

A body-part-specific impairment in the visual recognition of actions in chronic pain patients

Marc H.E. de Lussanet^{a,b,*}, Frank Behrendt^{c,1}, Christian Puta^{d,1}, Thomas Weiss^{e,1}, Markus Lappe^{a,b}, Tobias L. Schulte^f, Heiko Wagner^{b,c}

^a Department of Psychology, Westfälische Wilhelms-Universität Münster, Münster, Germany

^b Otto Creutzfeldt Center for Cognitive and Behavioral Neuroscience, Westfälische Wilhelms-Universität Münster, Münster, Germany

^c Department of Motion Science, Westfälische Wilhelms-Universität Münster, Münster, Germany

^d Department of Sports Medicine and Health Promotion, Friedrich Schiller University Jena, Jena, Germany

^e Department of Biological and Clinical Psychology, Friedrich Schiller University Jena, Jena, Germany

^f Department of Orthopedics, University Hospital Münster, Münster, Germany

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ABSTRACT

Most people suffer musculoskeletal pain sometime in their lives. Although the pain usually disappears with the healing, it may become chronic. Recent evidence suggests that high-level cortical representations play a role in chronic pain. Here we hypothesized that the sensorimotor representations of the affected body parts are specifically inhibited with chronic pain. Thus, if these representations are not accessible for the actions performed by one's own body, neither should they be for the perception of actions performed by others. Chronic pain patients are often focused on possibly painful movements, but visual processes are not affected by chronic pain, so we expected that patients should have no problems recognizing point-light biological motion displays, but should be unable to extract detailed somatosensory and motor information from such displays. Indeed, we found that patients had no difficulty perceiving point-light biological motion, and were not impaired in judging manipulated weight from movements they would be able to perform. However, patients with chronic shoulder pain were specifically impaired to judge the weight from observed manual transfer movements, whereas chronic low-back pain patients were specifically impaired for trunk-rotation movements. This result gives important new insights into chronic pain. Also, this new impairment of biological motion perception is unique in that it is unrelated to visual deficits.

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1. Introduction

Chronic musculoskeletal pain is usually defined as frequent, strong pain lasting over an extended period (more than 3–6 months) [18]. There are 2 kinds of global explanations for such chronification, both of which may apply to some of the cases. First, current diagnostic tools might not be sensitive enough to diagnose the clinical state. The second line of explanation seeks the problem more in central pain processing than in peripheral mechanisms. Here we concentrate on the second line of explanation.

Evidence suggests that high-level, cortical mechanisms play an important role in both somatosensory and motor representations during pain [1,2,14,23,37]. For example, the motor imagery of

adopting specific hand postures may cause pain and swelling in patients with chronic hand or wrist pain [33]. Conversely, a recent study found that bilateral and unilateral back pain is associated with a lower accuracy in the judgment of visually presented trunk rotations, compared to healthy controls [5].

In addition to this evidence for perturbed cognitive processes, there is evidence that the cortical activities are changed in chronic pain patients. For example, the motor representation in the brain of the deep postural abdominal trunk muscles is shifted and altered in individuals with chronic low-back pain (CLBP) [47,49]. Similarly, the activity in the somatosensory cortex, evoked by electrical stimulation of the back of CLBP patients, is shifted [7]. Two-point discrimination accuracy in the low back as well as the performance on lumbopelvic positioning tasks is decreased in CLBP patients [24]. Also, CLBP patients draw the affected region in a distorted fashion [29].

On the other hand, the somatosensory cortex is also known to be centrally involved in the visual observation of actions and the

* Corresponding author. Address: Department of Psychology, Westfälische Wilhelms-Universität Münster, Fliednerstraße 21, 48149 Münster, Germany. Tel.: +49 251 8334182; fax: +49 251 8334180.

E-mail address: lussanet@wwu.de (M.H.E. de Lussanet).

¹ These authors share first authorship.

imagery of actions, especially when tools are involved [8,35,38,42,46]. Also, the somatosensory representations in the brain are highly somatotopic, even for visual judgments of actions [6,25,48]. Thus, we reasoned that, if chronic pain affects somatosensory representations in the brain, and if somatosensory representations are involved when we observe the actions of others, chronic pain might also interfere with action observation.

