



# Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain

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## Abstract

Chronic pain is often associated with reduced tactile acuity. A relationship exists between pain intensity, tactile acuity and cortical reorganisation. When pain resolves, tactile function improves and cortical organisation normalises. Tactile acuity can be improved in healthy controls when tactile stimulation is associated with a behavioural objective. We hypothesised that, in patients with chronic limb pain and decreased tactile acuity, discriminating between tactile stimuli would decrease pain and increase tactile acuity, but tactile stimulation alone would not. Thirteen patients with complex regional pain syndrome (CRPS) of one limb underwent a waiting period and then ~2 weeks of tactile stimulation under two conditions: stimulation alone or discrimination between stimuli according to their diameter and location. There was no change in pain (100 mm VAS) or two-point discrimination (TPD) during a no-treatment waiting period, nor during the stimulation phase ( $p > 0.32$  for both). Pain and TPD were lower after the discrimination phase [mean (95% CI) effect size for pain VAS = 27 mm (14–40 mm) and for TPD = 5.7 mm (2.9–8.5 mm),  $p < 0.015$  for both]. These gains were maintained at three-month follow-up. We conclude that tactile stimulation can decrease pain and increase tactile acuity when patients are required to discriminate between the type and location of tactile stimuli.

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**Keywords:** Tactile acuity; Sensation; Physical therapy; Complex regional pain syndrome; Cortical reorganisation

## 1. Introduction

There is growing evidence that people with persistent pain are less able to identify the location and characteristics of a tactile stimulus, if that stimulus is delivered to their painful body part [28,38,44]. This loss of tactile acuity seems to correlate with the intensity of their pain

[21,38,53], but when pain resolves, tactile acuity increases again [37,54].

Changes in tactile acuity can be mediated by changes in the response profile of neurons at different levels of the somatosensory system. One level at which the response profile of neurons is known to change, for example in response to hyperstimulation [31] or deprivation of stimulation [20] of the skin of the relevant body part, is the primary sensory cortex (S1). Changes here are termed cortical reorganisation. Several studies show reorganisation of S1 in people with chronic pain [16,18,32,37,54,59] and the extent of reorganisation has been related to both the intensity of pain and the reduction in tactile acuity [16,18,37,54].

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These relationships provided the basis for an elegant study in patients with phantom limb pain after amputation [17]. In that randomised trial, treatment that aimed to improve sensory acuity led to both reduced phantom limb pain and normalisation of S1 reorganisation. This study raised the possibility that training sensory acuity may offer therapeutic benefit for other types of persistent pain.

To improve tactile acuity, it is thought necessary to stimulate the skin of the relevant body part, preferably in a way that makes the characteristics of the stimuli important, for example, reading Braille or playing the violin, or makes the objective of the task important, for example unwrapping food [4,31,63]. The present study applied this principle to training tactile acuity in people with unilateral limb pain. By doing so, we built on the trial by Flor et al. [17]. Our study differs from that one, however, because we used clinically relevant manually applied tactile stimuli instead of electrocutaneous stimuli, and our participants were diagnosed with complex regional pain syndrome (CRPS), in which the neural supply to the painful area is intact, instead of phantom limb pain, in which it is not.

Tactile stimuli were delivered to the affected area under two conditions. One in which participants discriminated the location and type of the stimuli, and one in which they did not. We hypothesised that the tactile discrimination condition would increase tactile acuity and decrease pain, but the tactile stimulation only condition would not.

## 2. Methods

### 2.1. Subjects

Patients who had been diagnosed with CRPS type 1 (CRPS) by their attending physiotherapist, general practi-

tioner or rheumatologist, and were referred to the research team, were then assessed to confirm the diagnosis, according to IASP criteria [5]. Thus, a convenience sample of seventeen patients with unilateral CRPS of one limb was eligible. One patient chose not to participate and three patients indicated that they would not be able to undertake home training, which left thirteen participants (nine female; means  $\pm$  SD age =  $37 \pm 12$  years, duration of symptoms =  $15 \pm 8$  months, Table 1). Informed consent was obtained and all procedures were in accordance with the Helsinki Declaration and approved by the institutional Ethics Committees.

