, reading a painful sentence might make the brain predict that it should experience pain, because prior experiences have associated pain-related words with painful experiences.

Predictions and modalities

If pain is subjective and prone to modulation, and a growing body of literature suggests that information is stored in sensory-motor modalities (Esopenko et al., 2012), the predictions made by the brain in these sensory-motor modalities could therefore potentially be influenced by the language we use.

It has been shown that people are faster at recognising visual or auditory stimuli that are associated or matched with semantic primes. Research here has shown that you are faster at recognizing a line drawing of an eagle in the nest compared to one flying if you read that the eagle was in the nest beforehand. Other research has shown that if you read a sentence that has a sound component in it, like ‘the engine clatter’, you will be faster at recognizing that sound (Zwaan, Stanfield, & Yaxley, 2002; Hoeben Mannaert, Dijkstra, & Zwaan, 2019; Brunyé, Ditman, Mahoney, Walters, & Taylor, 2010). It has been hypothesised that we are faster at recognizing these matched stimuli because of mental simulation. Which means that we simulate and predict incoming sensory information. So after hearing a word that is associated with a specific modality the activation from that word spreads, not only to related words, as in spreading activation ('(PDF) A Spreading Activation Theory of Semantic Processing', n.d.; Meyer & Schvaneveldt, 1971), but also to their respective modalities (Speed & Majid, 2019).

Neuroimaging studies have shown that this mental simulation might be presented in the brain area associated with that specific modality. This means that visual simulation is presented in the primary visual cortex and motor simulation is presented in the motor and premotor cortex. (Hauk, Johnsrude, & Pulvermüller, 2004; Kana, Blum, Ladden, & Ver Hoef, 2012). Many studies that have investigated mental simulation, has done so using simple reaction time tasks. Participants have been primed with semantic stimuli and then being presented with a picture or a sound, where they have to decide whether or not the picture was mentioned in the sentence or if the sound was real or computer generated (Zwaan, Stanfield, & Yaxley, 2002; Hoeben Mannaert, Dijkstra, & Zwaan, 2019; Brunyé, Ditman, Mahoney, Walters, & Taylor, 2010). Some research suggests that the results from the reaction time tasks might not be present in the modalities for the 'lower' senses, such as smell (Classen, 1997; Howes, 2003, as cited in, Speed & Majid, 2019). It might be the case, that this relationship cannot be explained by measuring reaction time, but by looking at how the intensity of perception in that modality changes, with different stimuli (Speed & Majid, 2018).

These lower modalities such as, smell, touch and odour, does not seem to be presented in the brain in quite the same way, as the higher modalities such as vision and hearing. (Speed & Majid, 2019). This paper will therefore look at one of these smaller modalities, namely touch. The sense of touch lets us experience different sensations such as temperature, texture and pain.

What is pain?

Pain is a complex subjective sensation which is defined by the International Association for the study of pain as: ‘An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.’ (‘IASP Terminology—IASP’, n.d para. 4). This definition is however further elaborated:

> *‘. . . pain is always subjective . . . Many people report pain in the absence of tissue damage or any likely pathophysiological cause; usually this happens for psychological reasons.*
> *. . . This definition avoids tying pain to the stimulus. Activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause’ (‘IASP Terminology—IASP’, n.d para 5)*

The further elaboration, stresses the idea that pain is always a subjective experience and can be experienced even in the absence of any physical cause. This definition of pain is supported by previous research, which investigates the underlying mechanism of pain. These studies find that pain is not merely a response to nociceptive stimuli (Mischkowski, Palacios-Barrios, Banker, Dildine, & Atlas, 2018), but a complex interplay between biological, psychological and sociological factors. (Darnall, Carr, & Schatman, 2017).

Previous research has investigated what is commonly referred to as the ‘pain matrix’ (PM) which is perceived to be a circuit which is responsible for the perception of pain intensity and unpleasantness from nociceptive stimuli (Legrain, Iannetti, Plaghki, & Mouraux, 2011). The brain areas involved in the PM includes the sensory nervous system, insular cortex and cingulate areas as well as frontal and parietal regions. It has also been shown that the PM gets activated during the processing of pain-related words. (Richter, Eck, Straube, Miltner, & Weiss, 2010).

One could therefore think that in the same way we mentally simulate written information in the visual, motor or auditory cortex, we might also mentally simulate pain-related information. This simulation could therefore give rise to increased pain perception after being primed with pain-related words. In the same way that odours seem to be intensified when matched with written stimuli (Speed & Majid, 2018).

Emotional states and pain

The valence of a sentence might also have an effect on pain perception, because of the way that it might affect emotions. This could have an effect on pain perception since words might change the emotional state of the person, and thus alter their attention.

One theory of attention states that visual attention can be seen as a zoom lens. This theory holds that attention can be focused specifically on a single thing or be widened to focus on the bigger picture (Eriksen & St. James, 1986). Emotions have been shown to be able to modulate this attentional zoom lens, where a negative state narrows the lens of attention, and a positive state broadens it (Fredrickson & Branigan, 2005). This alteration of the attentional lens could explain why the state of a person is a good predictor of whether someone is in chronic pain. A narrowed attentional lens will lead people to attend to their pain more directly, whereas with a broader attentional lens might have people focus on something else than their pain and therefore perceive the same nociceptive stimuli as less painful. Hence the findings that depression and anxiety are good predictors for the severity of pain-related outcomes (Edwards et al., 2007; Heer et al., 2014). Taken a bit further if people in a depressive or anxious state are more likely to pay attention to their pain, because of a more narrow lens of attention, they might also be more likely to anticipate pain, which will increase the likelihood of them experiencing pain because of predictive coding.