The aim of the study was to find out whether chronic pain does indeed interfere with action observation. For this, patients and healthy controls judged the invisible weight from visually presented movements, a task at which healthy subjects do well [40]. Some of the presented movements would be particularly painful for CLBP patients to perform, whereas the other movements would be particularly painful for chronic shoulder pain (CSP) patients. As the weight of a manipulated object is directly related to the somatosensory aspects of motor tasks, we reasoned that judging the weight should be especially affected by chronic pain.

We hypothesized that CLBP patients should be impaired specifically in judging the differences in lifted weight from movements involving trunk rotation, whereas the CSP patients should be impaired specifically if the visually presented weight is transferred overhead from one hand to the other. Further, the patients should be normal in their ability to describe the nonsensory nature of the presented action.

2. Methods

2.1. Subjects

CLBP patients ($n = 17$) and CSP patients ($n = 15$) were recruited from the Münster University Hospital Orthopedic Department (Table 1). The selection criteria were: 1) the pain was chronic, that is, the patient had suffered for at least 6 months; 2) the affected region did not overlap between the patient groups, that is, the CLBP patients did not report shoulder pain and the CSP patients did not report back pain; 3) no neurologic symptoms (paresis, incontinence), vertebral tumors, inflammatory vertebral disorders (spondylodiscitis, spondylitis, discitis), nor psychiatric disorders were present. Control subjects ($n = 20$) had no history of chronic pain, nor did they experience pain on the day of the experiment.

A number of patients had undergone a surgical operation between 20 years and 6 months before the experiment (Table 1). Eight of the CLBP patients had undergone a nucleotomy, 3 of them had an instrumented fusion of 2 or 3 lumbar vertebrae. Three of the CSP patients had prior surgeries (implantation of a shoulder hemiprosthesis, arthroscopy, and removal of calcific tendinitis, respectively). Pain ratings (Table 1) and performance measures of the operated patients were all within 1 SD of the patients without a prior surgery. To test whether a history of surgery influenced the results, we also analyzed the data without the operated patients (see Appendix A).

Participants gave written informed consent, in compliance with the Declaration of Helsinki. All procedures were approved by the local ethics committee of the University of Münster.

2.2. Visual stimuli

To test the hypothesis, we used a task in which the participants had to estimate the weight of invisible manipulated objects from point-light biological motion displays [3,40,41,45]. The point-light displays presented the manipulation of different weights, involving either a bending and rotation of the trunk, or a manual transfer transporting a load over the body from right to left, with the back supported (Fig. 1).

Kinematic data from 2 actors (ages 33/41, male, without acute or chronic pain) were recorded with a high-precision 3-dimen-

sional video system at 50 Hz (Qualisys Motion Capture Systems, Gothenburg, Sweden). In the trunk rotation movements, the actor lifted a box from the floor on his right, twisted his trunk, and placed it down on the floor on his left side. The object was a box ($32 \times 27 \times 32$ cm) with side-grips for holding, of 3 different weights (5, 10, and 15 kg). In the manual transfer movements, the actor sat on a bench with the back fully supported and leaning back by 45° . He took a dumbbell from the floor on his right side, moved it over his head, passed it to his left hand, and placed it on the floor to his left side. The dumbbell weighed 3.5 or 7.0 kg. The manual transfer movement was also recorded without dumbbell (0.0 kg).

From the recordings, computer-animated point-light stimuli (white dots on a dark background) were constructed (see Appendix A). Examples are presented in Fig. 1, where the points are connected for the sake of clarity. The 18 point-lights were located on the head, shoulders, elbows, wrists, hands, hips, knees, ankles, and feet of the actor, but not on the box or dumbbell. The stimuli measured 7×11 cm ($w \times h$) and 7×7 cm, respectively, for trunk rotation and manual transfer. A stimulus program written by one of the authors (M.de L.) using the standard software development tools for Macintosh OS X (XCode 3.1 and OpenGL; Apple, Cupertino, CA, USA) gave the written instruction, presented the point-light displays, and recorded the response.

On each trial, a point-light display was presented in a loop until the subject pressed the space bar. The cycle time of the trunk rotation movements was 6.4 seconds, and of the manual transfer movements, 9.0 seconds. On the space bar-press, the point-light display disappeared and was replaced by a response display. This response display consisted of a slider, controlled by horizontal movements of the mouse, that pointed at a horizontal scale (about 15 cm long) marked with ticks and the numbers 0–20 kg. Once the slider had been moved, another press of the space bar button confirmed the response setting and started the display for the next trial.