### 2.2. Experimental design

This study was a four phase (A–B–C–D) within subjects repeated measures design. The first phase was a no-treatment waiting period. The second phase was the stimulation only condition. The third phase was the discrimination condition. The duration of each of these phases was between 11 and 17 days (randomly allocated for each participant). The fourth phase was a three-month follow-up period. The order of phases was the same for all participants because pilot trials confirmed that patients who undertook the discrimination condition first (i) did not think the stimulation condition was credible, (ii) indicated that they would not perform home treatment during the stimulation condition and (iii) did not expect a treatment effect from the stimulation condition. We felt that these issues, combined with our desire to obtain follow-up data, outweighed the potential confounds introduced by not varying the order of treatment phases. We minimised the effect of time by randomising between participants the duration of the first three phases.

### 2.3. Assessments

The primary outcome variables were pain intensity and two-point discrimination threshold (TPD) in the affected area. All assessments were undertaken with and collected by an investigator not otherwise involved in the study and who was blinded to phase and time point of the assessment.

Table 1

Subject characteristics: M, male; F, female; MOI, mechanism of initiating incident; MVA, motor vehicle accident; CTS carpal tunnel release; Dur. (months), duration in months since the initiating injury; NRS, mean score on an 11-point numerical scale for ability to perform five patient-selected tasks; pain, mean pain over the last 2 days on a 100 mm visual analogue scale; TPD, two-point discrimination threshold for the affected (af) and opposite (op) area

Sex	Age (years)	Body part	MOI	Dur. (months)	NRS	Pain	TPD <sup>af</sup> (mm)	TPD <sup>op</sup> (mm)
M	48	L finger	Sprain	4	1	42	23	12
F	42	R ankle	Sprain	29	2	71	32	21
F	25	L ankle	MVA	10	2	54	39	30
M	44	R arm	Impact	26	2	56	27	23
M ↓	46	L wrist	Fracture	19	3	43	25	14
F	28	L knee	Impact	4	4	54	51	42
F ↓	20	L foot	Tic bite	9	3	61	46	39
M ↓	26	R elbow	Impact	9	2	57	38	34
F	20	R ankle	Tic bite	9	3	49	43	36
M ↓	58	L wrist	Fracture	17	2	62	34	29
F ↓	45	L wrist	CTR	23	2	40	36	30
F ↓	45	L hand	CTR	11	2	47	33	24
F ↓	41	L wrist	Fracture	15	1	70	35	29
F ↓	43	R leg	Fracture	14	4	44	42	38
M ↓	25	R arm	Infection	24	2	36	27	20

↓ denotes that the subject reduced analgesic medication during the review period.

### 2.3.1. Pain

The primary outcome measure of pain involved participants rating their pain in the affected body part by placing a mark on a 100 mm visual analogue scale (VAS) labelled with “How would you rate your average pain over the last two days?” The left anchor was “No pain” and the right anchor was “Worst pain”. A separate measure of daily pain was also collected but not analysed (Supplementary Fig. 1).

### 2.3.2. Two-point discrimination (TPD)

TPD was performed according to Moberg [43]. A mechanical calliper with a precision of 1 mm was applied until the very first blanching of the skin appeared around the prongs. The pressure was kept to a minimum to ensure that results reflected cutaneous sensibility. Testing commenced with 0 mm between the two points of the calliper, gradually increasing the distance until the subject was able to perceive two points instead of one. The subject was instructed to say ‘one’ when they felt one point and ‘two’ when they felt two points. A screen prevented the participant from watching the stimulation. Interstimulus interval was 7 s. The distance between points at which the participant reported feeling two stimuli for three consecutive stimuli presentations was deemed the TPD. The average of three assessments was used for analyses.

