Differential effects of visually induced analgesia and attention depending on the pain stimulation site

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Abstract

Background: The term ‘visually induced analgesia’ describes a reduced pain perception induced by watching the painful body part as opposed to watching a neutral object. In chronic back pain patients, experimental pain, movement-induced pain and habitual pain can be reduced with visual feedback. Visual feedback can also enhance the effects of both massage treatment and manual therapy. The impact of somatosensory attentional processes remains unclear.

Methods: In the current study, participants received painful electrical stimuli to their thumb and back while being presented with either a real-time video of their thumb or back (factor feedback). In addition, using an oddball paradigm, they had to count the number of deviant stimuli, applied to either their back or thumb (factor attention) and rate the pain intensity.

Results: We found a significant main effect for attention with decreased pain ratings during attention. There was no main effect for visual feedback and no significant interaction between visual feedback and attention. Post-hoc tests revealed that the lowest pain intensity ratings were achieved during visual feedback of the back/thumb and counting at the back/thumb.

Conclusion: These data suggest that the modulation of perceived acute pain by visually induced analgesia may be influenced by a simultaneous somatosensory attention task.

Significance: Somatosensory attention reduced experimental pain intensity in the thumb and back in the presence of both congruent and incongruent visual feedback. We found no significant visual feedback effect on the complex interplay between visual feedback and somatosensory attention.

Larissa Cordier and Eva Marie Ullrich are contributed equally.
1 | INTRODUCTION

Watching a painful part of the body or the site of painful stimulation can modulate the perceived pain intensity and has been coined visually induced analgesia. In healthy controls, real-time visual feedback of the hand during experimental painful stimulation reduces the perceived pain intensity compared with watching a neutral object (Longo et al., 2009). Real-time visual feedback reduces the perceived pain intensity of experimental painful stimuli applied at the site of chronic pain – the back – in chronic back pain (CBP) patients (Diers et al., 2013). In contrast to the hands, one’s own back cannot be seen directly and is usually only perceived when it causes trouble. Furthermore, it shows that also after learning experiences relevant for the development of chronic pain this manipulation is still working for acute painful stimuli. However, while the analgesic effect is rather small and context dependent (Beck et al., 2016; Osumi et al., 2014; Torta et al., 2015; Valentini et al., 2015), the simplicity of its application has motivated its use in clinical settings and treatments. The first report of visually induced analgesia was assessed in patients with complex regional pain syndrome, where movement-evoked pain of the hand increased when watching an enlarged image of their limb during movement and decreased when watching a scaled-down image (Moseley et al., 2008). In accordance, in chronic lower back pain patients, visual feedback of their back reduced movement-evoked pain during repeated lumbar spine movements (Wand et al., 2012). These results were interpreted as a top-down effect of body image on the integration of sensory information (Longo et al., 2012; Moseley et al., 2008). Recently, it was shown that real-time visual feedback could also reduce habitual pain intensity (Diers et al., 2016), and enhance massage treatment (Löffler et al., 2017) and manual therapy (Beinert et al., 2019) outcomes, suggesting that central processes involved in the processing of aversive memories might be targeted as well.

Visually induced analgesia might reflect multisensory integration of somatosensory and visual information. It is widely accepted that vision provides better spatial and temporal resolution of an acute stimulus than somatosensation, leading to the primacy of visual over somatosensory cues in multisensory integration (Ernst & Banks, 2002). Thus, visual features of a stimulus are generally more confined than its somatosensory features, suggesting that visual feedback can attenuate pain by reducing its perceived spatial extent. However, in contrast to other body areas, one’s own back cannot be seen directly but only with the help of a mirror or real-time feedback. This suggests novelty which might bind attention and is different from paradigms as those involving regularly seen extremities. The aim of this study was to explore a presumed effect of somatosensory distraction or attention as modulating factor for visually induced analgesia by performing a somatosensory attention task while seeing an own well-known or a not so well-known body part.