2.3. Protocol

Subjects sat in front of a laptop (13" MacBook; Apple) with both forearms resting on the table in a quiet room. They positioned themselves so that they were as comfortable as possible.

Before the experiment started, each participant saw a frontal lifting sequence and a trunk rotation sequence, and was asked to describe these visual biological motion stimuli orally. All patients and controls could spontaneously, accurately, and vividly describe the actions that were represented by the point-light figures. They then rated the just-seen action on a 100-mm visual analogue scale (VAS), in response to the question: "How painful would you rate the movement if you would perform it?"

Participants were then instructed to estimate the lifted weight in a total of 120 sequences using the response slider. No information about the weights or the number of different weights was given to the participants. The experiment took about 25 minutes, depending on the response times. Participants were instructed to report as accurately as possible.

The 120 trials consisted of the 2 movements: trunk rotation and manual transfer, executed with the 3 different weights, each presented 20 times in a randomized order. No feedback was given on the performance, neither during the practice period nor during the experiment.

2.4. Analyses

We were interested in the ability to discriminate between the different weights, that is, the dependency of the estimated weights on the actual weight in the presented movement. The required number of subjects in each group was estimated as follows. On

Table 1
Characteristics of the subjects.

Subjects	Sex	Age, y	Duration, mo	CPI	4WPI	OP	Reported current medications
CLBP1	F	49	22	80	80	+	Palladon, Pregabalin
CLBP2	M	26	72	61	78	–	Ibuprofen
CLBP3	F	37	216	80	78	+	–
CLBP4	M	67	>60	71	88	–	Ibuprofen
CLBP5	M	66	120	38	40	–	–
CLBP6	F	55	384	58	59	–	Diclofenac, Piroxicam, Paracetamol
CLBP7	M	46	264	93	93	–	–
CLBP8	M	66	20	64	64	+	Diclofenac
CLBP9	M	67	480	67	39	–	Diclofenac
CLBP10	M	67	188	89	89	+	Tilidine, Tramadol
CLBP11	F	48	120	70	74	+	Durogesic
CLBP12	M	38	114	59	40	–	–
CLBP13	M	53	9	58	46	–	Ibuprofen
CLBP14	F	41	180	15	63	–	Diclofenac
CLBP15	F	67	>45	13	19	–	–
CLBP16	F	31	24	0	75	+	Diclofenac, Novalgin
CLBP17	F	46	6	60	60	+	–
Mean (SD)		51 (14)	138 (136)	57 (27)	64 (21)		
CSP1	F	70	72	80	80	–	Ibuprofen, Metamizole
CSP2	M	40	33	25	60	+	–
CSP3	M	46	>60	5	53	+	Tramadol
CSP4	M	46	48	74	89	+	Ibuprofen, Paracetamol
CSP5	M	64	13	49	64	–	Piroxicam
CSP6	F	68	132	50	74	–	Dexibuprofen
CSP7	F	33	10	80	78	–	Ibuprofen
CSP8	F	53	300	50	50	–	Diclofenac
CSP9	F	39	36	30	20	–	–
CSP10	M	46	24	35	45	–	–
CSP11	M	52	6	70	70	–	–
CSP12	F	41	36	55	55	–	Ibuprofen
CSP13	M	60	60	45	45	–	–
CSP14	M	55	9	60	60	–	–
CSP15	M	42	14	60	90	–	Ibuprofen, Voltaren
Mean (SD)		50 (11)	57 (75)	51 (21)	62 (19)		

CLBP, chronic low-back pain; CSP, chronic shoulder pain; CPI, current pain intensity, rated on a 100-mm visual analogue scale (VAS) in response to the question: "How would you rate your current pain intensity?"; 4WPI, 4-week pain intensity rating response: "How would you rate your average pain over the last four weeks?"; OP, surgically operated: +,+, underwent surgical operation to treat the pain (all more than 6 months ago).

The control subjects (n = 20; 60% female) were aged 47 years (SD 14 years). The CLBP group was 47% female and the CSP group 40%.

the basis of the literature for point-light motion [3,40,41,45] and for filmed motion [4,13,36], we expected that the responses would depend on the presented weight with a slope of about 0.5 for the control group. Depending on the condition of interest, we hypothesized for the respective patient groups a slope of near zero. From pilot experiments, we expected an SD in the order of the effect size, so $d = 1$. Thus, according to a power analysis for a 1-sided *t*-test, a significance level of 0.05, and a power of 0.8, the required group size would be $n = 13$ (we used *pwr.t.test*-function in R, version 2.14.0). We aimed at $n = 15$ minimum. For the subjects' responses to each movement type, 2 linear mixed-effects models without intercept and subject as a random factor were computed: one for the *manual transfer* movements and one for the *trunk rotation* movements. For this analysis, the *lmer*-function of the *lme4* package in R was used. In order to obtain data without intercept, the average judged weights were subtracted from the judgments for each subject and movement kind. The same was done for the presented weights. The interaction effects of the different Subject Groups were modeled by 2 dummy-coded binary variables.