### 2.3.3. Task-specific scale

Although it was not a primary outcome variable, we used a task-specific scale to estimate the impact of CRPS on functional activities. An 11-point NRS was used to score each of five activities or tasks, which were selected by each participant as tasks that they regularly performed prior to their initiating injury but now found difficult to perform because of their disease. Participants were asked “How well can you perform that task now?” with 0 = “completely unable to perform” and 10 = “able to perform normally”. Mean score from five tasks was used for analysis and was called “function”. This measure is useful for groups in which the diagnoses, or the anatomical region of symptoms, or both, are variable. It is repeatable and sensitive to change [52] and has been used widely in people with disabling pain [6,64], including CRPS [46] and phantom limb pain [48].

### 2.4. Compliance and perceived similarity of home training and clinic training

Using a training diary increases participation in home programs [47]. A diary was used to record the time of day and the duration of each home session and to complete a 100 mm VAS in response to the question “How similar was home training to clinic training?” The VAS was anchored on the left with “Not at all similar – completely different” and on the right with “Exactly the same”. The VAS was converted to a numerical value by measuring the distance from the left anchor to the participant’s mark.

### 2.5. Treatment credibility

After the first session at the clinic for the stimulation condition and for the discrimination condition, participants completed a 100 mm VAS in response to the question “How

credible is this treatment?” The VAS was anchored on the left with “Not at all credible” and on the right with “Completely credible”. VAS scores were converted by measuring the distance from the left anchor to the participant’s mark.

## 2.6. Protocol

### 2.6.1. The waiting period phase

After initial assessment, participants were randomly allocated a day that was between 11 and 17 days later (Fig. 1), to return to commence the first condition. There were no limitations on behaviour, treatment or medications during this period.

### 2.6.2. Protocol for tactile stimulation sessions

On a digital photograph of the affected limb, five points were marked (Fig. 2). All five points were located in the affected area. The distance between points was approximately the same as the TPD established for that area in that participant. Pilot data suggested that this rule provides a success rate of about 80% when participants attempt to identify which point was stimulated (see discrimination condition below). Two cork probes (2 and 11 mm in diameter, respectively) were mounted atop a spring-loaded cartridge such that the pressure with which each probe could be applied to the skin was standardised. Pressure was kept to a minimum to avoid provocation of pain. A screen was positioned to prevent the subject from seeing the affected area. Stimulation involved applying one of the probes to one of the marked points. The type of probe and the marked point were randomised using a random numbers table. Interstimulus interval was 15 s. Three 6-min blocks of 24 stimuli were undertaken with a 3-min rest period between blocks. Thus, each treatment session involved 72 stimuli and lasted 24 min (Fig. 1A). This was repeated every weekday.

### 2.6.3. The stimulation phase

Participants attended a clinic session every weekday. Participants did not rate the stimuli, nor respond to them in any way. Participants listened to music or read a magazine, or did both.

At the first session during the stimulation phase, participants were accompanied by someone who could assist them to undertake training at home. That assistant was trained in the task and participants were advised to undertake one session per day of training at home, in addition to the clinic session. Participants were given a wine cork and a pen lid to use instead of the cork probes. They were given five lists of random combinations of numbers (1–5) and stimuli (cork or pen lid), and were advised to use a different list each day.

Prior to every second clinic session, TPD was reassessed, although measurements started at the previously determined threshold. This modification was included to save time but to make sure the distance between stimulation points remained roughly equivalent to the TPD threshold.

