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A brief intervention utilising visual feedback reduces pain and enhances tactile acuity in CLBP patients

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Abstract

BACKGROUND:

Chronic low back pain (CLBP) is a serious health problem in industrialised countries and the efficacy of current treatment options is unsatisfying.

OBJECTIVE:

The present study examines the effects of a combined intervention that utilizes visual feedback, motion and sensory discrimination training in CLBP patients.

METHODS:

30 patients of an outpatient orthopaedic rehabilitation unit were randomly assigned to either feedback or control group. In addition to standard treatment, patients of the feedback group received 6 feedback sessions where they watched the image of their back during a brief 2-point discrimination training and, after that, while they were tilting their pelvis up and down on the left and right side using their lumbar musculus multifidus solely. The control group received 6 sessions consisting of 2 units' physiotherapy, relaxation training and movement training (walking) each.

RESULTS:

A significant effect on self-reported pain and sensory discrimination threshold could be found for the feedback intervention, while, as expected, other pain related variables, like pain anxiety, pain vigilance, depression and cognitive appraisal of pain remained unchanged.

CONCLUSIONS:

These findings imply that very simple feedback interventions without major technical requirements could be a valuable supplement to standard treatment in CLBP.

Key Words: low back pain, tactile acuity, visual feedback, training, cortical reorganisation

1. Introduction

Acute low back pain is a common health problem in industrialised countries: With a lifetime prevalence of about eighty percent [1], the majority of people are affected at least once in their lives. In most cases low back pain is classified as non-specific and affected persons recover within a few months [2] , but about fifteen percent develop chronic low back pain (CLBP) symptoms [3,4]. Healthcare and socioeconomic costs resulting from CLBP are enormous [5] and rising due to increasing prevalence rates [6], escalating amounts of prescribed analgesic medication [7] and a growing number of surgical treatments [8].
In many cases, no MRI-defined lesions [9] or other biomechanical causes [10-13] can be identified as causal factors for CLBP, but instead, maladaptive pain behaviour, inappropriate pain-related attitudes and beliefs [14,15] as well as life-stress and depression [16,17] have been shown to predict the development of chronic low back pain. Encouraging patients to use active coping strategies including exercises, patient education, pharmacotherapy, physiotherapy and psychotherapy are recommended by the majority of current treatment guidelines [18-20]. Effect sizes for each of these interventions are in the medium range when compared to sham therapy [21] and decrease substantially when compared to standard treatment [22]. Notably, no treatment option seems to be superior to another [23] and a combination of evidence-based treatments does not raise effect sizes. In many cases, patients are still suffering from pain after treatment [24]. Recent reviews of treatment of CLBP therefore conclude that more effective interventions are urgently needed [10,21].

On the other hand, for patients suffering from complex regional pain syndrome (CRPS) and phantom limb pain it has been shown that interventions focusing on dysfunctional cortical changes caused by chronic pain coincide with reduced pain levels. Those interventions typically include two point discrimination threshold (TPDT) training and visual feedback during movement as well as during TPDT training [25-28]. However, CLBP patients also

show increased horizontal two point discrimination threshold levels and an impaired movement control [29,30], especially a reduced ability to activate deep trunk muscles like the musculus multifidus [31,32] and very first empirical evidence indicates that visual feedback leads to an immediate reduction of movement related back pain [33].

For this reason our study examined effects of a brief intervention that combines visual feedback, TPDT-training and controlled movement of the lower back on perceived pain levels and TPDT performance in patients suffering from CLBP. As only tactile acuity and motor control skills were targeted, we hypothesized that our intervention would mainly affect somatosensory representation of the back resulting in improved TPDT performance and reduced pain intensity while no effects would be present on pain anxiety and vigilance, cognitive appraisal to pain, depression and pain coping strategies because these variables are based on mechanisms more distant from the targeted sensory processes.

2. Material and Methods

2.1 Participants

Thirty-threepatients of an orthopaedic rehabilitation ward in Bamberg, Germany suffering from CLBP according to ICD10 criteria (M53.* or M54.*) were recruited. All of them had a history of at least 6 months of low back pain (therefore also meeting the IASP criteria for chronic pain) [34], were 18 years or older, did not suffer from cognitive impairment that would limit their participation (intelligence level above 85, estimated using a vocabulary test, see “measures” section) and had no history of psychiatric disorders or clinical signs of acute depressive symptoms measured by self-report and clinical expert rating.