Inspiration and motivation

Inspired and motivated by previous research, which has found that since pain is a very subjective feeling (Wilcox, 2015; Fillingim, 2017), it could therefore, be prone to change and modulation. We wanted to test this modulation using Danish written text and investigate if a change in the semantic context could change the perception of pain. Previous studies have shown that it is possible to change the perception of pain with written stimuli. The focus of these studies has been on the modulation of pain in an increasing way, with either literal versus metaphorical pain descriptors, or with negatively valence words versus pain-related words. (Richter et al., 2014; Vukovic, Fardo, & Shtyrov, 2018). It should be noted that the study by Ricther et al. (2014) has already found a decrease in pain perception from a positively valence condition, compared to a neutral condition.

Studies on attenuating effects on pain perception with visual stimuli have found that it is possible to attenuate pain perception compared to a neutral condition (Tse, Ng, Chung, & Wong, 2002).

This study will contribute to the evidence, by investigating how the perception of pain can be modulated through written stimuli. The study contributes to the evidence in several new ways. This study will use another form of noxious stimuli and it will use several sentences instead of words as prime stimulus, which provides context to the written stimuli. Lastly, the current study will investigate if the effects of conscious priming, which is used in the current body of literature, can be replicated with subconscious priming. This is thought to be important, because previous studies have investigated how conscious priming effects the participants' perception of pain. Here the participants are aware of the fact that semantic stimuli might change their perception of pain, and therefore their results would not be as generally applicable as results, found from a deception study. Furthermore, one study on subconscious visual priming found that the effects of pleasant visual stimuli was reversed, so that negative images had the effect of lowering pain intensity scores. (Peláez, Martínez-Iñigo, Barjola, Cardoso, & Mercado, 2016).

We hypothesis that pain-related, written stimulus (stimuli P) will increase participants' subjective pain perception and that comfortable-related written stimulus (stimuli C) has an attenuating effect on subjective pain perception.

Method (DEC, JFE)

To examine whether semantic content on a pain-relatedness scale could influence pain perception a pre study was conducted to determine which words to use to design the prime stimuli, in the main study.

Prestudy (JFE)

The words that were tested have previously been noted in and are picked from, FMRI research (Richter, Eck, Straube, Miltner, & Weiss, 2010), Mcgill pain questionnaire (Melzack, 1975) and the most frequently used adjectives in the Danish language. ('KorpusDK — ordnet.dk', n.d.). The prestudy was a 60-word questionnaire where independent participants (n = 30) were asked to rate the given words from a scale of comfortable to pain-related (See Appendix A). The words were hereafter categorised into three categories, neutral, painful or comfortable. The painful category had the criteria that the median score should be a score of 8 or above, the comfortable category, a median score of 3 or below and the neutral category was defined as having a median score between 4 and 6. Words with a standard deviation above 1.3 were excluded because of the ambiguity of that word (Figure 1). The words for each category were then selected based on the criteria that pain-related words compared to comfortable-related words should not differ in occurrence in a Danish database for word frequency (‘KorpusDK — ordnet.dk’, n.d.), which leaves 13 words for each category. The pain and comfortable-related words, did not differ in frequency t(23.974) = -0.60158 p = .55.

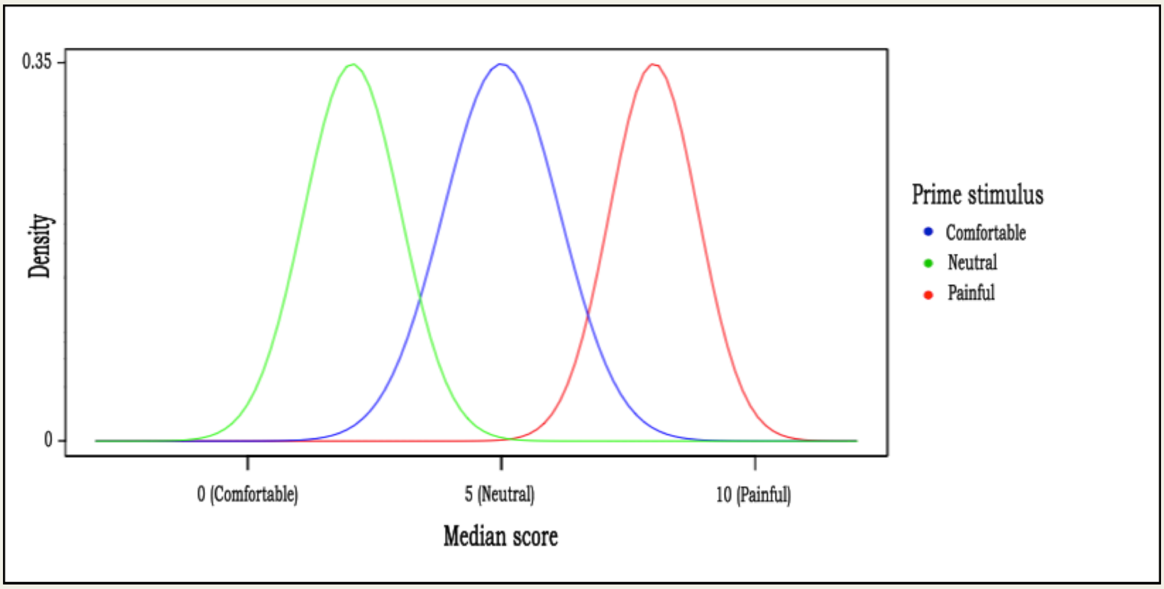

Figure 1. Shows the distribution of the different word categories neutral, comfortable and painful. Shows a clear difference in median scores between the three word categories from comfortable to pain-relatedness.