### 2.6.4. The discrimination phase

The tactile stimulation was identical during this phase to that delivered during the stimulation phase. However, participants were given a photograph of their limb on which the stimulation points were marked. They were also shown the two

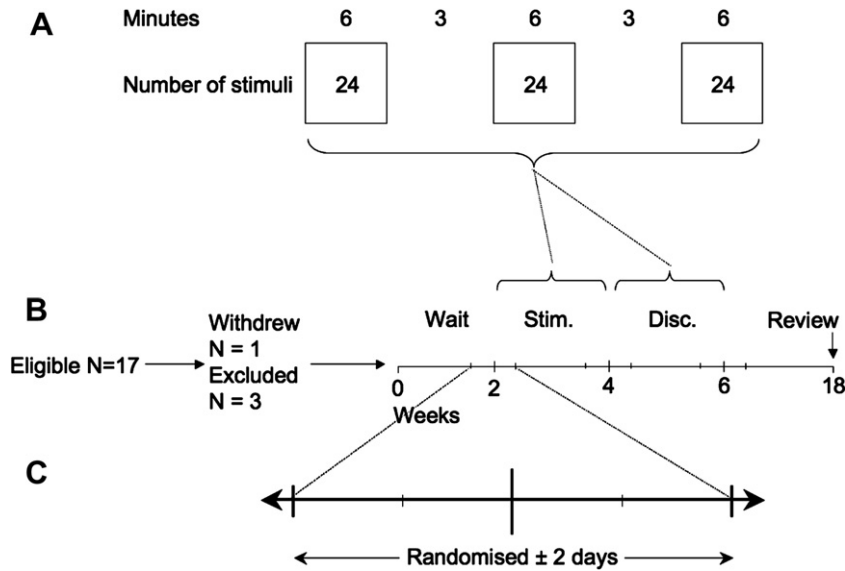


Fig. 1. (A) Each session involved three 6-min blocks of 24 stimuli each, with 3 min rest between blocks. There was one session per weekday. Participants were advised to undertake one session per weekday at home. (B) Experimental plan. After the waiting period, the stimuli were delivered in each session during the stimulation condition (Stim.), and then during the discrimination condition (Disc.). No limitations or requirements were made of participants during the two-week waiting period, nor between the end of the discrimination condition and the 18-week review. (C) The duration of each condition was randomised between 11 and 17 days (2 weeks ± 3 days).

probes. During the tactile stimulation, participants responded to each stimulus by stating (i) the location of the stimulus (i.e. the corresponding number on the photograph) and (ii) the type of probe. The distance between points was roughly equal to the TPD threshold. TPD threshold was remeasured before every second clinic session (as per the stimulation condition), and

the distance between points adjusted if it was required. Stimulus frequency, treatment duration and frequency were identical to the stimulation condition. At the first session, the participant's assistant for home training was retained and the same instruction to undertake one session per day at home was provided. Thus, there was one clinical session every weekday and