2 | METHODS

2.1 | Participants

We tested 31 healthy participants (12 males; aged 24.23 ± 4.759 years). The results of our previous study (Diers et al., 2013) with an effect size of 0.45 suggested a sample size of $n = 26$ for the two main effects of a within-group design with four conditions, an alpha error of 0.05 and a beta error of 0.95. We planned to include $n = 31$ to allow for a normal attrition rate of 20%. Participants were recruited from the campus of the Ruhr University Bochum and through advertisement in Social Media Groups. The experiment was announced as an investigation of the influence of visual information for the treatment of chronic pain. Participants were told that they would receive a real-time video of their back and hand and at the same time painful, but individually adapted, bearable stimuli at their back and thumb. The research appointment lasted 90 min, and the experiment had a duration of 12 min plus the individual time needed for the rating. We had no adverse side effects of the study to participants. All participants were right-handed, as assessed with the Edinburgh Handedness Inventory (Oldfield, 1971). Exclusion criteria were a chronic pain disorder, neurological complications, psychosis, drug abuse, current opioid intake and allergy to plaster. Written informed consent was obtained before the start of the experiment. The study was approved by the ethics committee of the Medical Faculty of the Ruhr University Bochum (approval number: 16–5624) and adhered to the Declaration of Helsinki.

2.2 | General design

The experiment was conducted in our laboratory at the Clinical and Experimental Behavioral Medicine unit, Department of Psychosomatic Medicine and Psychotherapy, LWL University Hospital, Ruhr University Bochum. Recruitment and data collection were conducted between March and June 2017. Participants received concurrently painful stimuli to the fingertips of the left thumb and the pars descendens of the left trapezius muscle using an oddball paradigm (presentation of repetitive standard stimuli intermittent with deviant stimuli, see below). The stimuli at both sites (back and thumb) had different timings (different starting points, different inter stimulus intervals), even though they were presented at both sites in every trial.

During painful stimulation, participants received real-time video feedback of either their back or hand (factor FEEDBACK). A camera filmed their back from behind them or their thumb, including the rest of the hand, from above and displayed the footage on a monitor in front of the participants in real-time. At the same time, they were asked to count deviant painful stimuli (see below for
details), presented to either their thumb or back (factor ATTENTION). This task was designed to control attentional focus. In each of these 2x2 = 4 conditions, four pain ratings were assessed (details see below), two regarding their back and two regarding their thumb. With respect to these ratings, attention and feedback were either congruent (e.g. feedback on back, rating of back) or incongruent (e.g. attention on back, rating of thumb). The conditions are depicted in Table 1. In total, 24 trials were obtained from 6 repetitions in each of the four conditions. We used 6 blocks consisting of 4 trials, one per condition. The order of the trials per block was randomized. Each trial was 30 s long, summing up to 12 min plus additional time for the ratings. Each trial of the same condition had a different stimulation pattern resulting in 6 different stimulation patterns (for details see below section electrical stimulation). Stimulation patterns were generated using http://randomization.com/. These 6 stimulation patterns were used for all 4 conditions and were randomized over the blocks. Randomization over the blocks was done with Python (Peirce, 2007).

Each trial started with the participant being instructed to count deviant electrical stimuli (see below) either to their back or thumb. Then, the real-time video of either their back or thumb started and simultaneously both the back and thumb were electrically stimulated for 30s. After the stimulation, the participant had to enter the number of identified deviant stimuli and rated the perceived intensity and unpleasantness of the painful stimuli to their back and thumb. The experiment was controlled with a custom-made script using PsychoPy (Peirce, 2007) and a NI USB-6251 BNC high-speed multifunction data acquisition module (National Instruments, Austin, TX, USA).

2.3 | Electrical stimulation

Electrical stimuli were applied by two constant current stimulators (model DS7A; Digitimer, Hertfordshire, England) with a pair of disposable needle electrodes (20 mm long, 0.35 mm uninsulated tip, 2 mm² stimulation area, 0.5 cm separation, model: 9013R0272, 28G, Alpine Biomed ApS, Skovlunde, Denmark), using an intraepidermal stimulation method (Inui et al., 2002; Inui, et al., 2002) slightly modified to provide a higher selectivity for the activation of nociceptors (Diers et al., 2007, 2008, 2013; Inui & Kakigi, 2006; Yamashiro et al., 2008, 2009). The needles were inserted into the epidermis of the back and into the uppermost skin layer of the left thumb pulp with 0.5 cm separation between the electrodes.