Prime stimuli (DEC)

From the above-found words, the prime stimulus was designed. The stimuli consisted of three sentences for each of the chosen categories, painful, neutral and comfortable. The neutral stimulus (stimuli N), was designed from the neutral words category. Stimuli C were designed from the comfortable-related words. A sentence from stimuli C is (translation from danish); *"The pain felt rushing and burning as I suddenly was awake during surgery. They were in the process of slicing my left breast open. I feared for life - thinking they would kill me."* (See Appendix B). Stimuli P, was designed from the pain-related words. A sentence from stimuli P is (translation from Danish); *"One of the most refreshing memories that always makes me happy. Is of my sweet and lovely little niece on a swing in the garden on a warm sunny day"* (See Appendix B).

Two questions for each of these sentences were made (See Appendix C) for the following reasons: (a) To filter out participants, who did not understand or convey the meaning of the stimulus. (b) To filter out participants who were not presented with the stimulus (skipped or for other reasons). (c) As a deceiving component, to strengthen the participants' idea that the study was about memory.

Deception study (JFE)

When initially approaching the participants, they were asked if they wanted to participate in a study of memory and pain. The two questions the participants had to answer for each of the stimuli, was a way to strengthen the idea of the experiment being such a study.

The reason for a deception study was to control the experiment as much as possible to make sure that each participant would think of the study in a likewise fashion. If we did not make use of a deception study, the participants would be aware of our hypothesis and that might influence the data and the results.

Before participating in the experiment the participants gave consent, which in brief terms meant that they could drop out at any point, they were aware that throughout the experiment they would receive electric shocks and that the researchers were not responsible for anything, including the risk of feeling uncomfortable. The informed consent was designed in a way to justify both the deception study and the actual intention of the study. The participants were also debriefed of the study afterwards and were all freely permitted to deny usage of the gathered data.

Presentation of stimuli and obtained subjective pain response

The experiment was run using PsychoPy (Peirce et al., 2019). The participants were not informed or guided beforehand. The script guided them through the entire experiment, with none or very few further explanations.

Data (DEC)

Each participant was given an ID, which was used to distinguish between one or the other. Furthermore, age, gender and whether or not any pain killers, have been used for the past 24 hours where obtained.

For each trial, a binary outcome, correct or not, of their response to the first question was obtained, the reason for not obtaining the response for the second question was that this question was designed to further strengthen the deception, and it was not related to the meaning of the prime stimuli.

For the same trial, the intensity of the electric shock (noxious stimuli) was obtained as for their subjective perception of that intensity – using an arbitrary scale that the script taught them to use at the start.

Participants (JFE)

We recruited 50 native Danish speakers, 36 males with an average age of 23.74 (SD = 4.92) and 14 females with an average age of 23.38 (SD = 4.65). Under the introduction phase, four participants, two males and two females, decided to drop out of the study, because they felt that the noxious stimuli was too unpleasant. The data from these participants were excluded from the analysis.

Participants' pain perception (DEC)

The participants would multiple times receive noxious stimuli. The stimulus was in the form of a small amount of electric shock, achieved through a device, which was placed on their right upper arm, same spot for each participant.

The device gives an arbitrary intensity output of 1 to 100, which has been tested to produce between 0.011 and 0.06mA, for a duration period of 800 milliseconds. The participants did not receive anything above 10 on the arbitrary scale at any point during the experiment, which was tested to be 0.02 mA. The noxious stimulus was controlled using a second device, which was in the hands of the researcher doing the experiment. The participants did not receive any noxious stimuli without indicating that they were ready and verbally confirming, each time.

To rate their perception of pain, their response to the noxious stimulus, they were introduced to a scale during the introduction of the experiment. The participants received the following amount, in the stated order; 1, 5, 10, 5, 1 on the arbitrary scale. This was done to make sure all participants, later on would respond, using this scale (figure 2).