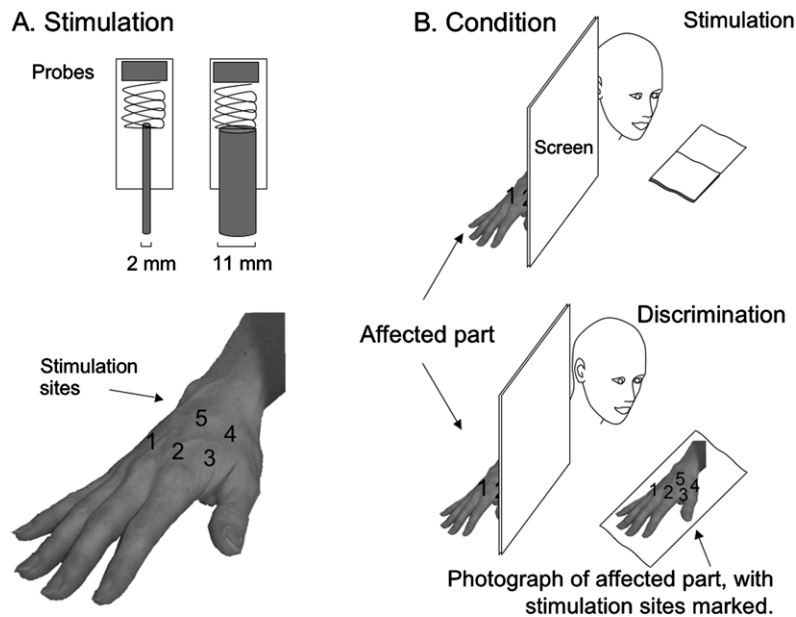


Fig. 2. Experimental setup. (A) Cork stimulation probes were fixed to spring-loaded cartridge and applied in random order to five sites on the affected area. If stimulation caused pain, the sites were moved. (B) Experimental conditions: for both conditions, participants could not see the stimulated area. Stimulation protocol was identical for both conditions. In the discrimination condition, participants discriminated between the type of probe used and the stimulation site, by referring to a photograph with the stimulation sites marked. In the stimulation condition, they read a magazine or listened to music.

patients were advised to undertake one home session every day.

For both the stimulation and discrimination conditions, stimuli were delivered by four physiotherapists who were trained for the study. For each individual participant, the physiotherapist, who delivered the initial session of both conditions and most of the other sessions, was called the primary clinician. There were times when scheduling and unforeseen absences meant that the primary clinician was unavailable, in which case one of the other trained clinicians delivered the session.

#### 2.6.5. Treatment during the three-month follow-up period

Pain rating, TPD and task-specific NRS were repeated three months after the conclusion of the discrimination condition. No constraints were placed on the participants regarding treatment or medication during this period. Patients were interviewed at follow-up regarding other treatment and analgesic use.

#### 2.7. Statistics

Statistics were performed using SPSS 11.0.0 (SPSS, Chicago, IL, USA).

##### 2.7.1. Performing methodological checks

The following methodological checks were undertaken with paired *t*-tests: the credibility of treatment; the number and duration of home-based sessions; the perceived similarity between home-based sessions and clinic-based sessions; the number of clinic-based sessions. In each case the grouping variable was the condition (stimulation or discrimination).

##### 2.7.2. Testing the hypotheses

In order to test the hypothesis that the tactile discrimination condition would increase tactile acuity and decrease pain more than tactile stimulation alone, we undertook a repeated measures ANOVA, with Bonferroni-corrected pairwise comparisons, on each primary outcome variable. The factor was time. There were five levels: pre-waiting period, post-waiting period, post-stimulation, post-discrimination and follow-up.

##### 2.7.3. Secondary analyses

We undertook a third repeated measures ANOVA, with Bonferroni-corrected pairwise comparisons, on our secondary outcome variable, function. Again, the factor, time, had five levels (baseline, post-waiting, post-stimulation, post-discrimination and follow-up).

### 3. Results

#### 3.1. Methodological checks

Methodological checks revealed that home treatment better mimicked clinic treatment during the stimulation phase than it did during the discrimination phase, but there were no other differences (Table 2). The primary clinician delivered  $7 \pm 3$  sessions in the stimulation phase and  $6 \pm 4$  sessions in the discrimination phase.

Table 2  
Methodological checks

	Stimulation	Discrimination
Credibility of treatment (100 mm VAS) $p = 0.18$	$82 \pm 12$	$88 \pm 9$
Number of clinic sessions $p = 0.59$	$14 \pm 2$	$13 \pm 2$
Number of home sessions $p = 0.78$	$9 \pm 3$	$9 \pm 4$
Duration of home sessions (min) $p = 0.85$	$26 \pm 2$	$26 \pm 3$
Similarity of home & clinic sessions (100 mm VAS) $*p = 0.02$	$84 \pm 13$	$74 \pm 10$

VAS, visual analogue scale.

The similarity of home and clinic sessions was perceived to be greater in the stimulation condition than in the discrimination condition, but there were no other differences ( $*p$  values relate to uncorrected paired *t*-tests).

Means  $\pm$  SD of clinicians who delivered clinic sessions was  $3 \pm 1$  for both conditions.