2.3.1 | Determining individual stimulation intensity

Perception threshold and pain threshold were determined by averaging ratings of three alternately ascending and descending series respectively. Pain tolerance was assessed with three ascending series. Stimulation intensity was determined as follows: Starting with an intensity of 70% above the pain threshold, we applied a train of 10 test stimuli and adjusted the intensity to yield a perceived pain intensity of 7 or 8 on a numerical rating scale (NRS) between 0 = no pain and 10 = strongest imaginable pain. Additionally, we assessed a visual analogue scale (VAS) rating (see below for details). Although the stimulation intensities were adjusted between 7 and 8 on the NRS, the ratings during the experiment were lower (4.5–5.5). This was also the case in our previous study (adjusted intensities between 7 and 8, ratings between 4.6 and 5.1, Diers et al., 2013). Longo et al. (2009) who used stimulation intensities 'eliciting clear sensations of pain' reported intensity ratings between ~ 4.5 and 5.5, which is similar to our ratings. Possible explanations are speculative but the difference might be due to a general sensitization to the electrical stimulation, which was longer during the experiment compared to the 10 test stimuli.

2.3.2 | Standard stimuli

Electrical stimuli were presented in 24 trials of 30 s duration. Each 30 s trial consisted of 30 painful electrical monophasic pulses. Standard stimuli had a duration of 2 ms and an interstimulus intervals of 600 to 800 ms. Number of standard stimuli was 30 minus number of deviant stimuli.

| TABLE 1 Experimental conditions and their meanings |
|---------------------------------------------------|
| Feedback | Rating of the BACK | Rating of the THUMB |
| Back     | congruent feedback | incongruent feedback |
|          | congruent attention | congruent attention |
| Thumb    | congruent feedback | incongruent feedback |
|          | incongruent attention | incongruent attention |

Note: Congruent and incongruent feedback/attention relate to the site of the ratings.
Deviant stimuli had a shorter interstimulus interval of 200 ms. On average, trials included 2.9 (±0.3) sequences consisting of 3 to 10 deviant stimuli (mean 5.7 ± 0.8).

2.4 | Pain ratings

During the experiment, participants had to rate perceived pain intensity and unpleasantness after each trial using VAS. The pain intensity VAS consisted of a 100 mm horizontal line with the anchors ‘no pain’ and ‘strongest imaginable pain’. The instruction to the rating scale was ‘How intense were the stimuli at the back/thumb?’. The pain unpleasantness VAS consisted of a 100 mm horizontal line with the anchors ‘not unpleasant’ and ‘very unpleasant’. The instruction to the rating scale was ‘How unpleasant were the stimuli at the back/thumb?’.

2.5 | Task

The participants saw either a real-time video feedback of their back or thumb on the monitor in front of them and were asked to count the deviant stimuli to either their back or thumb.

2.6 | Visual feedback

Using two video cameras (Logitech, Lausanne, Switzerland, C920 HD Pro Webcam, resolution 1080p/30 frames per
second), the participant's back or thumb was filmed and presented in real time on a monitor (LG Electronics, Seoul, South Korea, LG Flatron W2242T, screen size 22”, maximum resolution 1,680 x 1,050 pixels) in front of them with a distance of 50 cm. Their thumb was hidden by a screen, so no direct vision of the thumb was possible.

2.7 | Data processing and statistical analyses

Statistical analyses were conducted using the R environment for statistical computing and graphics (R Core Team, 2014) with the RStudio integrated development environment (RStudio Inc., Boston, MA, USA). Linear mixed models were analysed with lme4 and lmerTest packages (Bates et al., 2014; Kuznetsova et al., 2017); graphics were created using the ggplot2 package (Wickham, 2009).

Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. The level of significance was set at \( p < .05 \), if not otherwise specified.

Our primary aim was to assess the differential effects of visually induced analgesia and distraction (experimental factors) on pain experience (dependent measures). The ratings of pain intensity and unpleasantness were analysed using linear mixed models (LMM) for each measure and rating site. In each analysis, we used ATTENTION (factor 1: back or thumb) and FEEDBACK (factor 2: back or thumb) as a fixed within-subject factor with two levels each. We included participants as a random factor, allowing for inter-individual variability of intercepts. We fitted a model with the factors ATTENTION and FEEDBACK and an interaction factor. The primary outcome variable was experimental pain intensity for stimuli to the back and thumb. The secondary outcome variable was experimental pain unpleasantness for stimuli to the back and thumb. To test the differences in the ratings between the conditions, we used post-hoc tests because we hypothesized lower ratings for ‘FEEDBACK’ and higher ratings for ‘ATTENTION’.

