

1 *Research article*

2 Do tonic itch and pain stimuli draw attention towards their location?

3
4 Antoinette I.M. van Laarhoven*^{1,2,3}, Stefaan van Damme⁴, A. (Sjan) P.M. Lavrijsen⁵, Dimitri M. van Ryckegehém^{4,6},
5 Geert Crombez^{4,7}, Andrea W.M. Evers^{1,2,3}

6
7 ¹ *Health, Medical, and Neuropsychology Unit, Faculty of Social and behavioral sciences, Leiden University, Leiden,*
8 *the Netherlands*

9 ² *Leiden Institute for Brain and Cognition (LIBC), Leiden University, the Netherlands*

10 ³ *Department of Psychiatry, Leiden University Medical Center, Leiden, the Netherlands*

11 ⁴ *Department of Experimental-Clinical and Health Psychology, Ghent University, Belgium*

12 ⁵ *Department of Dermatology, Leiden University Medical Center, Leiden, the Netherlands*

13 ⁶ *University of Luxembourg, Faculty of Humanities and Social Sciences, Research Unit INSIDE, Institute of Health and*
14 *Behaviour*

15 ⁷ *Centre for Pain Research, University of Bath, United Kingdom*

16

17

18

19

20

21

22

23

24

25

26

27

28 *Correspondence to:*

29 A.I.M. van Laarhoven, PhD

30 Leiden University

31 Faculty of Social and behavioral sciences, Health, Medical, and Neuropsychology Unit,

32 PO Box 9555

33 2300 RB Leiden

34 The Netherlands

35 A.vanlaarhoven@fsw.leidenuniv.nl

36

37

1 **Abstract**

2

3 *Background:* Although itch and pain are distinct experiences, both are unpleasant, and may demand
4 attention and interfere with daily activities. Research investigating the role of attention in tonic itch and
5 pain stimuli, particularly ~~attentional~~ whether attention is drawn to at the stimulus location, is scarce.

6 *Methods:* In the somatosensory attention task, fifty-three healthy participants were exposed to 35-
7 seconds electrical itch or pain stimuli on either the left or right wrist. Participants responded as quickly as
8 possible to visual targets appearing at the stimulated location (ipsilateral trials) or at the arm without
9 stimulation (contralateral trials). During control blocks, participants performed the visual task without
10 stimulation. Attention allocation ~~at prioritization~~ at the itch ~~and~~ pain location is inferred when
11 responses are faster ipsilaterally than contralaterally.

12 *Results:* Results did not indicate that attention was directed towards or away from the itch and pain
13 location. Notwithstanding, participants were slower during itch and pain than during control blocks.

14 *Conclusions:* In contrast with our hypotheses, no indications were found for spatial attention allocation
15 towards the somatosensory stimuli ~~attention was not prioritized at the itch and pain location~~. This may
16 relate to dynamic shifts in attention over the time course of the tonic sensations. Our secondary finding
17 that itch and pain interfere with task performance is in line with attention theories of bodily perception.

18

19

20 *Key words:* pruritus, itch, pain, attention, attentional disengagement, perception

21

1. Introduction

Itch and pain are common somatosensory sensations, which, in acute form, function to protect body integrity, e.g., penetration of the skin or stinging insects [1]. When chronic, e.g., due to chronic inflammatory conditions of the skin, joints or viscera, they often have a serious impact on quality of life and performance in daily activities [2-4]. One of the primary reasons for this burden is that itch and pain demand attention in order to perform their protective role [1, 5-7]. For example, when we touch a sharp object or red ants crawl on our skin, fast detection and identification of the threat along with interruption from a concurrent task is adaptive as we can impose action to prevent bodily damage. The interplay between attention and pain has frequently been investigated. The interplay between attention and itch, however, has barely received attention.

Leading cognitive frameworks on pain, which might to some extent also apply for itch, propose that pain draws attention and as such interrupts ongoing task performance and goal pursuit [7-12]. Overall, studies indicate that patients with chronic pain attend more to pain related stimuli than control participants, and have difficulties disengaging their attention away from pain [5, 6]. Such impaired ability to disengage attention from pain or pain-related information is believed to detrimentally affect functioning in daily activities [5-7]. Pain interferes with task performance [13-19], probably by directing attention to the location where the pain is expected and/or experienced. More recently, studies have focused upon the spatial ~~prioritization of~~ attention allocation in pain [20-28]. It was found that attention was directed to the bodily location where threatening somatosensory stimuli were expected to occur [24-26]. It is reasonable to assume that individual differences in catastrophizing, worrying, and pain related fear amplify the threat value of somatosensory stimuli, and thus lead to a stronger prioritization of attention [5, 16, 29-33]. Also attempting to control pain, leads to a similar allocation ~~prioritization of~~ attention ~~towards~~ the location where somatosensory stimuli ~~are~~ expected to occur [22, 27]. A heightened level of attention for pain and its location may then intensify the pain sensation or its impact upon daily functioning. This prioritization of spatial attention is akin to an attentional bias (see [5]), and is assumed to worsen the pain sensation [5, 27]. These processes may also play a role in patients with chronic itch or pain [9, 10, 34, 35]. With regard to attention and itch, there are only some indications that itch-related information (e.g., words or pictures) draws attention [36-39] and that more bodily attention is related to heightened itch sensitivity [40]. However, research into spatial allocation of attention while experiencing itch is limited [39].

1
2
3 The investigation of spatial attention in pain and itch requires the use of specific paradigms. For
4 example, spatial attention allocation has been investigated while participants perceive somatosensory
5 pain stimuli on different locations while focusing on and responding to the location of
6 tactile/visual/auditory target stimuli that are ipsilateral or contralateral to the pain location (e.g., [20-
7 28]). ~~Prioritization of a~~Attention allocation to ~~at~~ the stimulation location is inferred when participants
8 respond faster to visual targets displayed ipsilaterally than on targets displayed contralaterally to
9 stimulation, as can be deduced from the attentional bias index (i.e. the difference in response time to
10 the contralateral minus the ipsilateral targets [21]). Enhanced focusing on the ipsilateral location is
11 indicative for an attentional engagement, whereas faster responses on the contralateral location are
12 indicative for disengagement of attention away from the stimulus, and when the attentional bias index
13 significantly deviates from zero, there is an attentional bias. It has generally been found that pain draws
14 attention towards its location, i.e. attentional engagement [20-28]. Most of these studies, with the
15 exception of [28], use phasic stimuli (≤ 1 s). However, patients often experience symptoms for a longer
16 duration, stressing the importance of being able to disengage attention from pain and focus on activities
17 in daily life. This is not only relevant for the study of pain, but also for itch, which is a sensation that is
18 often prolonged by attentional processes, given its contagiousness [41]. For itch, we developed a
19 somatosensory attention task (SAT) [39] with tonic itch stimuli of 35 s during which participants
20 responded as quickly as possible to visual targets located at the stimulated or non-stimulated location.
21 We did not find that healthy participants focused their attention towards the itch location, instead, we
22 found some indications that participants disengaged their attention away from the itch location during
23 the second half of the 35-s itch stimuli [39]. However, given the discrepancy with previous findings for
24 pain showing that pain draws attention to its location, additional research involving both tonic itch and
25 pain is required.

26 The aim of the present study was to investigate whether healthy participants focus their
27 attention at or away from the tonic itch and pain stimulus location. It was expected that the participants'
28 ~~would prioritize~~attention would be drawn atto the location of the itch and pain stimuli early on, but
29 later on during the stimulation, would disengage their attention from the stimulated location.
30 Additionally, the relationship between attentional processing of itch and pain and other psychological
31 characteristics, specifically self-reported catastrophizing, neuroticism, perceived threat of the

1 somatosensory stimuli, attention for bodily sensations, and attentional disengagement from itch and
2 pain was explored.

3
4

5 **2. Methods**

6

7 *Participants*

8 Fifty-three healthy volunteers (45 female/ 8 male; mean age of 22.0 years, SD = 2.2; range 18.6–29.4
9 years) were included. Participants were recruited through advertisements at Leiden University and the
10 Leiden University Research Participation system (SONA systems Ltd, Tallinn, Estonia). Inclusion criteria
11 for participation were being aged between 18 and 30 years (with the intention to include a homogenous
12 group since reaction times increase with age [42]) and fluent in Dutch language. Exclusion criteria for
13 participation were being a patient with chronic itch or pain, severe morbidity (e.g., multiple sclerosis,
14 diabetes mellitus, heart or lung disease, vasculitis), psychiatric disorders (e.g., depression), use of
15 pacemaker, current use of medication (e.g., analgesics, antihistaminics), and pregnancy. Of the
16 participants, 73.6% was following or had finished tertiary education, 24.5% was following or had finished
17 secondary education, and 1.9% had followed primary education. The protocol was approved by the local
18 Medical Review Ethics Committee and all participants provided written informed consent prior to
19 testing.