The models were evaluated using the *anova*-function of R. We first checked that each model was better when the interaction effects of Subject Group were included, which was indeed the case for both movement kinds ($P < 0.02$). Next, the possible influence of confounding variables was tested. For this, each model was stepwise expanded with one of the following factors as covariates: age, gender, the current pain intensity rating, or the 4-week pain intensity rating (see Table 1). The analyses of variance (ANOVAs) showed that none of the possible confounding variables

significantly improved the models. This was also confirmed by the Akaike and Bayesian information criteria (AIC, BIC). Therefore, the final statistical comparisons were made on the basis of the model without the inclusion of confounding variables.

For the a priori planned pairwise comparisons between the 3 subject groups, we used the *posthoc.fnc*, with a Bonferroni correction for 3 comparisons.

We also used a second analysis, computing the regression slopes. We find this analysis more straightforward and easier to follow than the linear random-effects model, but it has the disadvantages of a 2-step analysis and of disregarding the intertrial variances. This second analysis gave essentially the same results as the above linear mixed-effects model (see Appendix A).

Response time was defined as the start of the stimulus presentation to the first press of the space bar, when the stimulus was replaced by the response slider. Note that the trunk rotation movements lasted less time than the manual transfer movements, which is likely to affect the response times. To test for effects of response time, an ANOVA was performed on the mean response times, with Movement Type and Weight as within-subject factors, and Group as a between-subject factor.

3. Results

3.1. Discrimination between the lifted weights

To quantify for each subject the weight discrimination, that is, the ability to discriminate between the lifted weights, the slope