For the analyses of the correct responses of deviant stimuli in the attention task, we calculated a LMM with ATTENTION (counting of deviant stimuli, factor 1: back or thumb) and FEEDBACK site (factor 2: back or thumb). We used post-hoc tests to examine the differences between the conditions, as described above.

2.8 | Availability of code and data

All data presented in this article and code to reproduce the statistical results and figures are available online and can be accessed via: https://osf.io/z73q5/; DOI: 10.17605/OSF.IO/Z73Q5.

3 | RESULTS

Results are summarized in Table 2.

3.1 | Pain intensity: back

We found a significant main effect for the factor ATTENTION \((F(1,93) = 11.594, \, p = .0010)\), no significant main effect for the factor FEEDBACK \((F(1,93) = 0.543, \, p = .4630)\) and no significant interaction between ATTENTION and FEEDBACK \((F(1,93) = 0.209, \, p = .6488)\). Post-hoc tests revealed significantly lower ratings for ‘congruent feedback + congruent attention’ compared to ‘congruent feedback + incongruent attention’ \((t(93) = −2.731, \, p = .0038)\) or ‘incongruent feedback + incongruent attention’ \((t(93) = −2.929, \, p = .0021)\), and significantly lower ratings for ‘incongruent feedback + congruent attention’ compared to ‘congruent feedback + incongruent attention’ \((t(93) = 1.887, \, p = .0312)\) or ‘incongruent feedback + incongruent attention’ \((t(93) = −2.085, \, p = .0199)\), see Table 3 for mean and standard deviation. Interestingly, the lowest ratings were scored for the condition ‘FEEDBACK’.

Table 3: Pain Intensity and Unpleasantness Ratings

| Attention  | Feedback | Rating of the BACK* | Rating of the THUMB* |
|------------|----------|---------------------|----------------------|
|            | Back     | Thumb               | Back                 | Thumb               |
| Back       | Pain Intensity [M(SD)] | 5.07 (2.17) | 5.21 (2.04) | 4.80 (2.27) | 4.97 (2.12) |
|            | Unpleasantness [M(SD)] | 5.01 (2.29) | 5.17 (2.10) | 5.00 (2.42) | 4.97 (2.35) |
| Thumb      | Pain Intensity [M(SD)] | 5.52 (1.96) | 5.56 (2.07) | 4.59 (2.11) | 4.57 (2.20) |
|            | Unpleasantness [M(SD)] | 5.70 (2.09) | 5.60 (2.09) | 4.59 (2.30) | 4.63 (2.43) |

Note: Abbreviations: “The ratings were between 0, ‘no pain’ and 10, ‘strongest imaginable pain’ and 0, ‘not unpleasant’ and 10, ‘very unpleasant’; FEEDBACK, Visual Real Time Feedback; M, mean; SD, standard deviation.
3.2 | Pain unpleasantness: back

We found a significant main effect for the factor ATTENTION \((F(1,93) = 18.679, p = .00004)\), no significant main effect for the factor FEEDBACK \((F(1,93) = 0.057, p = .8118)\) and no significant interaction between ATTENTION and FEEDBACK \((F(1,93) = 1.074, p = .3027)\). Post-hoc tests revealed significantly lower ratings for ‘incongruent feedback + incongruent attention’ compared to ‘congruent feedback + congruent attention’ \((t(93) = -3.225, p = .0009)\) and ‘incongruent feedback + congruent attention’ \((t(93) = -2.323, p = .0112)\), significantly lower ratings for ‘congruent feedback + congruent attention’ compared to ‘congruent feedback + incongruent attention’ \((t(93) = -3.789, p = .0001)\) and significantly lower ratings for ‘incongruent feedback + congruent attention’ compared to ‘congruent feedback + incongruent attention’ \((t(93) = 2.887, p = .0024)\).