20

21 *Itch and pain induction*

22 Itch and pain were induced electrically by means of a constant current stimulator (Isolated Bipolar
23 Constant Current Stimulator DS5, Digitimer, United Kingdom) [38, 43]. For itch induction, two surface
24 electrodes were attached to the center of the lateral side of the wrist, a disk electrode (\varnothing 1 cm, VCM
25 Medical, the Netherlands) 1.5 cm proximal to the triquetrum, and a reference electrode (\varnothing 2 cm, VCM
26 Medical, the Netherlands) 2 cm proximal [38, 43]. For pain induction, two surface electrodes (two disk
27 electrodes of \varnothing 1 cm, VCM Medical, the Netherlands) were attached at the center of the dorsal side of
28 the wrist [21], one 1.5 cm proximal to the processus styloides ulnae, the other 2 cm proximal. In
29 accordance with our previous studies with electrically induced itch [38, 43], the stimulus characteristics
30 for the itch stimuli were 50 Hz frequency, 0.1 ms pulse duration, and a ramping of 0.05 mA/s. The itch
31 stimuli lasted for at maximum 35 seconds, the duration of the stimuli in the SAT. For pain, the stimulus
32 characteristics were partly based on previous studies (e.g., [25, 44]) and partly determined by extensive

1 piloting of the methods since electrical pain stimuli are not regularly applied for 35 seconds. Eventually,
2 pain stimuli were applied also at 50 Hz frequency and 0.4 ms pulse duration. Alike our previous studies
3 [38, 43], the maximum current for all stimuli was 5.00 mA. The levels of itch and pain evoked by each
4 electrical stimulus were scored on a numerical rating scale (NRS) ranging from 0 (no itch/pain) to 10
5 (worst itch/pain ever experienced).

6
7 *Determination of the intensity of the itch stimuli:* In order to determine the individual intensity at
8 which the 35-s baseline itch stimulus and the itch stimuli during the SAT were delivered, a step-up
9 procedure was executed with 35s stimuli starting at 0.25 mA, with 0.50 mA increments for every step.
10 For example, the first stimulus started at 0.25 mA and, as a consequence of the ramping, ended at 2.00
11 mA, the second started at 0.75 mA and ended at 2.50 mA. Because the first step ended relatively high,
12 just before the itch step-up, familiarization with the stimulation took place by assessing two perception
13 thresholds starting at 0.01 mA and ending when the participant reported “the moment that you
14 experience a sensation for the first time” [43]. The step-up procedure finished when the aimed NRS itch
15 was at least 5 or the maximum defined current intensity of 5.00 mA was reached (i.e. stimulus from 3.25
16 to 5.00 mA). However, in the case the NRS itch exceeded 7, the current intensity was decreased with 0.5
17 mA (when NRS itch ≥ 8) or 0.25 mA (when NRS itch ≥ 7) up until the NRS itch was between 5 and 7. In
18 this study, the determined starting current intensity for the baseline and SAT itch stimuli was on average
19 2.36 (SD=1.26) mA.

20
21 *Determination of the intensity of the pain stimuli:* In order to determine the individual intensity
22 at which the 35-s baseline pain stimulus and the pain stimuli during the SAT were delivered, a step-up
23 procedure was executed with 10s stimuli (in order to keep stimulation time better comparable to the
24 itch step-up procedure which consisted of less steps) that increased by 0.50 mA per step. The first
25 stimulus was given at 0.50 mA, the second at 1.00 mA, etc. The step-up procedure finished when the
26 aimed NRS pain was at least 5 or the maximum defined current intensity of 5.00 mA was reached.
27 However, in the case the NRS pain exceeded 7, the current intensity was decreased with 0.5 mA (when
28 NRS pain ≥ 8) or 0.25 mA (when NRS pain ≥ 7) up until the NRS pain was between 5 and 7. In this study,
29 the determined current intensity for the 35-s baseline pain stimulus before the SAT and the pain stimuli
30 during the SAT was on average 3.70 (SD=1.59) mA.

31
32 *Somatosensory attention task*

1 The somatosensory attention task (SAT) as used in our previous study [39], which was based on an
2 attention task developed for pain [21], was adopted to investigate attention ~~allocation at prioritization at~~
3 ~~towards~~ both an itch and pain stimulation ~~and their~~ location (see Fig. 1 for a schematic representation of
4 the setup). A plastic black curved screen of ca. 50 cm height with 3 LED lights at 10 cm height (middle
5 green fixation LED, the left and right were red target LEDs placed at 25 degrees from the middle LED) was
6 placed in front of the participant. The LEDs were controlled using E-prime software version 2.0
7 (Psychology Software Tools Inc., Sharpsburg, PA, USA) on a Dell optiplex 3010 computer with Philips
8 Brilliance 225 TFT screen (Resolution 1280x1024 at 60 Hz). Right below the left and right LED there was a
9 platform with finger response buttons (Pushbutton Switch, SPDT, Off-(On)) at a fixed position, attached
10 to a serial response box (Psychology Software Tools Inc. Sharpsburg, PA, USA).

11 The SAT consisted of 12 blocks of 35 seconds each, of which 4 blocks with pain stimuli (pain
12 blocks), 4 blocks with itch stimuli (itch blocks), and 4 blocks without somatosensory stimulation (control
13 blocks). The order of blocks was randomized by E-Prime for each participant. The standard interval
14 between two blocks was 1 minute, which was extended by 1 minute up to a maximum of 5 minutes in
15 the case the NRS pain or NRS itch exceeded 2.0. During each block 10 trials with visual targets were
16 administered, in which first the fixation light (green LED light) was turned on for 1000 ms, extinguished,
17 and then either the left or right target (red LED light) was turned on for 200 ms [39], while unilaterally
18 administering itch (itch blocks), pain (pain blocks) or no stimulation (control blocks). The response
19 window for participants to press a button was 1500 ms. The 10 target stimuli in each block were given in
20 random order with random time interval (varying between 0 and 2000 ms) before the next trial. Half of
21 the visual targets were presented at wrist where the electrodes were attached and itch or pain was
22 applied in the case of itch and pain block respectively (“ipsilateral trials”) and half of the visual targets
23 were presented oppositely (“contralateral trials”). Conform previous research (e.g., [21]), the difference
24 in participants’ responding to ipsilateral versus contralateral trials is a measure of spatial attention
25 allocation towards the somatosensory stimuli, with faster responses to ipsilateral trials being indicative
26 for an attentional bias.

27

28 <DISPLAY FIG. 1 ABOUT HERE>

29

30 *Self-report questionnaires*

31 The following self-report questionnaires were administered in Dutch using the online system Qualtrics
32 (Provo, Utah, USA).

1 The *presence of physical symptoms* was assessed by visual analogue scales (VAS) for itch and pain
2 from the Impact of chronic skin disease on daily life (ISDL) [45], inquiring about the levels of itch and pain
3 during the past two weeks on a scale from 0 (no itch/pain) to 10 (worst itch/pain experienced).

4 *Psychological distress* was measured with the *Hospital Anxiety and Depression Scale (HADS)* [46]
5 and a short version of the *Positive and Negative Affect Schedule (PANAS)* [47]. The HADS consists of 7
6 items measuring the subscale depression (Cronbach alpha 0.67) and 7 items measuring the subscale
7 anxiety (Cronbach alpha 0.71), scored on a scale from 0 to 3. The total score was obtained by summing
8 the items per subscale. The PANAS consists of 5 positive items (PANAS-PA; Cronbach alpha 0.59) and 5
9 negative items (PANAS-NA; Cronbach alpha 0.35) scored on a 5-point Likert scale from 1 to 5. Due to the
10 low reliability, the PANAS was excluded from data analyses.

11 *Catastrophizing* about physical sensations was measured using the *Pain Catastrophizing Scale*
12 [48], adjusted for physical sensations (PCS-A) in order to make it also applicable to itch (i.e. by
13 substituting the word “pain” for “physical sensations” for all concerning items). The questionnaire
14 contained 13 items, which were scored on a 5-point Likert scale from 0 to 4. The Cronbach alpha for the
15 PCS-A in the present study was 0.87.