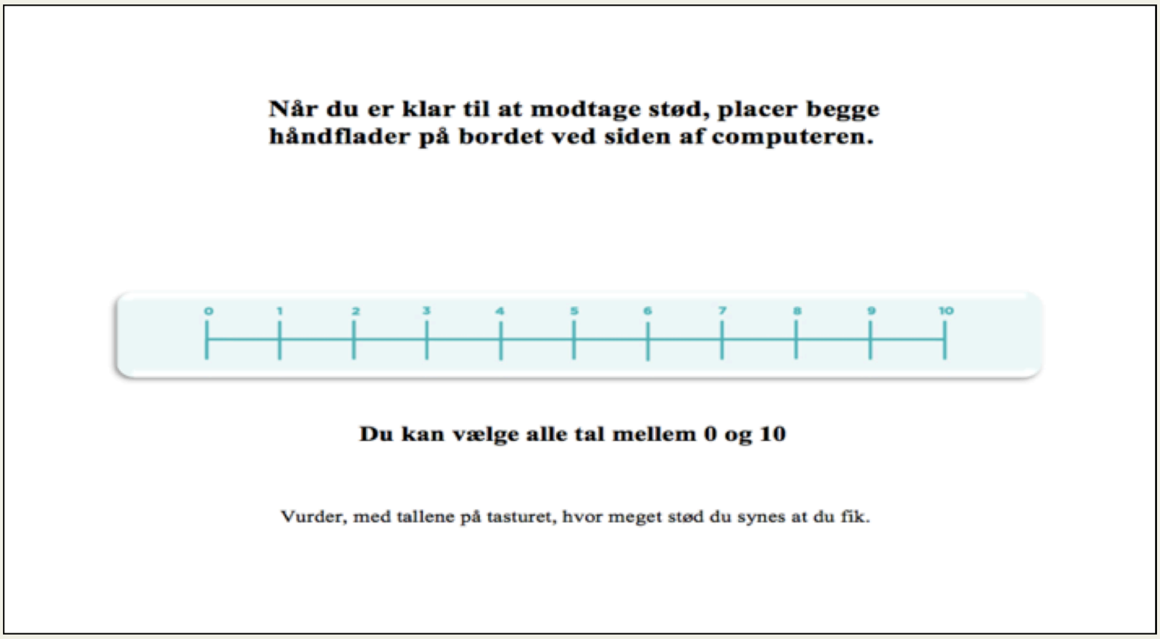

Figure 2: Display of the scale the participants received when having to rate the intensity of noxious stimulus

Translated from Danish (top to bottom):

- When ready to receive the electric shock, place both hands on the table next to the computer.
- You can pick any number between 0 and 10
- By using the keyboard numbers, rate the intensity of the electric shock

Experimental procedure (JFE, DEC)

The experiment was conducted in the same way across participants, with the only changing factor being the environment. The experiment took place in five different locations, which could be categorised into either; closed quiet room or open area with some noise and music in the background.

An approximate equal amount of male and female were asked for participation on the day of the experiment, and were – as stated earlier – told that the study was about memory and pain. They received an edible treat afterwards as gratitude.

A total of nine stimuli – three per category – were presented to the participants. They were presented randomly for each participant and after each stimulus they answered a question, which was related to the meaning of the stimulus.

Participants who did not answer correctly had the data for the respective stimulus excluded and we did not use these in the analyses. If a participant gave the wrong answer, it would indicate that the prime stimuli we presented for them was somehow not clear enough for this specific participant or that for other reasons, the participant failed to read the prime stimuli. After answering the first question, they would receive an unknown intensity, known to us, of the noxious stimulus, which they had to rate. The intensity of the noxious stimuli was randomised across the prime stimuli, which insures that the results are not due to any difference across the conditions.

A second question was asked, after the noxious stimulus was rated. This question was used to further strengthen the deception study. It was never about meaning, or anything related to the words used to design the prime stimuli. The reason for this was to get the participants out of the mood from the previous text and ready for the next stimuli. For each of the nine stimuli the participants goes through the steps in figure 3.

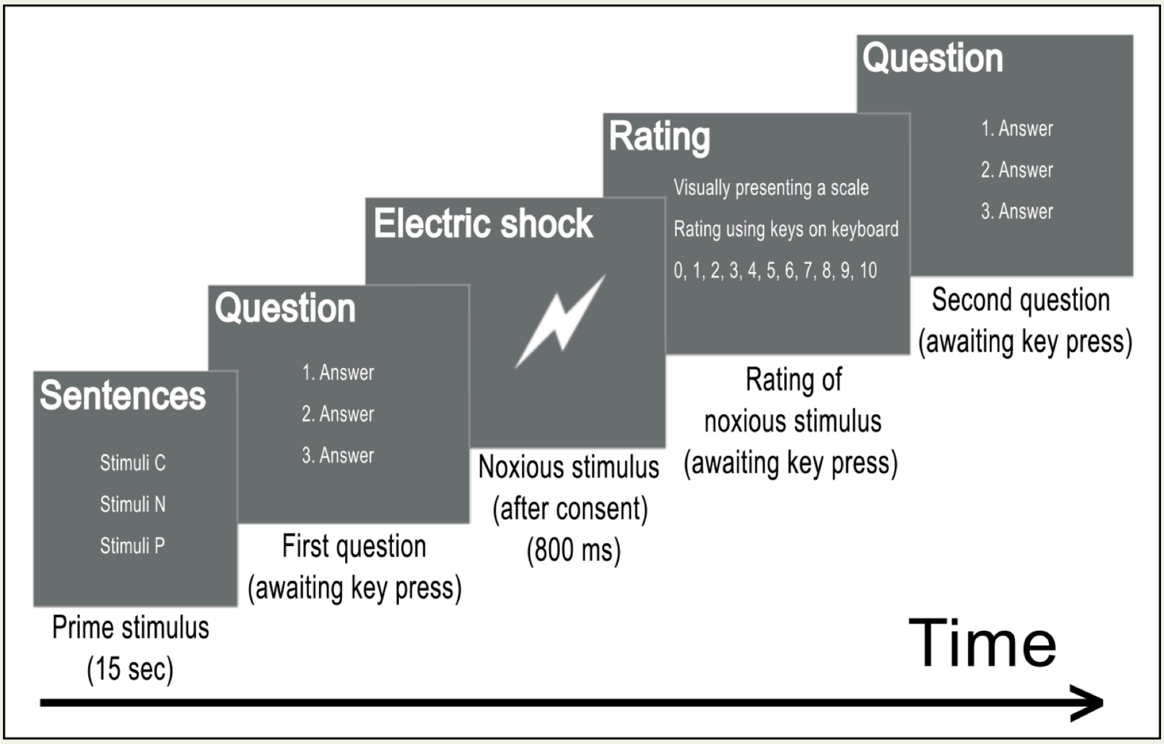

Figure 3: Design of experimental procedure, first participants was primed with one of three sentences, painful, comfortable or neutral. Next they had to answer a question related to the meaning of the text they had just read. After agreement they got the noxious stimuli and had to rate the intensity, at last they had to answer a second question, which was not related to the meaning or to the words used to design the stimuli.