#### 3.2. The effect of tactile stimulation and discrimination on average pain over the last 2 days

At baseline, means  $\pm$  SD pain VAS was  $54 \pm 11$  mm. Pain VAS changed over the course of the study (main effect of time on pain;  $F(4, 48) = 27.58$ ,  $p < 0.001$ ). Pairwise comparisons revealed that there was no change in pain VAS during the waiting period [ $52$  mm ( $44$ – $60$  mm)], nor during the stimulation phase [mean (95% CI) =  $51$  mm ( $44$ – $59$  mm)];  $p > 0.94$  for both]. Pain VAS was less at post-discrimination [ $24$  mm ( $16$ – $32$  mm)] than it was at post-stimulation, post-waiting period or baseline ( $p < 0.002$  for all). The mean (95% CI) effect size for pain VAS was  $27$  mm ( $14$ – $40$  mm). Pain VAS had not changed further at follow-up [ $28$  mm ( $18$ – $38$  mm),  $p = 0.32$ ], but it was still lower than it was at post-stimulation, post-waiting period or at baseline ( $p < 0.008$  for all).

#### 3.3. The effect of tactile stimulation and discrimination on TPD

At baseline, means  $\pm$  SD TPD was  $43 \pm 5$  mm. TPD changed over the course of the study (main effect of time on TPD;  $F(4, 48) = 20.5$ ,  $p < 0.001$ ). Pairwise comparisons revealed that there was no change in TPD during the waiting period [ $42$  mm ( $39$ – $46$  mm)], nor during the stimulation phase [mean (95% CI) =  $42$  mm ( $39$ – $45$  mm)];  $p > 0.96$  for both]. TPD, like pain VAS, was less at post-discrimination [ $36$  mm ( $34$ – $38$  mm)] than it was at post-stimulation, post-waiting period or at baseline ( $p < 0.014$  for all). The mean (95% CI) effect size for TPD was  $5.7$  mm ( $2.9$ – $8.5$  mm). TPD had not changed further at follow-up [ $36$  mm ( $33$ – $39$  mm),  $p = 0.95$ ], but it was still lower than it was at post-stimulation, post-waiting period or at baseline ( $p < 0.015$  for all) (Fig. 3).



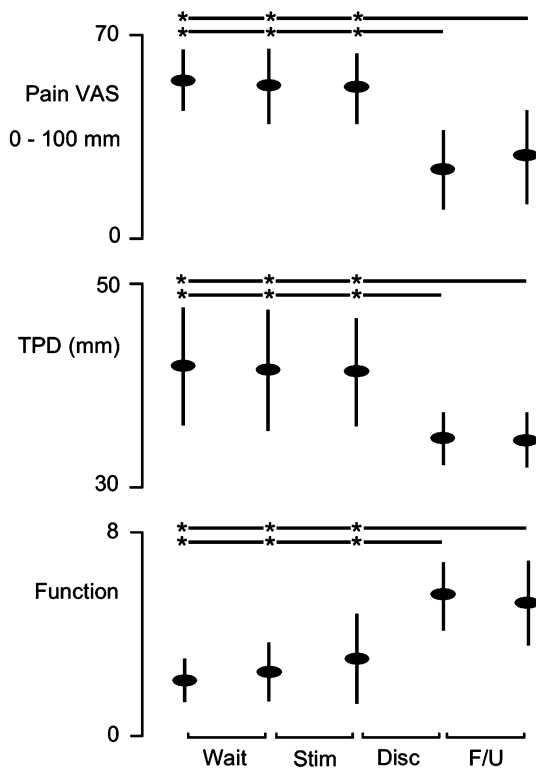


Fig. 3. Results. Mean (shapes) and standard deviation (error bars) for average pain over the last 2 days (Pain VAS), two-point discrimination threshold (TPD) and task-specific functional numerical rating scale (Function) at baseline, after a waiting period (Wait), after the stimulation phase (Stim.), after the discrimination phase (Disc.) and at follow-up (F/U). Asterisk denotes significant  $p < 0.02$ , Bonferroni-corrected.