16 *Neuroticism* was measured with the *Eysenck Personality Questionnaire revised short scale (EPQ-*
17 *RSS)* [49], consisting of different subscales, including the subscale neuroticism (Cronbach alpha=0.72),
18 which consists of 12 items rated on a dichotomous scale (yes = 1 /no = 0).

19 *Fear of pain* was measured using the *Fear of Pain Questionnaire III (FPQ-III)* [50], with 30 items
20 assessing the degree of fear participants would likely experience in potentially painful situations,
21 subdivided in the categories severe pain, minor pain, and medical pain. The items are rated on a 5-point
22 scale from 1 (not at all fearful of this pain) to 5 (extremely fearful of this pain). Cronbach alpha of the
23 FPQ-III in the present study was 0.90.

24 *Attentional focus on bodily sensations* was measured using the *Body Vigilance Scale (BVS)* [40,
25 51], the *Body Sensations questionnaire* [40, 52], and the *Pain Vigilance and Awareness Questionnaire*
26 [53] adjusted for physical sensations (i.e. by substituting the word “pain” by “physical sensations” for all
27 concerning items) (*PVAQ-A*) in order to make it broadly applicable to physical sensations, including itch
28 and pain. The BVS, used to measure attentional focus on bodily sensations, contained 4 items, of which
29 the fourth item consisted of 13 sub-items about anxiety-related bodily sensations. All items were rated
30 on a VAS from 0 to 10. Cronbach alpha of the BVS in the present study was 0.79. Additionally, two items
31 had been added that assess one’s attention directed towards itch and pain. Of the BSQ, the 15 items
32 concerning bodily sensations (omitting the 2 items concerning derealization) were used to measure of

1 attentional focus on the occurrence of bodily sensations when in a nervous or feared situation (e.g.,
2 heart palpitations, dizziness or sweating). Participants used a 5-point Likert scale that ranged from “the
3 sensation never occurs” (0) to “the sensation occurs almost always or always” (4). Cronbach alpha of the
4 BSQ in the present study was 0.79. The PVAQ-A was used to measure attention to bodily sensations by
5 asking subjects to consider their behavior in relation to physical sensations. The PVAQ-A (Cronbach alpha
6 0.85) consisted of 16 items, e.g., ‘I focus on physical sensations’. Items were scored on a 6-point Likert
7 scale (0 never to 5 always).

8 *Attentional disengagement from itch and pain* was assessed using two Likert scales ranging from
9 1 (not at all able to disengage attention) to 5 (always able to disengage attention).

10
11 In addition to these online questionnaires, participants indicated the perceived threat of the stimuli
12 experienced used in the experiment on a scale from 0 (not threatening) to 10 (very threatening).
13 Participants also rated the extent to which they were distracted by the itch or pain stimuli or other
14 factors during their responses to the visual targets in the SAT on 5-point Likert scales ranging from 1 (not
15 at all distracted) to 5 (distracted to very large extent).

16
17 *Procedure*
18 Potential participants were informed about the study via written information. When interested in
19 participation, they clicked on a link to fill out the questions concerning demographic variables, absence
20 or presence of medical or psychiatric conditions, intake of medication during the past 4 weeks, and
21 above-mentioned questionnaires: VAS for itch and pain, HADS, PANAS, PCS-A, EPQ-RSS, FPQ-III, BSQ,
22 PVAQ-A, and attentional disengagement from itch and pain. Based on the online assessment, eligibility
23 screening was performed on in- and exclusion criteria. Uncertainties about eligibility were solved by
24 telephone contact. Eligible participants made an appointment for participation. Participants were
25 instructed to refrain from intake of alcohol and drugs 24 hours before attending the experiment. Upon
26 arrival at the test facility, participants were verbally informed about the procedure and told that they
27 were free to terminate the experiment at any time. Then participants signed the informed consent. In
28 the lab, subjects also rated their current levels of spontaneous itch and pain on an NRS ranging from 0
29 (no itch/ pain) to 10 (worst itch/pain ever experienced) and filled out the BVS and PANAS.

30
31 In order to standardize the participants’ wrist temperature, which could influence electrical conductivity
32 [54], subjects held their wrists for 3 minutes in a warm water bath made at 34°C [see also [38, 43],

1 before the electrical stimulation. The side of itch and pain stimulation (left and right wrist or vice versa)
2 was randomized across participants. Then, the step-up procedures for itch and pain were carried out in
3 random order to determine the individual intensity of the itch and pain stimuli. At the individually
4 determined intensity, baseline itch and pain stimuli were applied for 35 seconds. Right before the SAT,
5 participants were asked to position their index fingers of the left and right hand on the left and right
6 response button, respectively. They were instructed to focus on the visual stimuli and to respond as
7 quickly as possible to the location of a target LED illuminating, by pressing the response button at the
8 ipsilateral side. Before each block, participants were informed whether they would receive a pain
9 stimulus (i.e., pain block), an itch stimulus (i.e., itch block), or no stimulus at all (i.e., control block). At the
10 start of each block, the experimenter counted down from 3 to 0, to indicate the onset (at 0) of a block.
11 Directly following each block, participants were asked to retrospectively report the levels of itch and pain
12 that were evoked (irrespective of any ongoing spontaneous itch or pain) during the block on NRSs
13 ranging from 0 (no itch/pain) to 10 (worst itch/pain ever experienced). After all measurements,
14 participants indicated the perceived threat of the itch and pain stimuli and the extent to which they were
15 distracted during their task performance to respond to the visual targets. After a short debriefing,
16 participants received a monetary reimbursement.

17

18 *Statistical analyses*

19 Reaction times (RT) for trials with $RT \geq 150$ ms (0.2% of the RT were excluded) and trials with correct
20 responses (0.6% of the RT were excluded) were extracted from E-prime. Data of two participants were
21 excluded [fire alarm evacuation ($n=1$), problems with itch stimulation ($n=1$)] because $\leq 70\%$ of the RT data
22 was available [39]. Using Matlab and Statistics Toolbox Release 2012b (The MathWorks, Inc., Natick,
23 Massachusetts, United States) the mean RT per trial type (ipsilateral and contralateral trials during pain,
24 itch, and control blocks) were calculated per participant. Accuracy for the SAT was checked, and none of
25 the participants had to be removed based on the criterion of $> 30\%$ mistakes [39]. Additionally, RT per
26 trial type were calculated for three consecutive time segments of the 35-s SAT blocks. Three was the
27 maximum number of segments the blocks could be split into to remain sufficient observations per trial
28 type.

29

30 All variables to be included in the statistical analyses were checked for normal distribution and
31 transformed when necessary. Transformation did not result in normal distribution of the NRS itch and
32 pain scores during the control blocks and assumptions for the majority of psychological characteristics

1 were not met. In addition, there were two participants displaying outlying RT (i.e. >3 SD of the overall
2 mean) for the majority of the trial types. Therefore, the analyses were conducted both in all 51
3 participants, and after excluding the two outliers (n=49) combined with log-transformed variables.

4
5 A manipulation check, to confirm that the intended sensations had been induced in the respective
6 blocks, was conducted comparing the NRS itch and pain scores for the itch and pain blocks, respectively,
7 to the control blocks using non-parametric Sign tests. Similarly, NRS unpleasantness ratings were
8 exploratorily compared across the different block types. An attentional bias index (AB-index) was
9 calculated for itch and pain [21] using the formula $RT_{\text{contralateral}} - RT_{\text{ipsilateral}}$, during itch and pain blocks,
10 respectively. A positive AB-index indicated that attention was directed ipsilaterally to the stimulus
11 location (attentional ~~dis~~engagement), while a negative AB-index indicated that attention was directed
12 contralaterally to the stimulus location (attentional disengagement). One-samples t-tests were
13 conducted to assess whether the AB-indices significantly differed from zero, i.e. implying attentional
14 bias. In order to test the main hypothesis of whether participants focused attention on the itch and pain
15 location, two repeated measures analyses of variance (RM-ANOVAs) were carried out with the within-
16 subjects factors location (ipsilateral vs. contralateral) and block type (either itch or pain vs. control).
17 Separate analyses for itch and pain were required because location in the control blocks referred to the
18 location of the attached itch and pain electrodes, which were oppositely attached, and, consequently,
19 for control blocks, the ipsilateral location was indecisive. Main effects of location and block type were
20 calculated, as well as location x block type interactions. Exploratorily, a similar RM-ANOVA was
21 conducted to compare the RT for the itch versus pain blocks (control blocks were not included). In order
22 to investigate the course of attention allocation over time, 2x2x3 RM-ANOVAs were conducted, for itch
23 and pain separately, with the within-subjects factors location (ipsilateral vs. contralateral), block type
24 (either itch or pain vs. control) and time (first segment, second, and third time segment of blocks). Main
25 effect of time and location x block type x time interactions were calculated. For all RM-ANOVAs, a
26 generalized eta squared was calculated [55, 56].