Statistical analysis

We used R (R Core Team, 2019), the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) and the Sentida package (Lauridsen, Dalsgaard, & Svendsen, 2019), to perform our data analysis.

Results (JFE, DEC)

We performed a linear mixed effect analysis to predict participants' subjective pain perception, as fixed predictors the objective scale from the device and the categories of the prime stimulus was entered. As random intercepts participant ID was entered to account for individual differences, since pain perception is highly subjective (Wilcox, 2015; Fillingim, 2017), additionally, having ID as random intercept, people that had taken painkillers in the last 24 hours, prior to the experiment, was accounted for.

Before making the analysis, incorrect answers were removed, because people that answered incorrect have probably not engaged with the prime stimuli enough, to be affected by the prime stimulus, or they might even have failed, to read the prime stimulus.

Furthermore, we checked for clear outliers. A visual inspection of a scatter plot showed no clear outliers. We checked standardized residuals above 3.29 and below minus 3.29, it turned out that 20 data points equivalent to 6% of the data, met this criteria. When only about 1% of the data should lie in this area we keep these data in our main analysis (Osborne & Overbay, 2004). In addition, removing data would also not be reasonable, since our outcome variable is a subjective measure of pain perception. The potential outliers are cases where a participant felt something way higher or lower than the model predicts – but if this was how they felt, they should not be excluded, hence the subjective outcome variable. The data is therefore included to decrease the probability of committing a type I error – rejecting the null hypothesis, where the null hypothesis is true.

Visual inspection of the residual plot did not show any violation of the assumptions of homoscedasticity or linearity, after the removal of incorrect answers. The participants subjective perception of noxious stimuli was significantly predicted by the objective measure from the device, $\beta = 0.560$ $SE = 0.048$, $t = 11.576$, $p = .000$. Stimuli C compared to stimuli N did not predict subjective pain perception $\beta = -0.358$ $SE = 0.257$, $t = -1.392$, $p = .165$. Stimuli P compared to stimuli N did not predict subjective pain perception $\beta = 0.197$ $SE = 0.259$, $t = 0.762$, $p = 0.447$. Comparing stimuli P to C, did significantly predict subjective pain perception β = 0.555 SE = 0.253, t = 2.198 , p = .029 (Figure 4). No other significant predictors were found.

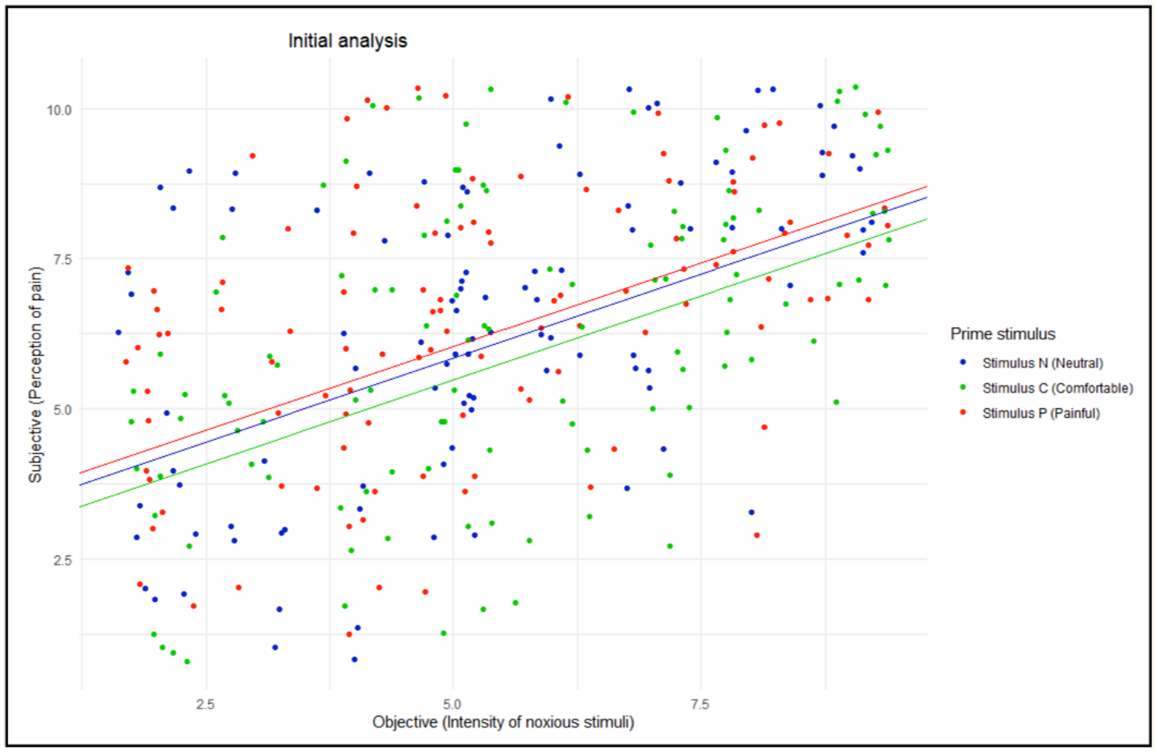

Figure 4. Scatterplot and regression lines of data for stimuli C, stimuli P and stimuli N. Where wrong answers have been filtered out and individual differences are taken into account by having ID as random intercepts.