3.3 | Pain intensity: thumb

We found a significant main effect for the factor ATTENTION \((F(1,93) = 5.219, p = .0246)\), no significant main effect for the factor FEEDBACK \((F(1,93) = 0.346, p = .5579)\) and no significant interaction between ATTENTION and FEEDBACK \((F(1,93) = 0.488, p = .4865)\). Post-hoc tests revealed significantly lower ratings for ‘incongruent feedback + incongruent attention’ compared to ‘congruent feedback + congruent attention’ \((t(93) = 2.110, p = .0188)\) and significantly lower ratings for ‘congruent feedback + incongruent attention’ compared to ‘congruent feedback + congruent attention’ \((t(93) = -2.031, p = .0225)\).

3.4 | Pain unpleasantness: thumb

We found a significant main effect for the factor ATTENTION \((F(1,93) = 6.754, p = .0109)\), no significant main effect for the factor FEEDBACK \((F(1,93) = 0.001, p = .9733)\) and no significant interaction between ATTENTION and FEEDBACK \((F(1,93) = 0.091, p = .7637)\). Post-hoc tests revealed significantly lower ratings for ‘incongruent feedback + incongruent attention’ compared to ‘congruent feedback + congruent attention’ \((t(93) = 1.814, p = .0365)\), significantly lower ratings for ‘congruent feedback + incongruent attention’ compared to ‘congruent feedback + congruent attention’ \((t(93) = 2.051, p = .0216)\) and significantly lower ratings for ‘incongruent feedback + congruent attention’ compared to ‘congruent feedback + incongruent attention’ \((t(93) = -1.861, p = .0329)\).

3.5 | Exploratory descriptive analyses

For ratings of the back, 15 participants had the lowest ratings in the condition ‘congruent feedback + congruent attention’, 6 in the condition ‘incongruent feedback + incongruent attention’, 8 in the condition ‘incongruent feedback + congruent attention’ and 2 in the condition ‘congruent feedback + incongruent attention’ (see Figure S1).

For ratings of the thumb, 13 participants had the lowest ratings in the condition ‘congruent feedback + congruent attention’, 10 in the condition ‘incongruent feedback + incongruent attention’, 5 in the condition ‘incongruent feedback + congruent attention’ and 3 in the condition ‘congruent feedback + incongruent attention’.

3.6 | Attention task

In total, participants were 73% correct in the attention task (For the % correct responses in the four conditions, see Table 4). The LMM with the factors ATTENTION and FEEDBACK revealed a significant main effect for ATTENTION \((F(1,713) = 84.2406, p < .0001)\) and FEEDBACK \((F(1,713) = 4.2296, p = .0401)\) suggesting a higher correct response rate for counting deviants to the back and for feedback of the thumb. However, there was no significant interaction effect \((F(1,713) = 0.0172, p = .8958)\).

3.7 | Thresholds

The assessed pain thresholds and stimulation intensities for the whole sample can be found in Table 5.

4 | DISCUSSION

This study was designed to explore a presumed effect of somatosensory attention on visually induced analgesia.
TABLE 5 Pain thresholds and pain ratings

|                          | Back [M(SD)] | Thumb [M(SD)] |
|--------------------------|--------------|---------------|
| Level of electric stimulation in mA |              |               |
| Detection threshold      | 2.21 (0.91)  | 2.34 (1.27)   |
| Pain threshold           | 9.68 (8.37)  | 5.55 (3.05)   |
| Pain tolerance           | 19.98 (18.60)| 8.21 (4.94)   |
| Calculated stimulation intensity | 16.87 (15.32)| 7.41 (4.27)   |
| Adjusted stimulation intensity | 18.49 (16.40)| 7.33 (3.87)   |
| Ratings of the adjusted train of 10 test stimuli |              |               |
| Pain intensitya          | 6.73 (1.0)   | 6.98 (1.16)   |
| Pain unpleasantnessb     | 5.28 (3.41)  | 5.56 (3.37)   |

Abbreviations: *visual analogue scale: 0, ‘no pain’, 10, ‘strongest imaginable pain’; b visual analogue scale: 0 = ‘not unpleasant’, 10 = ‘very unpleasant’; M, mean; mA, milliampere; SD, standard deviation.