27
28 Finally, Pearson correlation coefficients were calculated between the AB-indices for itch and pain. Non-
29 parametric correlation coefficients (Spearman) were calculated between the psychological
30 characteristics (EPQ-RSS-n, BVS, BSQ-f, PVAQ-A, PCS-A, FPQ-III, attentional focus on and disengagement
31 from itch and pain, and perceived threat of the stimuli) and itch and pain AB-indices [21].

32

1 Statistical analyses were conducted using SPSS 23.0 software (IBM SPSS Statistics for Windows, Armonk,
2 NY, USA). All values displayed are means \pm SD, unless stated otherwise. A $p < 0.05$ was considered
3 statistically significant.

4
5

6 **3. Results**

7
8

Participants

9 The baseline levels of itch, pain and fatigue and outcomes of self-report questionnaires measuring the
10 psychological characteristics of the 53 participants included are displayed in Table 1. The reasons for
11 baseline spontaneous itch levels >0 ($n=10$ in total, $M_{\text{NRS-itch}>0} = 1.1 \pm 0.5$, ranging from 0.5 to 2.0) were
12 talking/thinking about itch as a result of this specific question ($n=5$), dry skin ($n=2$), sweating due to
13 traveling ($n=1$), epilated armpit ($n=1$), some skin irritation ($n=1$). The reasons for baseline spontaneous
14 pain levels >0 ($n=8$ in total; $M_{\text{NRS-pain}>0} = 1.1 \pm 0.5$, ranging from 0.3 to 2.0) were sore throat ($n=2$), muscle
15 ache ($n=2$), back ache ($n=1$), knee pain resulting from surgery some weeks ago ($n=1$), menstruation pain
16 ($n=1$), and finger cut ($n=1$).

17

18 <DISPLAY TABLE 1 ABOUT HERE>

19

Manipulation check: induced itch and pain

21 The itch, pain, and unpleasantness scores for the baseline itch and pain stimuli and those during the SAT
22 blocks are displayed in Table 2. Non-parametric Sign tests showed that median NRS itch scores were
23 significantly higher during itch than control blocks of the SAT and median NRS pain scores were
24 significantly higher during pain than control blocks (both $p < 0.0001$). Median NRS unpleasantness scores
25 were significantly higher during itch and pain blocks than during control blocks (both $p < 0.0001$) and also
26 significantly higher during pain blocks than during itch blocks ($p < 0.0001$).

27

Perceived threat of the stimuli

29 The induced pain and itch were, on average, perceived as 2.8 ± 2.4 and 1.5 ± 1.8 threatening,
30 respectively. With regard to the degree to which participants were distracted from the task to respond
31 to the visual targets, they indicated to be distracted by the itch and pain stimuli on average 3.2 ± 1.0 and
32 2.5 ± 1.1 respectively and 1.8 ± 0.6 by other factors.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31

<DISPLAY TABLE 2 ABOUT HERE>

Behavioral outcomes

With regard to the accuracy, the average number of mistakes made during the SAT over all participants was 0.6 ± 1.3 (range 0 to 8; theoretical maximum 120), with overall 0.5% mistakes during itch blocks, 0.4% mistakes during pain blocks, and 0.6% mistakes during control blocks. The mean RTs during itch, pain, and control blocks for the ipsilateral and contralateral trials are displayed in Table 3.

<DISPLAY TABLE 3 ABOUT HERE>

Of primary interest to this study was the location x block type interaction effect as this indicated whether attention was ~~prioritized~~drawn to the stimulus location. For itch, the RM-ANOVA comparing the ipsilateral and contralateral trials (factor 1: location) during the itch and control blocks (factor 2 block type) did not show a significant location x block type interaction effect ($F(1,50)=0.78$, $p=0.38$, $\eta_G^2=0.0014$). There was, however, a significant main effect of block type ($F(1,50)=12.80$, $p< 0.001$, $\eta_G^2=0.019$), with longer RT for itch blocks than control blocks. The main effect of location was not significant ($F(1,50)=0.13$, $p=0.72$, $\eta_G^2=0.0003$). For pain, the RM-ANOVA did not show a significant interaction effect of location x block type ($F(1,50)=0.71$, $p=0.41$, $\eta_G^2=0.00012$). Again, there was a significant main effect of block type ($F(1,50)=21.29$, $p< 0.0001$, $\eta_G^2=0.05$), with longer RT for pain blocks than for control blocks, but no significant main effect of location ($F(1,50)=0.16$, $p=0.69$, $\eta_G^2=0.00032$). After removing the two outliers, similar levels of significance were obtained. In line with the main findings of the non-significant location x block type interaction, no significant attentional biases were found as the AB-indices for itch ($t(50) = -0.51$, $p=0.61$) and pain ($t(50) = 0.18$, $p=0.86$) did not significantly differ from zero.

Explorative comparison of the itch and pain blocks showed no significant interaction effect of location x block type ($F(1,50)=0.13$, $p=0.72$, $\eta_G^2=0.00036$), nor a significant main effect of location ($F(1,50)=0.004$, $p=0.952$, $\eta_G^2=0.00001$), but the overall RT were significantly longer for the pain than for the itch blocks ($F(1,50)=5.26$, $p=0.026$, $\eta_G^2=0.0109$).

1 *Time course of attention during the SAT*

2 In a further analysis of the data, Fig. 2 displays the RT for the ipsilateral and contralateral trials during the
3 itch (Fig 2A), pain (Fig 2B) and control (Fig. 2C) blocks, which are subdivided into three equal time
4 segments. For itch, there was no significant location x block type x time interaction ($F(2,100) = 2.01$,
5 $p=0.140$, $\eta_G^2 = 0.0068$), but a significant main effect of time ($F(2,100) = 3.77$, $p=0.026$, $\eta_G^2 = 0.015$)
6 emerged. Simple contrast analyses showed that RT were significantly faster in the second than in the
7 first segment ($F(1,50) = 6.73$, $p=0.012$, $\eta_G^2 = 0.006$). There were no significant differences in RT when
8 comparing the second with the third segment, although a non-significant trend was observed ($F(1,50)$
9 $= 4.03$, $p=0.050$, $\eta_G^2 = 0.038$), or when comparing the first and the third segment ($F(1,50) = 0.48$, $p=0.494$,
10 $\eta_G^2 = 0.0094$). For pain, there was no significant location x block type x time interaction ($F(2,100) = 0.41$,
11 $p=0.662$, $\eta_G^2 = 0.0012$), nor a significant main effect of time, although a trend was observed ($F(2,100) =$
12 2.99 , $p=0.055$, $\eta_G^2 = 0.012$).

13

14 <DISPLAY FIG. 2 ABOUT HERE>

15

16 After removing the two outliers, similar results were obtained in the 2x2x3 RM-ANOVA for itch. For pain
17 results were also comparable after removing the two outliers, although now a significant main effect of
18 time ($F(2,96) = 3.17$, $p=0.047$, $\eta_G^2 = 0.015$) was found. Simple contrast analyses showed significantly faster
19 RT in the second than in the first segment ($F(1,48) = 7.30$, $p=0.010$, $\eta_G^2 = 0.026$), but no significant
20 differences in the second compared to the third segment ($F(1,48) = 1.43$, $p=0.237$, $\eta_G^2 = 0.011$) nor in the
21 first compared to the third segment ($F(1,48) = 1.54$, $p=0.221$, $\eta_G^2 = 0.019$).