One female patient did not agree to participate. The remaining 32 patients were randomly selected to either feedback or control group and underwent pre-test procedures. One female patient had to be excluded from the control group because she reported zero current back pain at pre-test evaluation. One male subject of the feedback group had to quit rehabilitation because of a newly herniated disc.

The study protocol was approved by the Ethical Review Board of the University of Bamberg. After complete description of the study, written informed consent was obtained from all subjects.

2.2 Procedure

Participants were randomly assigned to feedback group (FG) and control group (CG) using a random list created before the inclusion of the fist participant (external randomisation). Both groups received identical treatment for about 6 hours every day according to the evidence based modules for chronic back pain [35] as specified by the German statutory pension insurance scheme (Deutsche Rentenversicherung) consisting of relaxation training,

movement therapy (physiotherapy, sports therapy), massage, pain education intervention as well as psychological and social consultation if necessary. The treatment was offered during their stay at the rehabilitation ward. None of these standard therapeutic modules utilized visual feedback in any manner.

2.2.1 Intervention

FG received six feedback sessions during a two week intervention period (3 sessions per week) lasting about 20 minutes each. Patients lay prone with their faces downward on a bench while watching an image of their back recorded in real time by a webcam that was placed on a rack behind and above (see fig. 1). At the beginning of each session TPDT levels were obtained following the procedure described in section 2.2.2. Then a TPDT training was administered: Above and slightly below the individual threshold distance (+/- 5 mm) one or two points were touched in a randomised order and patients had to report whether they noticed one or two stimuli. Immediately after each stimulation, visual feedback was turned on so that the participants were able to see where on their back the stimulation was performed and whether their judgement was correct. This procedure was repeated 10 times for each side. After the threshold training, subjects had to alternately tilt their pelvis up and down on the left and right side using their lumbar musculus multifidus (MM) solely for about 10 minutes. Subjects had been taught this movement before by a senior physiotherapist, who also surveyed accuracy of the movement. While doing so, patients watched themselves on the computer screen.

Instead of 6 feedback sessions, CG patients received 6 additional 30 minute sessions consisting of 2 units of physiotherapy, relaxation training and movement training (walking) each.

2.2.2 Measures

All patients had to keep a pain diary during the two weeks duration of the intervention. They were asked to estimate their resting low back pain levels three times a day using a visual analogue scale (VAS) reaching from 0 (no pain) to 10 (unbearable pain). For statistical analyses mean values of VAS scores during day 1 (beginning of the intervention) and day 14 (end of intervention) were used.

Horizontal two-point-discrimination threshold levels were measured by a plastic calliper ruler for patients of both groups on both sides of the participant's lower back on day 1 and 14 according to an established protocol [36]. Stimuli were applied at the height of the third lumbar vertebra with a medial point of 5 cm from the midline. Following the procedure described in [37], a descending and an ascending series were performed (steps of 5 mm between minimum 10 and maximum 100 mm). The threshold was defined as the minimum distance between the two calliper points necessary that the participants were able to perceive two distinct points. Since no difference could be found between left and right side (t-tests for paired samples: $t_{(29)}$=-.474, p=.639 for pre-assessment and $t_{(29)}$=.423, p=.676 for post-assessment), mean values of thresholds for left and right side were used for statistical analyses.

The German Multi-Choice Vocabulary Intelligence Test ("Mehrfachwahl-Wortschatz-Intelligenz Test" MWT-B) [38] was used to screen for cognitive impairment that would exclude participation.