Participants received concurrent acute pain stimuli to their back and thumb while receiving real-time visual feedback of either their back or thumb and were asked to perform a somatosensory attention task directed at either their back or their thumb. Electrical stimuli to both body parts were rated on intensity and unpleasantness. In respect to these ratings, feedback and attention were either congruent (e.g. feedback on back, rating of back) or incongruent (e.g. attention on back, rating of thumb).

We did not find any significant effect for feedback: Participants ratings did not differ systematically between congruent and incongruent visual feedback. However, we found a significant main effect for attention: Focusing on the stimulated body part led to lower pain ratings for that body part than focusing on the non-stimulated body part.

4.1 Pain modulation by visual feedback

Previous studies have shown that visual feedback of the painfully stimulated body part reduces the perceived pain intensity of acute experimental pain in healthy participants when applied to the hand (Longo et al., 2009), and in CBP patients when applied to the back (Diers et al., 2013). Furthermore, it reduces the perceived motion-induced pain in chronic back pain (Wand et al., 2012) and in complex regional pain syndrome (Moseley et al., 2008) as well as habitual pain in chronic back pain (Diers et al., 2016). Additionally, it can enhance the effects of a massage (Löffler et al., 2017) or manual therapy (Beinert et al., 2019) in the treatment of chronic back pain patients.

Previous results suggest that the pain reducing effect of visual feedback is modulated via multisensory integration of incoming somatosensory and visual information. Visually induced analgesia may modulate the pain processing network located in posterior parietal brain areas that are responsible for the integration of multisensory aspects of the body (Longo et al., 2012). In this study, they report that this analgesic effect was accompanied by reduced activity in the ipsilateral primary somatosensory and contralateral operculo-insular cortex. Brain areas involved in the visual perception of the body increased the effective connectivity between posterior parietal areas and the secondary somatosensory cortex, anterior and posterior insula and anterior cingulate cortex (Longo et al., 2012).

However, there are also reports with conflicting results. Torta et al found no effect for visual feedback of the painful stimulated body part (Torta et al., 2015) for painful laser stimuli delivered to the hand. It is possible that different processes are behind the modulation of acute and chronic pain and that in chronic pain especially the induced or conditioned anxiety might be a target of pain modulation. Another study reported that a forced choice discrimination of medium and high heat pain stimuli to the hand led to more medium heat-pain stimuli being perceived as high during visual feedback of the hand compared to an object (Beck et al., 2016). Additionally, viewing an image of a needle pricking a hand on a screen over one’s own hand increases ratings of concurrently administered painful stimuli (Höflie et al., 2012). These results suggest that the analgesic effect might be rather small and context dependent.

4.2 Pain modulation by attention

Attentional modulation of nociceptive stimuli is an extensively researched form of cognitive-emotional pain modulation. Diverting attention away from the pain stimulus and focusing on something else can reduce pain (Van Damme et al., 2010). There is a plethora of studies investigating the neuronal effects of attentional modulation of pain processing. To investigate these effects, painful stimulation has been intermixed with stimuli from the same modality changing the spatial aspects of the pain stimulus (e.g. presented to different hands or fingers, e.g. Desmedt & Robertson, 1977; Hauck et al., 2007; Kida et al., 2004a) or stimuli of another sensory modality. In further studies, the participants were instructed to either attend to the painful stimuli by performing a task (e.g. rating the intensity of the painful stimuli (e.g. Dowman, 2004), counting all painful stimuli (e.g. Milten et al., 1989; Wang et al., 2004) or some of them, e.g. stimuli with a different intensity (e.g. Hauck et al., 2007; Kida et al., 2004a, 2004b), pressing a button for target stimuli (with a different intensity) (e.g. Kida et al., 2004b), or attend to them without instruction (e.g. Desmedt & Robertson, 1977; Yamasaki et al., 2000)) or distract their attention from the painful stimulation by performing a task on stimuli from
another modality (e.g. performing an oddball auditory task (García-Larrea et al., 1997), a memory test (Friederich et al., 2001), or a word puzzle (Miltner et al., 1989), reading a book (Kida et al., 2004b), conducting arithmetic calculations (Dowman, 2004; Yamasaki et al., 2000) or relaxing (Kida et al., 2004a)); for a more comprehensive review, see Legrain et al. (2012). In some studies, participants were simply asked to ignore the painful stimuli in the distraction condition without any other task (Wang et al., 2004).