22

23 *Exploratory analyses: Association between individual characteristics and attentional bias towards itch*
24 *and pain*

25 The AB-index for itch was on average -2.9 ± 39.9 and ranged from -80.1 to 90.2 ; 39.2% of the participants
26 displayed a positive AB-index (i.e. towards the itch stimulus location). The AB-index for pain was on average
27 1.0 ± 41.0 and ranged from -79.5 to 86.5 ; 54.9% of the participants displayed a positive AB-index (i.e.
28 towards the pain stimulus location). The AB-indices for itch and pain were not significantly correlated ($R =$
29 -0.252 , $p=0.074$). The AB indices were generally not significantly correlated with the psychological
30 characteristics neuroticism (EPQ-RSS), catastrophizing of physical sensations (PCS-A), fear of pain (FPQIII),
31 self-reported attention to itch and pain and to bodily sensations in general (BVS, BSQ-f, PVAQ-A),
32 attentional disengagement from itch and pain, and the perceived threat of the itch and pain stimuli. Only

1 four significant correlations were observed. There were positive associations between the AB-index for itch
2 on the one hand and catastrophizing ($r_s = 0.40$, $p=0.003$), neuroticism (EPQ-RSS-n) ($r_s = 0.37$, $p = 0.008$), and
3 the threat value of the itch stimulus ($r_s = 0.29$, $p=0.04$) on the other hand. There was a negative association
4 between the AB-index for pain the threat value of the pain stimulus ($r_s = -0.30$, $p= 0.03$).

5
6

7 **4. Discussion**

8

9 The present study investigated whether attention of healthy volunteers would be spatially drawn
10 ~~prioritized to the spatial~~to the stimulus location ~~of stimulation~~ early on during tonic itch and pain stimuli,
11 and, whether they would disengage their attention away from the stimulated location later on during
12 stimulation. In the somatosensory attention task, participants received tonic somatosensory itch or pain
13 stimuli, or no stimulation while responding to the location of visual targets, either ipsi- or contralaterally
14 displayed to the somatosensory location. In contrast with our ideas, no significant differences were
15 found between responding to visual targets ipsilaterally compared to contralaterally to the stimulation,
16 neither over the total duration of stimulation nor across the three successive time segments during the
17 tonic itch and pain stimuli. Of further note, we observed that itch and pain stimulation slowed down
18 participants' task performance (i.e. responding to visual targets) compared to no stimulation, indicating
19 towards attentional interference by itch and pain. Overall, these results seem to indicate that itch and
20 pain affect attentional processes, but that attention is not systematically directed towards nor
21 disengaged from the location of tonic itch and pain stimulation.

22

23 There were no indications that attention was directed away from or towards the location of the itch and
24 pain stimulation: reaction times for ipsilateral and contralateral trials did not significantly differ, nor was
25 there a significant difference in spatial attention allocation between itch and pain. The indications for an
26 attentional disengagement effect during the last part of the 35 s itch stimulation in our previous study
27 [39] could not be confirmed here. In addition, we were also not able to replicate previous findings that
28 pain directs attention towards its spatial location [20-28]. However, most of these studies used phasic
29 pain stimuli with each trial consisting of one pain stimulus and one target stimulus [20-27] or pain stimuli
30 of maximally 10 seconds [28]. It could be that the 35 s somatosensory stimuli in the present study along
31 with multiple trials of visual targets during that stimulus may not draw attention to the stimulus location
32 for the entire time frame. Attention likely continuously shifted between the somatosensory stimuli and

1 visual targets. This process may have been enhanced because the participants were aware that the visual
2 targets could be displayed ipsilateral or contralateral to the stimulation and the central fixation light
3 before each trial could have influenced attention allocation. Moreover, the intensity of the itch and pain
4 stimuli as well as the threatening character of the stimuli was relatively mild, and therefore the stimulus
5 saliency may have been limited. Generally, in the present and the previous study there was a time effect
6 showing that participants responded faster after the first segment. This may be owing to a learning
7 effect as the participants learned to respond faster to the visual targets, leaving less attention to focus
8 on the itch and pain sensations. This effect was, however, irrespective of the spatial location of the
9 somatosensory stimuli. It could be that somatosensory stimuli only draw attention to the spatial location
10 in the very beginning, but clearly still result in attentional interference. The current segmentation of
11 three time segments might not be sufficiently fine-grained to determine continuous attentional shifts.

12
13 Of further note, our study did show that participants were generally slower in task performance of
14 responding to the targets during itch and pain, which is indicative for attentional interference by itch and
15 pain. That pain interferes with attention previously been demonstrated [13-19] although most studies
16 used stimuli with a duration shorter than 35 s. Surprisingly, in our previous study with itch stimuli similar
17 to those in the present study we did not find such an interference effect [39]. Exploratory findings
18 indicate that pain may interfere more in attentional processing than itch, as overall reaction times (i.e.
19 independent of stimulus location) were slower during pain than during itch. Explanations for this may
20 include that pain is evolutionarily more aversive, as indicated by the higher reported threat value and
21 unpleasantness of the pain stimuli presented here, and consequently, a higher saliency [10, 12].
22 However, it could also be related to the lower levels of evoked itch than pain. Reversely, participants
23 may have better been able to ignore the itch and therefore perceived itch less intense during the
24 attention task, akin previous findings showing that focusing away from pain can result in less intense
25 pain [28, 57]. Support for this explanation comes from the large decline in itch when comparing the itch
26 stimuli, at the same intensity, given at baseline and during the attention task. Another possible
27 explanation could be that people habituate more easily to itch than to pain, but this has, to our
28 knowledge, not yet been investigated.

29 Of the psychological characteristics the individual level of catastrophizing of physical sensations and
30 neuroticism were related to a higher attentional bias index for itch. However, given the non-significant
31 association between catastrophizing and the attentional bias index for pain, these findings should be
32 interpreted with caution. There were also some indications that higher perceived threat of the itch

1 stimulus was related to a higher attentional bias index for itch, but higher perceived threat of the pain
2 stimulus was associated with a lower attentional bias index for pain, which is contrary to what would be
3 expected. Other psychological characteristics, including fear of pain, self-reported attention to and
4 disengagement from physical sensations and itch and pain in particular, did not play a role in attention
5 allocation towards the itch and pain stimuli. Future research should further investigate the role of
6 individual characteristics in spatial attention allocation towards itch and pain.
7 This study has several limitations. First, the levels of itch induced during the attention task were
8 relatively low and not directly comparable to pain. Second, after each block in the SAT, participants
9 retrospectively rated the intensity of itch and pain during the somatosensory stimulation. It cannot be
10 ruled out that participants also intentionally focused on the stimulation while responding to the visual
11 targets. Third, the current design did not allow the investigation of fast attentional switches between
12 somatosensory and visual stimuli. Future research may use more fine-grained time segments. Fourth,
13 the included group was homogenous with respect to age, but has the disadvantage that extrapolation to
14 other age groups is limited.

15
16

17 **5. Conclusions**

18

19 This study showed that, although tonic itch and pain stimuli interfere with task performance, ~~these do~~
20 ~~not prioritize~~ attention is not consistently drawn towards their spatial location, probably because
21 attention shifts over the time course of tonic stimuli. Additional research focusing more closely on time
22 aspects of attention allocation is required to elucidate how tonic itch and pain stimuli are being
23 processed in healthy participants and in clinical populations. When focusing attention on the location of
24 itch or pain aggravates symptoms, patients with chronic itch and pain may benefit from learning to
25 disengage their attention away from itch or pain, respectively.

26
27

28 **Conflicts of interest**

29 The authors declare that there is no conflict of interest regarding the publication of this article.

30
31

32 **Acknowledgements**

1 The authors would like to thank Maureen Meekel for technical support and programming of the
2 attention task, Vico Beerepoot for technical support with the electrical stimulator. Rik Schalbroeck,
3 Marije Bakker, Sarah van Biert, Kimberley van Donk, Lindsey de Pundert, Elvan Kaya, Joyce Snijdwint,
4 and Ilona Tresfon are acknowledged for their help with participant recruitment and/ or testing.
5 This research is supported by an Innovation Scheme (Veni) Grant (451-15-019) of the Netherlands
6 Organization for Scientific Research (NWO), granted to A.I.M. van Laarhoven, and an ERC Consolidator
7 Grant (617700) from the European Research Council (ERC), granted to A.W.M. Evers.