#### 3.4. The effect of tactile stimulation and discrimination on function (task-specific NRS)

Tasks selected by each participant reflected the body part that was affected. For example, most participants selected sleeping; most participants with CRPS of the upper limb selected ‘dressing’, ‘eating’ and ‘driving’; participants with CRPS of the dominant upper limb selected ‘writing’ or ‘using my hand’; all participants with CRPS of the lower limb selected ‘walking’ and ‘wearing a shoe’.

At baseline, mean  $\pm$  SD function score was  $2.2 \pm 0.8$ . Function changed over the course of the study (main effect of time;  $F(4, 48) = 70.05$ ,  $p < 0.001$ ). Pairwise comparisons revealed that there was no change in function during the stimulation phase [mean (95% CI) = 3.1 (2.0–4.1)], nor during the waiting period [2.5 (1.9–3.2);  $p > 0.34$  for both]. Function was higher at post-discrimination [5.5 mm (34–38 mm)] than it was at post-stimulation, post-waiting period or at baseline ( $p < 0.001$  for all). The mean (95% CI) effect size for the function score was 1.9 (1.1–2.8). Function had not changed further at follow-up [5.5 (4.5–6.5),  $p = 0.98$ ], but it was still higher than it was at post-stimulation,

post-waiting period or at baseline ( $p < 0.001$  for all) (Fig. 3).

#### 3.5. Treatment undertaken during the three-month follow-up period

Seven participants reported at the three-month follow-up that they had continued with tactile training at weekly physiotherapy sessions and at home. Three of these participants, and five others, reported that they had participated in other modes of physiotherapy, three including motor imagery training and all including graded exposure to functional tasks.

At the review, nine participants reported that they had reduced their analgesic medications (Table 1).

## 4. Discussion

This study demonstrates for the first time that discriminating the location and diameter of tactile stimuli applied to the affected limb of patients with unilateral CRPS can decrease pain and TPD threshold, but tactile stimulation alone cannot.

That tactile stimulation of the affected limb can improve tactile function corroborates data obtained from animals [23,65], from healthy volunteers [24] and, anecdotally, from patients with CRPS [37,54]. In the current paradigm, however, stimulation alone did not reduce pain, nor improve tactile function. At first glance, this seems contrary to several studies that show stimulation alone can change both S1 organisation and TPD [23,24,26]. However, these stimulation paradigms depend on tight temporal relationships between stimuli and are thought to require well in excess of 3 h continuous stimuli [23], neither of which occurred here.

Three possible mechanisms by which having to discriminate between stimuli could have reduced pain and TPD are: distraction, exposure and cortical reorganisation. Although we did not measure attention and cannot be sure that participants did not also attend to the stimuli in the stimulation alone condition, it is reasonable to conclude that participants attended more to the tactile stimuli during the discrimination condition than they did during the stimulation alone condition.

Perhaps attending to the tactile stimuli simply diverted attention away from noxious cues. Many studies have investigated the interrelationship between attention and pain [2,7–10,12–15,39,42,51] and distraction remains an important part of clinical practice. Strategies as simple as asking a patient to look away while they receive an injection, and as sophisticated as immersion in a virtual reality environment [27], attempt to utilise distraction to reduce pain. Alternatively, a perceptual-cognitive approach [33] might suggest that, by attending towards the affected area in a neutral, objective way

(‘sensory monitoring’), the threat of somatic input from that area was reduced, which in turn reduced pain.