At the neuronal level, the changes in pain intensity are accompanied by a reduction in peak amplitudes around 100 ms after stimulus onset in EEG (e.g. Desmedt & Robertson, 1977; García-Larrea et al., 1995; Kida et al., 2004a, 2004b; Michie, 1984) and MEG studies (Diers et al., 2020; Mauguire et al., 1997; Mima et al., 1998; Wang et al., 2004) or by activation in the insula, somatosensory cortices and anterior cingulate cortex in fMRI and PET studies (Bantick et al., 2002; Brooks et al., 2002, 2017; Frankenstein et al., 2001; Petrovic et al., 2000; Peyron et al., 1999; Villemure & Bushnell, 2009). The observation of attentional modulation of brain activity/activation in a network of cortical pain processing regions is compatible with the view that attentional modulation of nociceptive input is achieved via descending pathways (Torta et al., 2017).

4.3 Interaction of attention and visually induced analgesia

The first surprising finding in our study is that – contrary to most previous reports – somatosensory attention seems to reduce the perceived experimental pain in the respective body part: Congruent attention yielded significantly lower ratings than incongruent attention. This may be due to our particular paradigm: First, in our study, participants had to discriminate between all painful stimuli and count all deviant stimuli at one site (e.g. their back) while ignoring the stimuli at the other site (e.g. their thumb). Second, at the same time they received visual feedback, which in itself was either congruent or incongruent with the rating they were asked to give. In combination, this “attentional noise” was quite high, so that a fair amount of distraction was present in each of the conditions. However, one could also argue that these demands are much closer to real life than artificially creating full focus or full distraction, as in many previous studies.

Pain always occurs in a motivational context of goal pursuit. Pain as an evolutionarily acquired alarm signal of bodily threat will draw attention and interrupt ongoing goals. A bottom-up process by the attention system of unintentional pain selection might depend upon the interaction of pain-related (e.g. high/novel versus low/well known pain) and goal-related (e.g. highly interesting task/related to an important goal versus boring/irrelevant task) characteristics. In case the currently pursued goal also concerns pain, the processing of this goal might be accompanied by increased processing of pain and pain-related information, simultaneously inhibiting other information via top-down mechanisms (Van Damme et al., 2010). These findings might explain the evidence in our and other studies for no detectable effect, or the opposite effect of distraction from pain. A reason might be the experimental details of the design (time point of rating, instruction, etc.) or simply that the rating of the pain intensity may direct the attention back to the pain stimulus (Seminowicz & Davis, 2007).

4.4 Limitations

We did not publish a study protocol and analysis plan prior to commencement of the study, which is a practice now recommended (Lee et al., 2018) and would have brought transparency of the process. However, we reassure that the protocol of our study was followed as planned. We assessed the sensory and the affective dimension of pain separately as usually done and expected in experimental studies. However, a recent systematic review including 12 studies states that the sensory and the affective dimension of pain cannot be differentiated and might be even at best pointless and at worst fallacious (Talbot et al., 2019). Another limitation is that we investigated our research question in a young student population, which has implications for the generalization of our findings. However, this allows a comparison of our results to other published studies on visually induced analgesia in similar populations.

5 Conclusion

We found clear evidence that somatosensory attention can reduce perceived pain intensity in the presence of both congruent and incongruent visual feedback, but did not find any significant effect of visual feedback itself when an additional attentional task is also presented. In the light of previous reports on pain-reducing effects of visual feedback and pain-increasing effects of attention, our findings suggest a complex interplay between visual feedback and somatosensory attention, which should be taken into consideration in future studies.

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Author Contributions

M.D. and JT designed the research, L.C. and E.M.U. performed the research, L.C., E.M.U., J.T. and M.D. conducted statistical analysis, L.C., E.M.U., J.T. and M.D. interpreted
results, L.C., E.M.U., J.T. and M.D. wrote the article, L.C., E.M.U., S.H., W.Z., J.T. and M.D. discussed the results and commented on the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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