8
9

10 **References**

- 11 1. A. Ikoma, M. Steinhoff, S. Stander, G. Yosipovitch and M. Schmelz, "The neurobiology of itch," *Nature*
12 *Reviews Neuroscience*, vol. 7, no. 7, pp. 535-547, 2006.
- 13 2. H. Breivik, B. Collett, V. Ventafridda, R. Cohen and D. Gallacher, "Survey of chronic pain in Europe:
14 prevalence, impact on daily life, and treatment," *European Journal of Pain*, vol. 10, no. 4, pp. 287-333,
15 2006.
- 16 3. U. Mattered, C. J. Apfelbacher, A. Loerbroks, T. Schwarzer, M. Buttner, R. Ofenloch, T. L. Diepgen and
17 E. Weisshaar, "Prevalence, correlates and characteristics of chronic pruritus: a population-based
18 cross-sectional study," *Acta Dermato-Venereologica*, vol. 91, no. 6, pp. 674-679, 2011.
- 19 4. S. P. Kini, L. K. DeLong, E. Veleidar, A. M. McKenzie-Brown, M. Schaufele and S. C. Chen, "The impact of
20 pruritus on quality of life: the skin equivalent of pain," *Archives of Dermatology*, vol. 147, no. 10, pp.
21 1153-1156, 2011.
- 22 5. G. Crombez, D. M. Van Ryckeghem, C. Eccleston and S. Van Damme, "Attentional bias to pain-related
23 information: a meta-analysis," *Pain*, vol. 154, no. 4, pp. 497-510, 2013.
- 24 6. D. E. Schoth, V. D. Nunes and C. Lioffi, "Attentional bias towards pain-related information in chronic
25 pain; a meta-analysis of visual-probe investigations," *Clinical Psychology Review*, vol. 32, no. 1, pp. 13-
26 25, 2012.
- 27 7. S. Van Damme, V. Legrain, J. Vogt and G. Crombez, "Keeping pain in mind: a motivational account of
28 attention to pain," *Neuroscience & Biobehavioral Reviews*, vol. 34, no. 2, pp. 204-213, 2010.
- 29 8. G. Crombez, C. Eccleston, S. Van Damme, J. W. Vlaeyen and P. Karoly, "Fear-avoidance model of
30 chronic pain: the next generation," *Clinical Journal of Pain*, vol. 28, no. 6, pp. 475-483, 2012.
- 31 9. M. Leeuw, M. E. Goossens, S. J. Linton, G. Crombez, K. Boersma and J. W. Vlaeyen, "The fear-
32 avoidance model of musculoskeletal pain: current state of scientific evidence," *Journal of Behavioral*
33 *Medicine*, vol. 30, no. 1, pp. 77-94, 2007.
- 34 10. C. Eccleston and G. Crombez, "Worry and chronic pain: a misdirected problem solving model," *Pain*,
35 vol. 132, no. 3, pp. 233-236, 2007.
- 36 11. T. Pincus and S. Morley, "Cognitive-processing bias in chronic pain: a review and integration,"
37 *Psychological Bulletin*, vol. 127, no. 5, pp. 599-617, 2001.

- 1 12. V. Legrain, F. Mancini, C. F. Sambo, D. M. Torta, I. Ronga and E. Valentini, "Cognitive aspects of
2 nociception and pain: bridging neurophysiology with cognitive psychology," *Clinical Neurophysiology*,
3 vol. 42, no. 5, pp. 325-336, 2012.
- 4 13. N. Attridge, E. Keogh and C. Eccleston, "The effect of pain on task switching: pain reduces accuracy
5 and increases reaction times across multiple switching paradigms," *Pain*, vol. 157, no. 10, pp. 2179-
6 2193, 2016.
- 7 14. N. Attridge, D. Noonan, C. Eccleston and E. Keogh, "The disruptive effects of pain on n-back task
8 performance in a large general population sample," *Pain*, vol. 156, no. 10, pp. 1885-1891, 2015.
- 9 15. G. Crombez, C. Eccleston, F. Baeyens and P. Eelen, "When somatic information threatens,
10 catastrophic thinking enhances attentional interference," *Pain*, vol. 75, no. 2-3, pp. 187-198, 1998.
- 11 16. G. Crombez, C. Eccleston, F. Baeyens and P. Eelen, "When somatic information threatens,
12 catastrophic thinking enhances attentional interference," *Pain*, vol. 75, no. 2-3, pp. 187-198, 1998.
- 13 17. G. Crombez, C. Eccleston, F. Baeyens and P. Eelen, "Habituation and the interference of pain with
14 task performance," *Pain*, vol. 70, no. 2-3, pp. 149-154, 1997.
- 15 18. C. Sinke, K. Schmidt, K. Forkmann and U. Bingel, "Phasic and tonic pain differentially impact the
16 interruptive function of pain," *PLoS One*, vol. 10, no. 2, pp. e0118363, 2015.
- 17 19. D. J. Moore, E. Keogh and C. Eccleston, "The interruptive effect of pain on attention," *Quarterly
18 journal of experimental psychology*, vol. 65, no. 3, pp. 565-586, 2012.
- 19 20. S. Van Damme, G. Crombez and C. Eccleston, "The anticipation of pain modulates spatial attention:
20 evidence for pain-specificity in high-pain catastrophizers," *Pain*, vol. 111, no. 3, pp. 392-399, 2004.
- 21 21. S. Van Damme, G. Crombez and J. Lorenz, "Pain draws visual attention to its location: experimental
22 evidence for a threat-related bias," *The Journal of Pain*, vol. 8, no. 12, pp. 976-982, 2007.
- 23 22. S. Van Damme and V. Legrain, "How efficient is the orienting of spatial attention to pain? An
24 experimental investigation," *Pain*, vol. 153, no. 6, pp. 1226-1231, 2012.
- 25 23. C. Vanden Bulcke, G. Crombez, W. Durnez and S. Van Damme, "Is attentional prioritization on a
26 location where pain is expected modality-specific or multisensory?," *Consciousness and Cognition*,
27 vol. 36, pp. 246-255, 2015.
- 28 24. C. Vanden Bulcke, G. Crombez, C. Spence and S. Van Damme, "Are the spatial features of bodily
29 threat limited to the exact location where pain is expected?," *Acta Psychologica*, vol. 153, pp. 113-
30 119, 2014.
- 31 25. C. Vanden Bulcke, S. Van Damme, W. Durnez and G. Crombez, "The anticipation of pain at a specific
32 location of the body prioritizes tactile stimuli at that location," *Pain*, vol. 154, no. 8, pp. 1464-1468,
33 2013.
- 34 26. L. Van Hulle, W. Durnez, G. Crombez and S. Van Damme, "Detection of tactile change on a bodily
35 location where pain is expected," *Perceptual and Motor Skills*, vol. 120, no. 1, pp. 219-231, 2015.
- 36 27. W. Durnez and S. Van Damme, "Trying to fix a painful problem: the impact of pain control attempts
37 on the attentional prioritization of a threatened body location," *The Journal of Pain*, vol. 16, no. 2, pp.
38 135-143, 2015.
- 39 28. D. M. Van Ryckeghem, S. Van Damme, G. Crombez, C. Eccleston, K. Verhoeven and V. Legrain, "The
40 role of spatial attention in attentional control over pain: an experimental investigation," *Experimental
41 brain research*, vol. 208, no. 2, pp. 269-275, 2011.