Further analysis (DEC)

In our initial analysis we wanted to have valence as a random intercept, but that over fitted the data. However, when not removing the wrong answers, it was possible to compute a model with random intercepts for both valence and ID. Valence for the prime stimuli was obtained with Sentida – a Danish sentiment analysis tool (Lauridsen, Dalsgaard, & Svendsen, 2019).

We therefore performed another linear mixed effect analysis, predicting subjective pain perception. The fixed predictors were still the objective scale from the device and the categories of the prime stimuli. As random intercepts, ID and valence of the prime stimuli was entered. Visual inspection of the residual plot did not show any violation of the assumptions of homoscedasticity or linearity.

The participants subjective pain perception was significantly predicted by the objective measure of the device $\beta = 0.556$ $SE = 0.044$, $t = 12.692$, $p = .000$. Stimuli C compared to stimuli N did not predict subjective pain perception $\beta = -0.288$ $SE = 0.240$, $t = 1.2$, $p = .276$ Stimuli P compared to stimuli N did not predict subjective pain perception $\beta = 0.319$ $SE = 0.238$, $t = 1.34$, $p = .231$. Comparing stimuli P to C, did significantly predict subjective pain perception $\beta = 0.601$ $SE = 0.239$, $t = 2.54$, $p = .045$ (Figure 5).

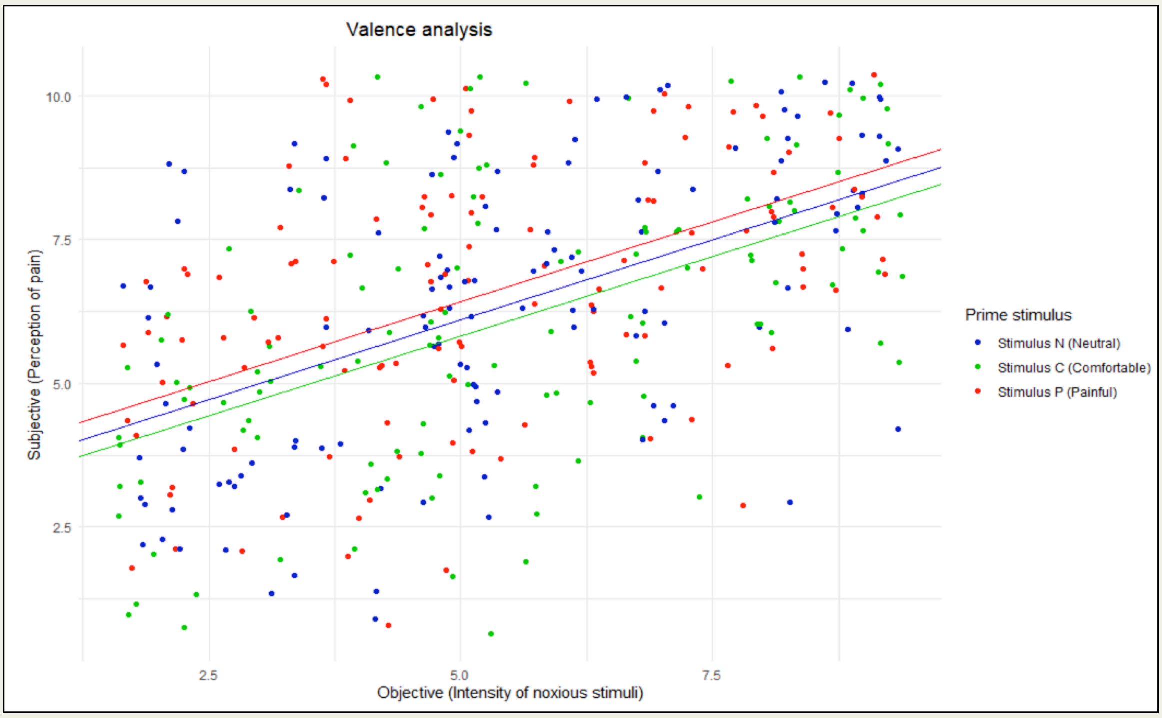

Figure 5. Scatterplot and regression lines of data for stimuli N, stimuli C and stimuli P. Where valence and individual differences are taken into account by having these as random intercepts.

Discussion (DEC, JFE)

It should be noted that the study primarily recruited male subjects – even though an approximate equal amount was asked – and the results of the analyses should therefore be interpreted in that regard. The reason to why the study mainly recruited male subjects, may be due to the environment participants were collected from, or that they were going to receive electric shocks and females are generally thought to be less risk taking than males (Byrnes, Miller, & Schafer, 1999).

We hypothesised that a written text stimuli designed from pain-related words, has an increasing effect on subjective pain perception. Which is supported by previous research (Vukovic, Fardo, & Shtyrov, 2018; Richter et al., 2014).

Secondly we hypothesised that we could decrease subjective pain perception by presenting written text stimuli designed from comfortable-related words.