Another mechanism that may have imparted the effect is exposure. Exposure to threatening stimuli, without eliciting the unwanted response, is a cornerstone of anxiety disorder management and is gaining support in chronic pain rehabilitation. Specifically, exposing patients in pain to the very movements and tasks of which they are most fearful has been shown to reduce pain and improve function [11,60,61]. Certainly, patients with CRPS are likely to be fearful of their limb being touched and visual input suggesting the limb is being touched (even though it is not) can elicit pain and evoke a sympathetic response [1]. Importantly however, stimulation alone also exposed patients to touch, did not evoke pain, but had no therapeutic effect. That makes it difficult to endorse exposure as the mechanism of effect. At this stage, the extent to which attending to threatening stimuli is important in the therapeutic effect of exposure for chronic pain states has not been demonstrated. In order to draw clearer inferences about the role of exposure in the effect of discrimination, we would need to measure fear of touch, which we did not do here.

The final possibility is that discrimination had its effect via cortical reorganisation. This study was motivated in part by work in amputees where sensory discrimination reduced phantom limb pain. In that randomised clinical trial, patients underwent a program of electrical stimulation of the stump, during which they had to discriminate the frequency or location of each stimulus. There was ~60% reduction in phantom limb pain. Notably, there was a strong three-way relationship between decrease in pain, decrease in TPD threshold and normalisation of cortical organisation [17]. This raised the possibility that the sensory discrimination treatment reduced pain via its effect on cortical organisation.

There are two aspects of the literature that seem to support that possibility. First, for tactile input to change S1 representation in non-pathological groups, attention to the input or a behavioural objective associated with the input is thought to be critical [4,30,63]. Spatial attention has been shown to modulate S1 activation during touch – focussing one’s attention on the stimulated area increases S1 response to touch and improves tactile performance [34]. Even looking in the direction of the stimulated part [35] and receiving visual input of the skin of the area [58] increase S1 response to touch and improve tactile performance. Second, observational studies report a three-way relationship between S1 representation, tactile acuity and pain in CRPS patients [36,53,55] and this relationship is maintained when pain resolves [37,54].

Although there is mounting evidence from patients with pathological pain syndromes that normalisation of S1 representation relates to decreased pain, a causal

link has not been demonstrated. Theoretical arguments suggest that S1 reorganisation distorts the internal body maps that the brain uses to control movement, that this distortion causes incongruence between motor commands and sensory feedback and that this incongruence causes pain [25,40] (see [19] for a comprehensive proposal relating to phantom limb pain). Attempts have been made to interrogate this proposal [40,49], but it remains neither endorsed nor refuted.

The secondary finding that treatment increased functional capacity was not surprising, but has been overlooked in many clinical trials [3,29,41,45,50,57,62] and observational studies [37,54] (also see [11,22,46,56] for exceptions) of treatment for CRPS. The extent of the increase in functional capacity was similar to that observed using the same measure in a study of motor imagery for CRPS [46]. By using a scale for the selected tasks the participants found to be difficult, we probably maximised the sensitivity of detecting a functional change, which makes comparison to data obtained from generic tools problematic.

There are obvious limitations of the current work. The major threat to its validity is that although the experimental design controls for an effect of time, it does not control for an effect of order. We established in pilot trials that if patients first undertook the discrimination condition, they no longer thought that the stimulation alone condition was credible, they were unlikely to comply and they were likely to withdraw. Thus, by avoiding a systematic effect of these issues, we were unable to exclude an effect of order – perhaps discrimination is only effective if it is preceded by stimulation. Sample size is a common problem in this patient group and multi-centre collaborations such as TREND (Dutch Trauma Related Neuronal Dysfunction: [www.trendconsortium.nl](http://www.trendconsortium.nl)) are required. Finally, we did not measure cortical organisation and can only speculate on the basis of other work.

The present results suggest that the treatment used here is an effective and clinically viable treatment for some patients with CRPS. It is simple, requires inexpensive equipment (cork and pen lid for home program) and minimal training. It can be replicated at home and is perceived by patients as being credible. We have previously shown that a training diary increases participation with a home program [47], and a diary has the extra function here of encouraging patients to record their performance at the task, which may introduce a motivational element to training.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.pain.2007.10.021](https://doi.org/10.1016/j.pain.2007.10.021).

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