- 1 29. L. Leung, "Pain catastrophizing: an updated review," *Indian Journal of Psychological Medicine*, vol. 34,
2 no. 3, pp. 204-217, 2012.
- 3 30. S. Van Damme, G. Crombez and C. Eccleston, "Retarded disengagement from pain cues: the effects of
4 pain catastrophizing and pain expectancy," *Pain*, vol. 100, no. 1-2, pp. 111-118, 2002.
- 5 31. S. Van Damme, G. Crombez and C. Eccleston, "Disengagement from pain: the role of catastrophic
6 thinking about pain," *Pain*, vol. 107, no. 1-2, pp. 70-76, 2004.
- 7 32. S. Van Damme, G. Crombez, C. Eccleston and L. Goubert, "Impaired disengagement from threatening
8 cues of impending pain in a crossmodal cueing paradigm," *European Journal of Pain*, vol. 8, no. 3, pp.
9 227-236, 2004.
- 10 33. M. L. Peters, J. W. Vlaeyen and A. M. Kunnen, "Is pain-related fear a predictor of somatosensory
11 hypervigilance in chronic low back pain patients?," *Behaviour Research and Therapy*, vol. 40, no. 1,
12 pp. 85-103, 2002.
- 13 34. L. Verhoeven, F. Kraaimaat, P. Duller, K. P. van de and A. Evers, "Cognitive, behavioral, and
14 physiological reactivity to chronic itching: analogies to chronic pain," *International Journal of
15 Behavioral Medicine*, vol. 13, no. 3, pp. 237-243, 2006.
- 16 35. J. W. Vlaeyen and S. J. Linton, "Fear-avoidance and its consequences in chronic musculoskeletal pain:
17 a state of the art," *Pain*, vol. 85, no. 3, pp. 317-332, 2000.
- 18 36. M. Willebrand, F. Norlund, M. Kildal, B. Gerdin, L. Ekselius and G. Andersson, "Cognitive distortions in
19 recovered burn patients: the emotional Stroop task and autobiographical memory test," *Burns*, vol.
20 28, no. 5, pp. 465-471, 2002.
- 21 37. D. G. Fortune, H. L. Richards, A. Corrin, R. J. Taylor, C. E. Griffiths and C. J. Main, "Attentional bias for
22 psoriasis-specific and psychosocial threat in patients with psoriasis," *Journal of Behavioral Medicine*,
23 vol. 26, no. 3, pp. 211-224, 2003.
- 24 38. A. I. van Laarhoven, D. J. Ulrich, O. H. Wilder-Smith, N. E. van Loey, M. Nieuwenhuis, N. J. van der
25 Wee and A. W. Evers, "Psychophysiological Processing of Itch in Patients with Chronic Post-burn Itch:
26 An Exploratory Study," *Acta Dermato-Venereologica*, vol. 96, no. 5, pp. 613-618, 2016.
- 27 39. A. I. M. van Laarhoven, S. van Damme, A. P. M. Lavrijsen, D. M. van Ryckeghem, G. Crombez and A.
28 W. M. Evers, "Attentional processing of itch," *Psychological Research*, doi: 10.1007/s00426-00017-
29 00878-00422. [Epub ahead of print], 2017.
- 30 40. A. I. M. van Laarhoven, F. W. Kraaimaat, O. H. Wilder-Smith and A. W. M. Evers, "Role of attentional
31 focus on bodily sensations in sensitivity to itch and pain," *Acta dermato-venereologica*, vol. 90, no. 1,
32 pp. 46-51, 2010.
- 33 41. C. Schut, S. Grossman, U. Gieler, J. Kupfer and G. Yosipovitch, "Contagious itch: what we know and
34 what we would like to know," *Frontiers in Human Neuroscience*, vol. 9, pp. 57, 2015.
- 35 42. D. L. Woods, J. M. Wyma, E. W. Yund, T. J. Herron and B. Reed, "Factors influencing the latency of
36 simple reaction time," *Frontiers in Human Neuroscience*, vol. 9, pp. 131, 2015.
- 37 43. D. J. Bartels, A. I. van Laarhoven, E. A. Haverkamp, O. H. Wilder-Smith, A. R. Donders, H. van
38 Middendorp, P. C. van de Kerkhof and A. W. Evers, "Role of conditioning and verbal suggestion in
39 placebo and nocebo effects on itch," *PLoS One*, vol. 9, no. 3, pp. e91727, 2014.
- 40 44. S. Van Damme, D. M. Van Ryckeghem, F. Wyffels, L. Van Hulle and G. Crombez, "No pain no gain?
41 Pursuing a competing goal inhibits avoidance behavior," *Pain*, vol. 153, no. 4, pp. 800-804, 2012.

- 1 45. A. W. Evers, P. Duller, P. C. van de Kerkhof, P. G. van der Valk, E. M. de Jong, M. J. Gerritsen, E. Otero,
2 E. W. Verhoeven, C. M. Verhaak and F. W. Kraaimaat, "The Impact of Chronic Skin Disease on Daily
3 Life (ISDL): a generic and dermatology-specific health instrument," *British Journal of Dermatology*, vol.
4 158, no. 1, pp. 101-108, 2008.
- 5 46. A. S. Zigmond and R. P. Snaith, "The hospital anxiety and depression scale," *Acta Psychiatrica*
6 *Scandinavica*, vol. 67, no. 6, pp. 361-370, 1983.
- 7 47. D. Watson, L. A. Clark and A. Tellegen, "Development and validation of brief measures of positive and
8 negative affect: the PANAS scales," *Journal of Personality and Social Psychology*, vol. 54, no. 6, pp.
9 1063-1070, 1988.
- 10 48. M. J. L. Sullivan, S. R. Bishop and J. Pivik, "The Pain Catastrophizing Scale: Development and
11 validation," *Psychological Assessment*, vol. 7, no. 4, pp. 524-532, 1995.
- 12 49. H. J. Eysenck and S. B. G. Eysenck, *Manual of the Eysenck Personality Scales (EPS Adult)*, Hodder &
13 Stoughton, London, 1991.
- 14 50. D. W. McNeil and A. J. Rainwater, 3rd, "Development of the Fear of Pain Questionnaire--III," *Journal*
15 *of Behavioral Medicine*, vol. 21, no. 4, pp. 389-410, 1998.
- 16 51. N. B. Schmidt, D. R. Lerew and J. H. Trakowski, "Body vigilance in panic disorder: evaluating attention
17 to bodily perturbations," *Journal of consulting and clinical psychology*, vol. 65, no. 2, pp. 214-220,
18 1997.
- 19 52. C. De Ruiter, B. Garssen, H. Rijken and F. Kraaimaat, "Fear of bodily sensations in anxiety disorder
20 patients," in *Fresh perspectives on anxiety disorders*, P. M. G. Emmelkamp, W. Everaerd, F. Kraaimaat
21 and M. J. M. van Son, Ed., Swets & Zeitlinger, Amsterdam/Lisse, Lisse/Amsterdam, 1989.
- 22 53. J. Roelofs, M. L. Peters, L. McCracken and J. W. Vlaeyen, "The pain vigilance and awareness
23 questionnaire (PVAQ): further psychometric evaluation in fibromyalgia and other chronic pain
24 syndromes," *Pain*, vol. 101, no. 3, pp. 299-306, 2003.
- 25 54. L. Kubisz, "The influence of storage time on the temperature dependence of the dc electrical
26 conductivity of horn keratin," *Bioelectrochemistry*, vol. 53, no. 2, pp. 161-164, 2001.
- 27 55. R. Bakeman, "Recommended effect size statistics for repeated measures designs," *Behaviour Research*
28 *Methods*, vol. 37, no. 3, pp. 379-384, 2005.
- 29 56. D. Lakens, "Calculating and reporting effect sizes to facilitate cumulative science: a practical primer
30 for t-tests and ANOVAs," *Frontiers in Psychology*, vol. 4, pp. 863, 2013.
- 31 57. G. Crombez, C. Eccleston, A. Van den Broeck, L. Goubert and B. Van Houdenhove, "Hypervigilance to
32 pain in fibromyalgia: the mediating role of pain intensity and catastrophic thinking about pain,"
33 *Clinical Journal of Pain*, vol. 20, no. 2, pp. 98-102, 2004.

34
35

1 **TABLES**

2

3 *Table 1 Total scores of self-reported questionnaires (n=53)*

	Mean score ± SD	Range
Level of spontaneous itch at baseline	0.2 ± 0.5	0.0 – 2.0
Level of spontaneous pain at baseline	0.2 ± 0.4	0.0 – 2.0
Level of fatigue at baseline	1.8 ± 1.3	0.0 – 5.5
Affect		
Anxiety (HADS-Anxiety)	2.4 ± 0.5	0.9 – 3.0
Depression (HADS-Depression)	2.7 ± 0.3	1.9 – 3.0
Personality characteristics		
Neuroticism (EPQ-RSS)	3.2 ± 2.5	0 – 11
Attention to bodily sensations		
Attentional focus on itch	2.2 ± 1.9	0 - 6.5
Attentional focus on pain	3.3 ± 2.4	0 - 8.0
BVS	2.8 ± 1.5	0.2 – 6.8
BSQ	2.0 ± 0.5	1.3 – 3.3
PVAQ-A	24.2 ± 9.5	4 – 45
Catastrophizing		
PCS-A	7.5 ± 6.4	0 – 29
Fear of pain		
FPQ-III	63.3 ± 15.9	36 - 101
Attentional disengagement from		
Itch	4.3 ± 1.0	1 – 5
Pain	4.0 ± 0.9	1 – 5

4 *Abbreviations: HADS: Hospital Anxiety and Depression Scale (theoretical range 0–21 per subscale); EPQ-*
 5 *RSS: Eysenck Personality Questionnaire revised short scale (theoretical range 0-12 neuroticism subscale);*
 6 *Single items assessing attentional focusing on itch and pain (theoretical range 0-10); BVS: Body Vigilance*
 7 *Scale (theoretical range 0-10); BSQ: Body Sensations Questionnaire (theoretical range 1-5); PVAQ-A: Pain*
 8 *Vigilance and Awareness Scale, adjusted for physical sensations (theoretical range 0-80); PCS-A: Pain*
 9 *Catastrophizing Scale, adjusted for physical sensations (theoretical range 0-52); FPQ: Fear of pain*
 10 *questionnaire (theoretical range 30-150); Single items about attentional disengagement (theoretical*
 11 *range 1-5).*