From the initial analysis we reject both hypotheses, because the painful written stimuli and the comfortable written stimuli did not show a change in the subjective perception of pain, compared to a neutral written stimuli. However, when comparing the painful stimuli in relation to the comfortable stimuli, we did find a significant difference in pain perception. The subjective perception of pain was lower for participants who were given the comfortable stimuli in relation to the perception of pain when given the painful stimuli. Which indicates that the rejection of the hypothesis might be due to either statistical power or the design of the neutral stimuli, when comparing the painful stimuli to the comfortable stimuli, the results would confirm both hypotheses.

Further analysis (JFE)

To account for the difference in valence between the nine different stimuli, a further analysis was conducted. To make this analysis no data points could be excluded, and was therefore conducted with data points from participants who answered incorrectly on the first question. This analysis showed the same results as the initial analysis. Which indicates that valence does not explain all the variance that the prime stimuli did. The prime stimuli were designed from comfortable and pain-related words; therefore the effect is not only due to the valence of these words but potentially due to the difference between the comfortable and pain-relatedness of the words in the given stimuli.

Main discussion (JFE, DEC)

Both analyses showed that as objective noxious stimuli increased so did the participants' perception of pain.

Our results show that written language can have an effect on pain perception. This effect might be small since the paper did not find any significant differences between the neutral condition compared to the painful and comfortable condition. These findings might indicate that the noxious stimuli given by the device was not nuanced enough to be reliable, which could also describe why 6% of the data, could be considered outliers. These results might also show that the effect on the subjective pain perception might be even harder to detect when participants are not consciously aware of the intention of the experiment. Our results might therefore actually be more applicable, since in everyday life you will not be aware nor informed before reading something that whatever and however this might be formulated, could influence your perception of pain.

Our results indicate that pain-related words might activate the pain matrix, because they seem to affect how we perceive the noxious stimuli, even when taking valence into account. This hypothesis is supported by FMRI studies, which shows that pain-related words are processed differently in the brain (Ritter, Franz, Miltner, & Weiss, 2019; Richter, Eck, Straube, Miltner, & Weiss, 2010). This increased perception of pain might be due to the fact that we associate pain-related words with painful experiences, and we therefore expect to experience more pain when represented with a painful sentence, because of predictive coding.

Our results might also support the idea that there is something inherently different about pain-related words, compared to negatively valence words. This idea has also been shown by an FMRI study (Richter, Eck, Straube, Miltner, & Weiss, 2009), however a follow-up study investigated pain perception from pain-related words in relation to negatively valence words, found no difference. It should however be noted, that the effect size was greater in the pain-related condition (Richter et al., 2014).

Other research has investigated the modulation of pain while keeping valence constant, with pain-related metaphoric sentences versus pain-related literal sentences, here a difference was found between literal and metaphorical pain sentences. This suggests that it is the active process of thinking about pain-related words that modulates the perception of pain, and not only the valence of the given stimuli. This idea of explicitly thinking about pain-related words is also supported by imaging studies (Gu & Han, 2007). This is consistent with our results, since the participants had to remember the context of the story, which was either pain, neutral or comfortable-related. Therefore valence and pain-relatedness of words or sentences seems to have modulating effect on subjective pain perception (Vukovic, Fardo, & Shtyrov, 2018). The modulation of pain perception from written stimuli has been shown with participants being aware of the intention of the study and now, in our study, not aware of the intention. Our study shows that pain-related stimuli, has an increasing effect on pain perception, even though evidence has shown that this effect could be completely opposite, when investigating subconscious priming (Peláez, Martínez-Iñigo, Barjola, Cardoso, & Mercado, 2016). These results suggest that it is important to be aware and cautious when dealing with pain patients. We know that many Europeans suffer from pain, which can affect their psychological state and influence their work life (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006). Since semantic context and possible pain-related words can be a factor in predictive coding, doctors, psychologists, therapists and in general everyone in contact with people that possible suffers from pain – should be very careful about how issues and themes are explained and talking about and which words are used. If however comfortable-related words could have an attenuating, this could be a very straightforward way of lowering the amount and intensity of pain that someone feels.

Future studies are needed to conclude that pain-related words are inherently processed differently and therefore increase pain perception more than just negatively valence words. In addition, future studies should investigate whether the effects of modulated pain perception is identical when participants are not aware, compared to being aware, of the purpose of the study. This is thought to be important because in a real life setting patients will not be explicitly thinking about how the words they read could potentially change their perception of pain.

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Appendix

Appendix A

Table of words used for prestudy

Word	Median score	Standard deviation	Word frequency	Word	Median score	Standard deviation	Word frequency
Sønderrivende	9	1.47	50	Sød	2	1.11	4417
Kyssende	2	0.98	2190	Grundig	4	1.36	3554
Billig	5	1.49	7101	Dejlig	2	0.83	6959
Jagende	8	1.21	1445	Stødende	7	1.11	2786
Gammel	6	1.56	51316	Bankende	7	1.04	2757
Fortryllende	2	0.9	161	Daglig	5	0.91	8311
Grufuld	8	1.08	133	Forkert	6	1.1	6441
Varmende	2	1.05	5961	Kærtegnende	2	1.55	501
Fattig	7	1.49	3994	Skærende	8	0.99	7751
Lang	5	0.63	5000	Hamrende	7	1.31	902
Oprfriskende	3	1.11	36	Venlig	3	1.03	3747
Ødelæggende	8	0.92	4776	Latter	2	1.16	1456
Modbydelig	9	1.41	288	Sviende	8	1.16	634
Rød	5	1.12	9673	Kløvende	6	1.42	153
Officiel	5	0.59	4832	Rigtig	4	1.07	28591