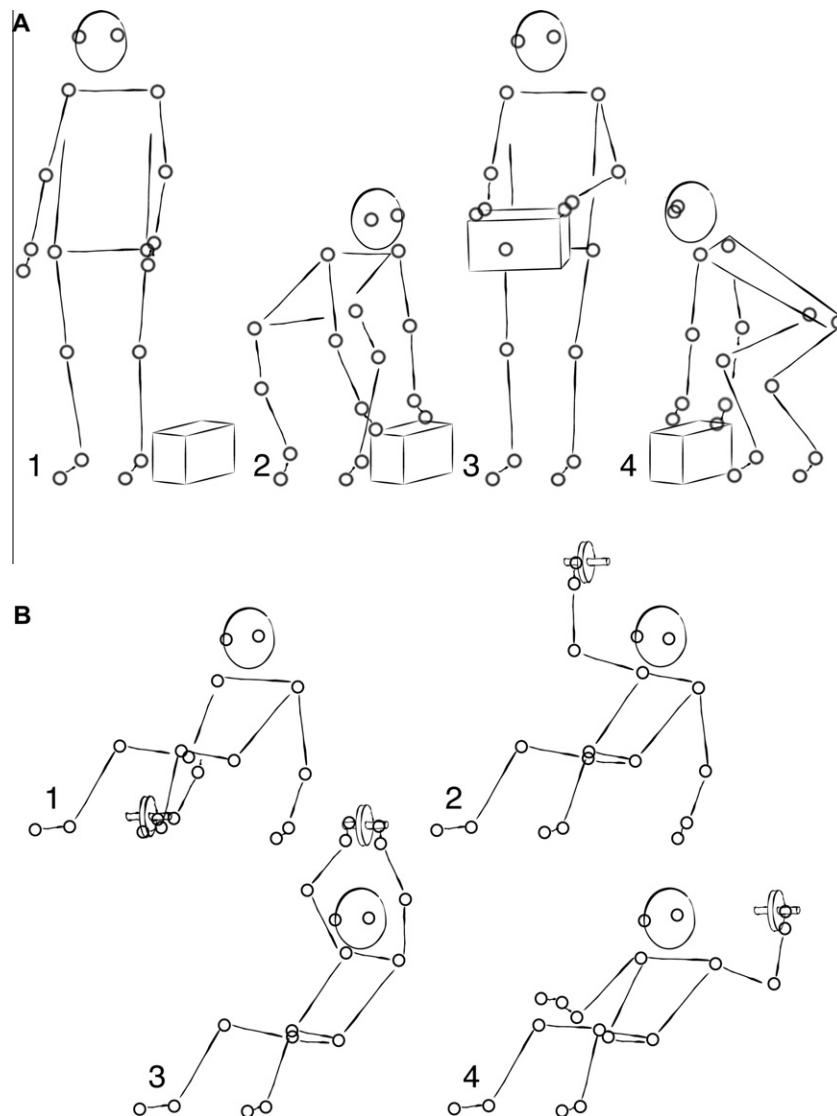


Fig. 1. Static representations of two of the point-light stimuli. (A) Trunk rotation. (B) Manual transfer. In the experiments, only the points were visible; the connecting lines are for illustrative purpose only.

of a regression analysis was computed. This is displayed for 2 typical subjects in Fig. 2. A slope of approximately 0 (the CLBP patient) indicates that the subject did not judge the point-light movements with heavy loads heavier than those with light loads. A slope of 1 is expected for perfect judgments, but the healthy control did not reach this, indicating that the task was difficult. Slopes of <0.5 for healthy subjects have mostly been found in earlier work [3,4,13,36,45].

Fig. 3 shows the weight discrimination results for the present study. The control participants, on average, had a slope of 0.47 for the weight discrimination in the trunk rotation movements and a slope of 0.24 for the manual transfer movements. A detailed analysis of the slopes is presented in the supporting online material (Appendix A).

The statistical analysis was performed on the reported judged weights (Fig. 4). The linear mixed-effects models without intercepts described the data best without the inclusion of gender, age, current pain intensity, or 4-week pain intensity as covariates, so these variables were all omitted. The a priori Bonferroni-corrected comparisons showed that the CLBP patients discriminated the weights significantly worse than the controls for the trunk rotation movements ($t_{2485} = 3.7$, $P_{\text{corrected}} = 0.0006$), but not

for the manual transfer movements ($t_{2473} = 0.9$, $P_{\text{corrected}} > 0.9$). The CSP patients were significantly worse than the controls for the manual transfer movements ($t_{2473} = 2.8$, $P_{\text{corrected}} = 0.017$), but not for the trunk rotation movements ($t_{2485} = 2.0$, $P_{\text{corrected}} = 0.12$). For the manual transfer movements, the two patient groups also differed significantly ($t_{2473} = 2.6$, $P_{\text{corrected}} = 0.030$).

3.2. Judgment errors

The judgment error is simply the difference between the reported judgment and the presented weights. The errors can therefore be read directly from Fig. 4 if one compares each bar with the corresponding horizontal line. On the average, the subjects of all groups underestimated the weights in the trunk-rotation task (mean error: -1.8 ± 2.7 kg, Mean \pm SD, $t_{51} = -1.8$), and overestimated the weights in the manual transfer task (mean error: 3.5 ± 3.0 kg, $t_{51} = 3.5$; Fig. 4). ANOVAs on the mean error of each subject and weight were performed, one for the manual transfer and one for the trunk rotation movements. Consistent with the above analyses of the discrimination between the weights, both ANOVAs showed significant main effects for presented Weight [$F(2,97) > 300$; $P < 0.0001$], as well as small, significant interactions

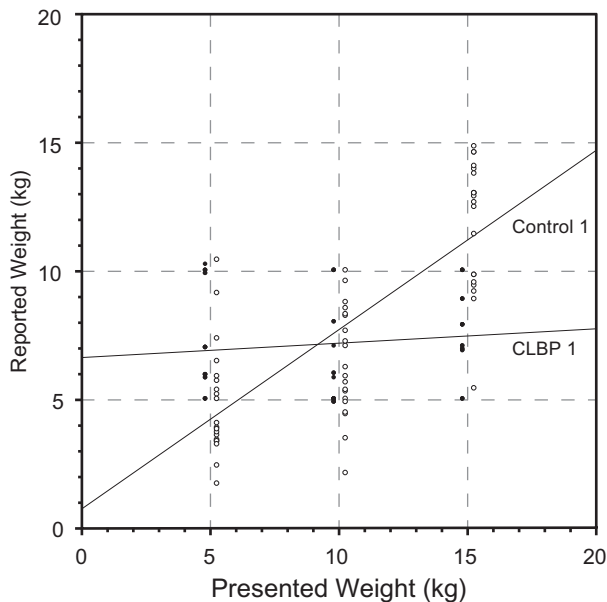


Fig. 2. Two examples of the weight discrimination, for subjects with chronic low-back pain (CLBP 1; filled circles) and Control 1 (open circles), on the trunk rotation movements. The weight discriminations, computed as the regression slopes, were 0.056 and 0.70, respectively.

between subject Group and Weight [$F(4,97) > 4.0$; $P < 0.05$]. Post hoc t -tests showed that there were no significant differences between the subject groups ($P_{\text{corrected}} > 0.75$).