12

1 *Table 2 Means ± standard deviations of NRS itch, pain, and unpleasantness scores at baseline and during*
 2 *the pain, itch and control blocks of the somatosensory attention task (SAT) (n=51)*

	NRS itch	NRS pain	NRS unpleasantness
Baseline itch stimulus	3.5 ± 2.2	0.6 ± 1.1	2.3 ± 2.0
Baseline pain stimulus	0.9 ± 1.3	3.9 ± 1.7	3.4 ± 1.8
SAT itch blocks	1.8 ± 1.6	0.2 ± 0.4	1.2 ± 1.5
SAT pain blocks	0.5 ± 0.8	3.0 ± 1.7	2.7 ± 1.7
SAT control blocks	0.1 ± 0.2	0.0 ± 0.1	0.0 ± 0.1

3 *Note: the electrical current at which the itch and pain stimuli were applied was tailored to individual*
 4 *sensitivity and was identical during baseline measurements and the SAT.*

5
6
7
8
9
10

11 *Table 3 Mean reaction times (in ms) ± standard deviation for the ipsilateral and contralateral trials of the*
 12 *somatosensory attention task (SAT) during itch, pain, and control blocks (n=51)*

	Ipsilateral trials (ms)	Contralateral trials (ms)
Itch blocks	466.2 ± 91.0	463.7 ± 84.4
Pain blocks	470.7 ± 81.8	472.5 ± 80.9
Control blocks	450.4 ± 81.2 ¹	457.4 ± 88.5 ²

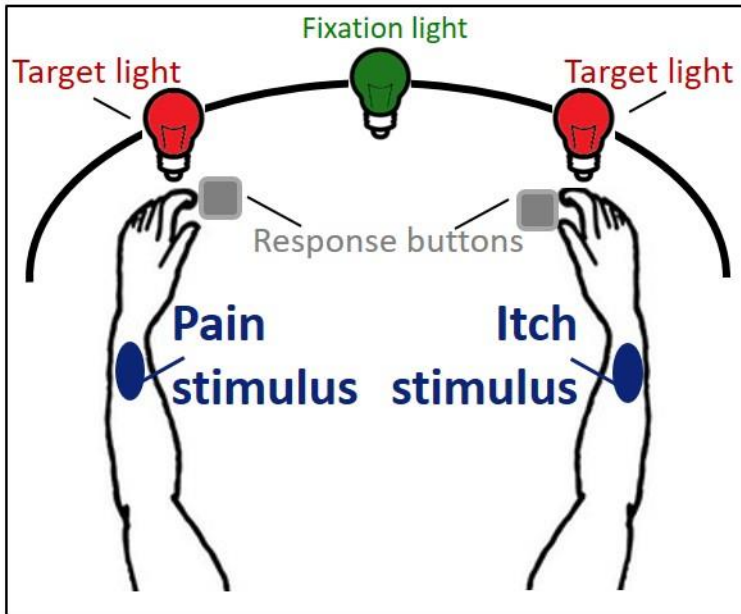
13 ¹ *Reaction times during control blocks (no somatosensory stimulation) ipsilateral to attached itch*
 14 *electrodes location*

15 ² *Reaction times during control blocks (no somatosensory stimulation) ipsilateral to the attached pain*
 16 *electrodes location*

17

1

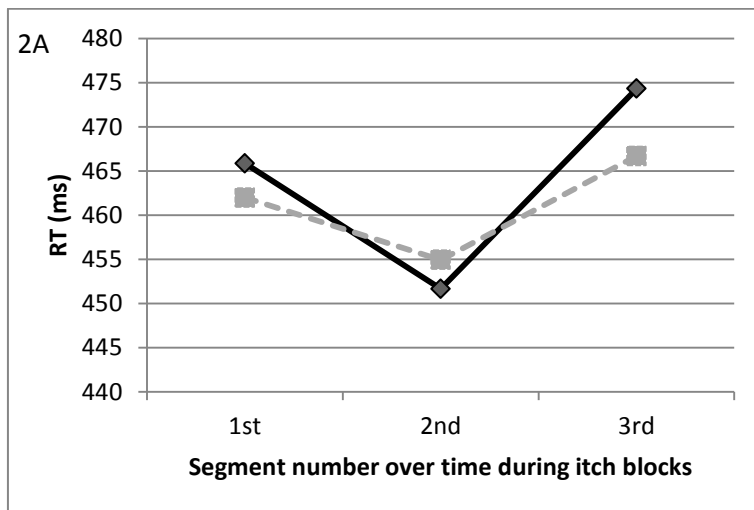
2 **FIGURES**



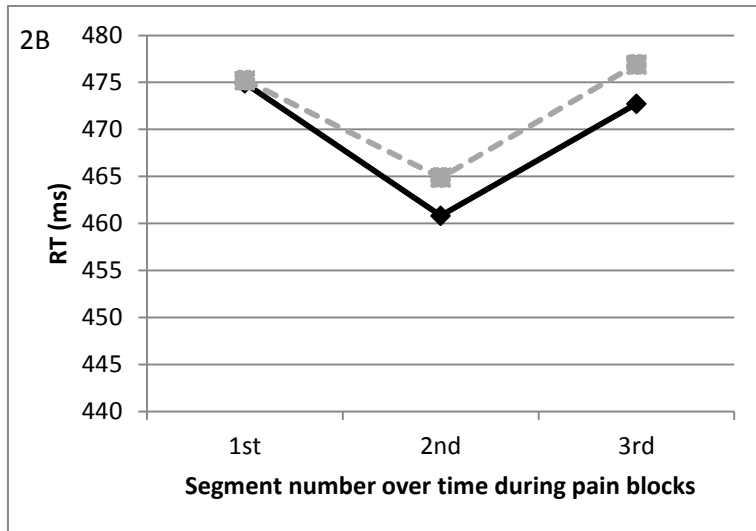
3

4 **Fig. 1:** Schematic representation of the setup of the somatosensory attention task. The side of itch
5 stimulation was contralateral to the pain stimulation (randomized across participants). During a block, an
6 itch (itch block) or pain (pain block) stimulus is being applied, or no stimulation (control blocks), while,
7 after short onset of the fixation light, one of the target lights is illuminated. Participants respond to the
8 target light location using response buttons right below both target lights, either at the ipsilateral or
9 contralateral location as opposed to the somatosensory stimulation.

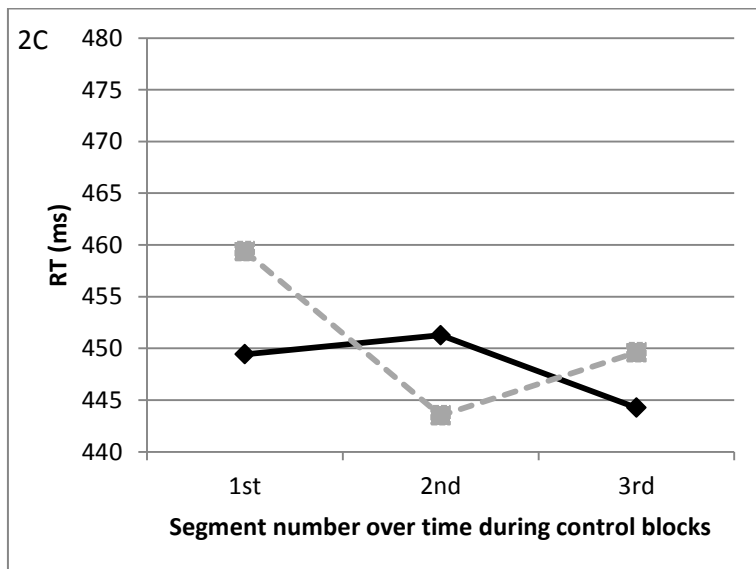
10



11



1



2

3 **Fig. 2:** Reaction times (in ms) for participants' ($n=51$) responding to the visual target lights during the 35-s
 4 somatosensory itch (Fig. 2A) or pain blocks (Fig. 2B) or in control blocks, in which no somatosensory
 5 stimulation was applied (Fig. 2C). Visual targets were either displayed at the side of the itch or pain
 6 stimulation *cq.* attachment of the itch or pain electrodes in the case of the control blocks (*i.e.* ipsilateral
 7 trials – solid line) or at the opposite side (*i.e.* contralateral trials – dashed line).

8