Lav	*5*	*0.72*	*46351*	*Tynd*	*5*	*1.29*	*4456*
Lykkelig	*1*	*0.97*	*3531*	*Trofast*	*3*	*1.04*	*1021*
Krammer	*1*	*1.06*	*302*	*Heroisk*	*4*	*1.49*	*241*
Knusende	*8*	*1.95*	*1735*	*Forfærdelig*	*8*	*1.25*	*2033*
Kvælende	*9*	*1.24*	*1119*	*Frygtelig*	*8*	*1.22*	*1846*
Borgerlig	*5*	*1.18*	*4299*	*Klar*	*5*	*1.2*	*37880*
Almindelig	*5*	*0.95*	*3907*	*Klassisk*	*5*	*0.88*	*3897*
Flirter	*3*	*0.97*	*558*	*Naturligt*	*4*	*1.19*	*8025*
International	*5*	*0.54*	*15520*	*Enormt*	*5*	*0.68*	*4478*
Huggende	*7*	*1.59*	*1199*	*Skoldende*	*8*	*1.26*	*117*
Lynende	*8*	*1.55*	*357*	*Himmelsk*	*2*	*1.1*	*374*
Behagelig	*1*	*1.17*	*1411*	*Solskin*	*2*	*1.1*	*497*
Kraftig	*6*	*1.09*	*8576*	*Forløbig*	*5*	*0.62*	*5560*
Sød	*2*	*1.11*	*4417*	*Smuk*	*2*	*1.15*	*10956*
Grundig	*4*	*1.36*	*3554*	*Grusom*	*8*	*1.3*	*651*
Dejlig	*2*	*0.83*	*6959*	*Tom*	*7*	*1.15*	*6333*
Stødende	*7*	*1.11*	*2786*	*Dræbende*	*10*	*1.27*	*5478*

Appendix B

Prime stimuli:

Comfortable stimuli

1.Det var en varm og dejlig solskinsdag, jeg var lige kommet hjem og havde krammet min dejlige kæreste, da jeg fik det mest fortryllende kys nogensinde.
2. Jeg flirter lidt med den dejlige mand jeg har mødt. Jeg kan simpelthen ikke lade være, han er helt og aldeles himmelsk, og så har han den sødeste og mest trofaste hund.
3. En af de mest opfriskende minder, som gang på gang gør mig lykkelig. Er af min søde og dejlige lille niece, der gynger ude i haven på en varm solskinsdag.

Neutral Stimuli

1. Jeg skulle bo på et klassisk hotel, mens mit almindelige hus blev renoveret. Hotellet var rødt og blev bygget i 1999, og har udsigt ud over den enorme by.
2. Samtalen hos den foreløbige chef, havde været lang og vi snakkede kun om officielle emner, som ikke påvirkede borgerne. De lange samtaler var ved at blive dagligdag for mig.
3. Jeg havde altid været lav og tynd i hele gymnasietiden, men efter at jeg havde været ude på den lange internationale rejse, var der sket en klar ændring.

Painful stimuli

1. Jeg kom ind på hospitalet, det var forfærdeligt. Min arm var blevet skoldet og smerten blev ved med at føltes varm og sviende, det havde været en grusom oplevelse.
2. Smerten føltes jagende og sviende, da jeg vågnede op midt i operationen. De var igang med at skære mit venstre bryst op. Jeg frygtede for livet – tænkte at de ville dræbe mig.

3. Mit hjerte bankede og jeg havde en frygtelig tom fornemmelse i maven efter den grufulde og ødelæggende oplevelse. Det var forfærdeligt og jeg følte mig kvalt i situationen.

Appendix C

Questions:

Neutral

1: Hvorfor boede personen på et hotel? - Det var et flot hotel fra 1999 - Grundet renovering af eget hus - Han skulle se den gode udsigt
2: Hvad handlede samtalen i sætningen om? - Hvem der skulle være den nye chef - Hvordan samtalerne var blevet dagligdag - Emner der ikke påvirkede borgerne
3: Hvad tror du var sket med personen efter at han havde været ude på sin rejse? - Han havde fået en masse internationale kontakter - Han var blevet verdenskendt og havde fået en masse venner - Han havde taget en del kilo på og blevet højere

Comfortable

1: Hvad skete der da personen var kommet hjem? - Han krammede sin dejlige kæreste og fik et fortryllende kys - Han mødte sin venlige kæreste der krammede ham

- Han kyssede sin kæreste og de gik ud i det fine vejr
2: Hvorfor flirter personen med den dejlige mand? - Fordi han var sød og dejlig - Fordi han havde hjulpet hende igennem en svær tid - Fordi han var himmelsk og havde en sød og trofast hund
3: Hvilket minde gjorde personen lykkelig gang på gang? - Mindet om en sød og dejlig niece, der gynger i solskinsvejr - Mindet om en sød og dejlig niece der leger ude i solskinsvejret - Mindet om den søde niece som hopper i vandpytter

Painful

1: Hvad kunne have været sket med personen i historien? - Han havde fået tredje-grads forbrændinger - Hans far var lige død og skulle ind og se ham for sidste gang - Hans kæreste var blevet indlagt efter et slagtilfælde
2: Hvorfor tror du at personen troede de ville dræbe ham? - Fordi han havde aldrig givet samtykke til operationen - Fordi han følte en intens smerte - Fordi han var blevet taget til fange dagen forinden
3: Hvilken situation kunne passe på historien? - Personens bror faldt om på gaden - Personen faldt og slog sit knæ - Personen væltede på sin cykel