3.3. Response times

The response times did not differ significantly between subject groups nor between weights. The response times were significantly shorter for the trunk rotation movements (8.3 ± 3.0 s) than for the manual transfer movements (10.9 ± 4.4 s), [$F(1,49) = 53.9$; $P < 0.0001$], and there were no significant interactions. The response times to each movement were, on average, 1.9 seconds longer than the cycle times (6.4 and 9.0 s, respectively), which probably explains the effect.

3.4. Estimated painfulness of the visual stimuli

To verify that the movements were perceived as painful, all subjects gave ratings of how painful the movement would be to

perform (see Section 2). The CLBP patients rated the trunk rotation as highly painful (Mean $69 \pm \text{SD } 17$ mm on the 100-mm VAS), but not the manual transfer movement (5 ± 13 mm). The CSP patients rated the manual transfer movements as highly painful (52 ± 18 mm), but not the trunk rotation movement (4 ± 12 mm). All control subjects rated the movements as painless (0 mm).

4. Discussion

Since high-level cortical mechanisms presumably play an important role in chronic musculoskeletal pain [1,2,14,23,37], and include somatosensory and motor representations of the affected body parts [7,47,49], we hypothesized that chronic pain should specifically interfere with the recognition of sensorimotor aspects of visually presented actions. Indeed, patients with CLBP were impaired at recognizing differences in the lifted weight for movements that involved a trunk rotation, but not for manual transfer movements. Conversely, patients with CSP were impaired at recognizing differences in the lifted weight for manual transfer movements but not for movements that involve a trunk rotation. Thus, we demonstrated for the first time that pain patients are specifically impaired in the perception and description of movements that would lead to pain when they would perform the movements themselves.

The current finding adds important fundamental understanding because it demonstrates an interaction between two well-established cognitive functions, that is, between chronic pain sensations and the judgment of actions performed by others. Our finding is not obvious, since the anatomical overlap between the networks, from which we hypothesized the impairment, does not imply a significant functional interaction. We therefore argue that the impairment is not caused by visual processing mechanisms (even though the task was visual).

4.1. Visual recognition of actions in chronic pain

It is known that pain interferes with sleep, and is thus regularly associated with the symptoms of chronic sleep deprivation such as depression, task interference, reduced vigilance, and increased alertness [28]. However, although chronic pain patients display an increased attention for avoidable movements, chronic pain apparently does not affect attention directly [2,19,34,39]. The present study corroborates these findings in that the chronic pain patients were different from the control group only in their weight discrimination ability and only for the movements that were rated as painful.

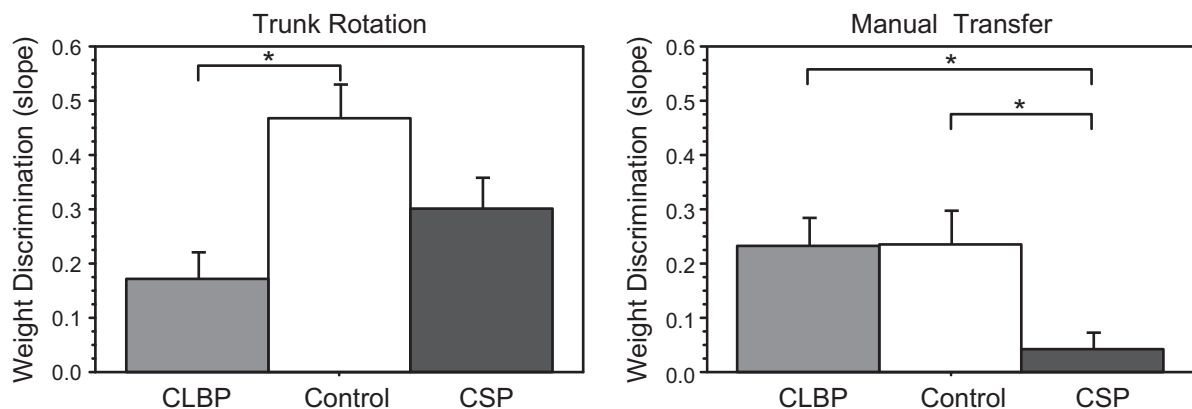


Fig. 3. The mean (\pm SEM) weight discrimination slopes of the presented weight. The slopes were calculated for each subject individually as the regression slope of the estimated weight on the presented weight. Asterisks (*), significant effect; CLBP, chronic low-back pain; CSP, chronic shoulder pain.

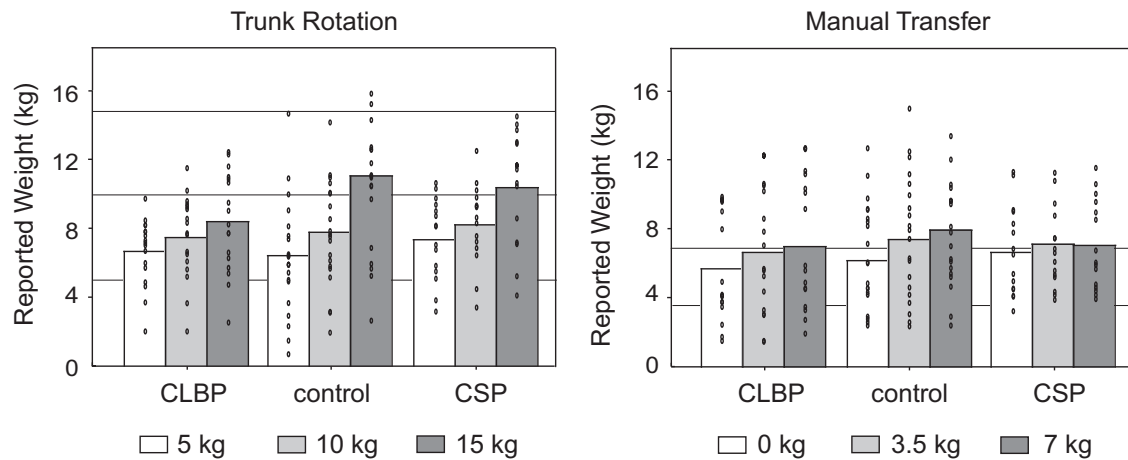


Fig. 4. The mean reported weight judgments for the point-light trunk rotation movements (left panel) and manual transfer (right panel) movements, for the chronic low-back pain (CLBP), Control, and chronic shoulder pain (CSP) groups. Mean individual judgments are indicated as dots. The presented weights are shown in the legend and as horizontal lines in each panel.

Point-light biological motion is devoid of image information but is nevertheless easily recognized [16]. Such stimuli activate a cortical network including extrastriate visual cortical areas, ventral temporal (fusiform) areas, and the right posterior superior temporal sulcus (pSTS) [11,27], as well as premotor and somatosensory areas [25,43]. Healthy human subjects who subsequently lift different, unexpected weights display increased activity in the inferior parietal lobe, the primary somatosensory cortex, and the motor cortex [15]. Thus, motor and somatosensory experiences can be expected to be essential for an accurate judgment of weight from *visually* presented lifting movements.

The fusiform cortex and the pSTS are involved with the impaired perception of point-light biological motion in autism [17]. Also, lesions of the pSTS cause specific impairments in the recognition of biological motion [44,51]. Furthermore, individuals with congenital prosopagnosia not only are impaired in the recognition of faces, but also in the recognition of point-light biological motion [20]. All these impairments cause delayed and inaccurate responses, and seem to be primarily caused by malfunctioning in the visual cortical system.

The impairment that we found in the present study is of a different nature. All patients could easily and spontaneously recognize and describe the actions represented by the stimuli. Also, the patients' descriptions for painful and painless movements did not differ in precision or richness. The patients were also normal in their response times and the average judgment of the loads for each movement type. However, the patients did rate the painful actions as painful on a VAS. Consistently, the judgment of somatosensory and motor aspects, that is, the lifted weight, was affected for painful movements. This impairment is thus different from the typical impairments that are attributed to impaired visual processing, in that it does not affect visual recognition and response time, and is highly action-specific.

This new kind of impairment might have parallels with the finding that an individual born without hands, who had phantom experience of the hands, tended to interpret implied hand movements in a kinematically realistic manner, whereas a handless individual without phantom experiences did not [9].

4.2. Clinical implications

The method developed in the present study provides a potentially simple way to identify the specific impairment in the visual recognition of actions in chronic pain patients using visually

presented actions. For this, it is important to understand why the pain patients were impaired on the weight-judging task.

One interpretation of our results might be that the inability to discriminate the weight handled in a visually presented action is due to an inability to move. We do not favor such an explanation. In an experiment comparable to ours, patients suffering from Parkinson disease had to judge the lifted weight (a hand-held container) from a short movie of a human arm [36]; no significant difference was found between Parkinson patients and healthy controls in their ability to discriminate between the lifted weights. Since Parkinson disease is caused by a malfunctioning of the basal ganglia, it seems likely that they can judge the weight from visual present movements because their high-level (cortical) motor and somatosensory representations of such movements are intact. Thus, the inability to move does not necessarily impair sensorimotor judgment of such movements when these are presented visually.

Two kinds of mechanisms might explain our results and, in part, why motor-centered rehabilitation programs often prove ineffective, since these are usually strongly based on exercise therapy programs (eg, for low back pain [26,50]).

First, our finding fits in well with neglect-like phenomena in chronic pain [10,22,31]. If chronic pain causes the suppression of cortical sensorimotor networks in a manner such that the overlapping networks of action observation are affected as well, then the symptoms should be expressed as a form of sensory neglect and spatial affordance suppression on the peripersonal space [21]. Consequently, chronic pain patients might fail in the embodiment of movements and actions that involve the affected region.

Second, joint kinematics of phantom limbs can change dramatically after learning, and this was found to interfere with motor imagery tasks [30,32]. Thus, if patients would similarly learn different kinematic abilities of the back, this might interfere with the visual judgements of the normal kinematic range.

The current findings are potentially of clinical relevance to develop new diagnostic tools and therapeutic approaches. Other recent experimental approaches may be combined in such a diagnostic tool (eg, [5,37]).

4.3. Limitations of the study

To avoid learning effects, we chose a cross-sectional rather than a longitudinal design. The disadvantage is that the results provide no information regarding the development of the deficit to judge

weight differences. Although the performance did not depend on the duration of the pain (cf. Table 1), this may simply be due to the small sample, or because the deficit develops over the first 6 months along with the chronification process.

Some of the healthy control participants performed as poorly as the patients. Thus, it is possible that some of the patients would have performed poorly on the task even before the disease started. One possibility for the poor performance of some control subjects is that the use of point-light stimuli made the task too difficult for some subjects.

Another possibility is that there are large differences between healthy participants to match their own motor representations to other people's actions. In the first case, it might be advantageous to make the task easier (eg, by presenting real videos). In the second case, one might speculate that the inability to judge other people's actions is a factor in the development of chronic pain.

The present study cannot distinguish whether the nature of the pain plays a role in the impairment to judge lifted weight. It was recently found that substantial reductions in the thalamic gray matter occur in pain patients with neuropathic syndromes, but not in other chronic pain patients [12]. If we take surgical treatment as an indication of neuropathic pain (cf. Table 1), then the data do not indicate that the nature of the pain differentially influenced the judgments. For both operated and nonoperated patients, the judgments suffered specifically for the judgments of weights lifted with affected body parts, but not for the other movements.

Several more questions remain to be answered. It remains unclear how long it takes before action recognition deteriorates with chronic pain; we sampled only patients with a pain history of at least 6 months. Another interesting issue is whether the deterioration can be reversed if the pain is relieved (but see Martel et al. [26]). Further, it is not clear whether the acute and the long-lasting intensity of the chronic pain have differential effects on the level of deterioration.

4.4. Conclusion

The current findings demonstrate that a direct link exists between chronic pain and the recognition of other people's actions and thus, indicate that chronic pain functionally changes the cortical networks that are involved in action recognition. A likely explanation is that the execution of actions by the affected body parts is suppressed at a high (cortical) level. Consequently, it might be possible to treat the chronic nature by therapies that aim at the reactivation of these cortical networks. Furthermore, the judgment of weight is of potential diagnostic value in that the cortical involvement in different kinds of pain syndromes can be measured.

Conflicts of interest statement

Except for the government funding reported below, none of the authors has any financial or other relationships that might lead to a conflict of interest with respect to this manuscript.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.pain.2012.04.002>.

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