To evaluate possible effects on pain attitudes and pain behaviour, the Pain Vigilance and Awareness Questionare (PVAQ) [39], the Pain Catastrophizing Scale (PCS) [40], the Pain Anxiety Symptom Scale (PASS) [41] and the Multidimensional Pain Inventory (MPI) [42] were administered. The PVAQ was developed as a comprehensive measure of attention to

pain and has been validated for use in chronic pain and nonclinical samples. It consists of 16 items that are rated on a 6-point scale assessing awareness, vigilance, preoccupation, and observation of pain. For further analyses, we used the combined sum score of the PVAQ. The PCS was developed as a measure of catastrophizing related to pain. It contains 13 items that can be divided into 3 subscales, namely rumination, magnification, and helplessness. The items are rated on a 5-point scale. For further analyses, we used the combined sum score of the PCS. The PASS is composed of 4 subscales—cognitive anxiety, escape/avoidance, fearful appraisal, and physiologic anxiety—and is designed to measure fear of pain across cognitive, behavioral, and physiologic domains. The items are rated on a 6-point scale. For further analyses, we used the combined sum score (40 items) of the PASS.

The Multidimensional Pain Inventory (MPI) covers three sections containing several subscales that assess a wide range of aspects concerning pain experience. All items are rated on a 7-point scale.

Depression symptom levels were obtained with the Beck Depression Inventory (BDI) [43] and the Hamilton Depression Symptom Scale (HAMD) [44] scores; HAMD scores were rated by the physicians of the rehabilitation ward.

2.2.3 Statistical analyses

To screen for differences between CG and FG at pre-test time before treatment, in a first step, chi-square tests (surgery, gender, pain medication and partnership) and t-tests for independent samples (all other variables of table 1 and all variables listed in table 2) were performed. Then, to avoid multiple testing, multivariate analyses were computed using treatment group (FG vs. CG) as group factor and “time” (pretest at day 1 vs. posttest at day 14) as within subject factor with the following (groups of) dependent variables that were included simultaneously: pain intensity (VAS mean values, MPI subscale “pain severity”), depression

(HAMD, BDI), MPI pain impact (subscales “Interference”, “Life Control”, “Affective Distress” and “Support”) , MPI response by significant others (subscales “negative responses”, “solicitous responses” and “distracting responses”) and MPI activities (subscales “Household chores”, “Outdoor work”, “Activities away from home" and “Social Activities”).

For those groups of variables where multivariate analyses yielded significant ($\alpha < 0.05$) interaction effects (group x time) and thus indicated differential effects of feedback treatment, univariate analyses of variance using treatment group (FG vs. CG) as group factor and “time” as repeated measures factor were performed for each dependent variable of the corresponding group.

For the depression and MPI pain impact group univariate analyses were performed despite nonsignificant multivariate interaction effects, because numerical values for these measures pointed to possible effects that would contradict our hypotheses.

Univariate analyses using the same design were performed for 2-point discrimination threshold, PVAQ, PASS and PCS total scores.

Kolmogorov-Smirnov tests and Levine tests were performed to check for normality and h omogeneity of variance of all scores used in the analyses of variance.

Effect sizes for the entire pretest-posttest-control group design (d_{ppc}) as well as separate estimates for the control and the feedback intervention alone (d_{pp}) were calculated according to the following formulas [45]:

$$d_{ppc} = c_1 \left[\frac{(M_{post,F} - M_{pre,F}) - (M_{post,C} - M_{pre,C})}{SD_{pre,CF}} \right] \quad \text{with} \quad SD_{pre,CF} = \sqrt{\frac{(n_T - 1)SD_{pre,F}^2 + (n_C - 1)SD_{pre,C}^2}{n_F + n_C - 2}}$$

$$\text{and} \quad c_1 = 1 - \frac{3}{4(n_T + n_C - 2) - 1}$$

$$d_{pp} = c_2 \left[\frac{(M_{post} - M_{pre})}{SD_{pre}} \right] \text{ with } \quad c_2 = 1 - \frac{3}{4(n-1) - 1}$$

3. Results

Clinical and demographic characteristics as well as questionnaire results of all participants are listed in tables 1 and 2 - the groups did not differ in any of the measures (t-values between .04 and 1.49, n.s.; χ^2 for surgery, gender and pain medication .600, .144, .000, n.s.; Fisher's exact test for partnership n.s.). This also applies to the numerical differences in VAS pain (t=1.30, p=.204) and MPI "pain severity" (t=1.14, p=.263).

Results of multivariate and univariate ANOVAS are shown in table 2. Deviations from normality could only be found for HAMD (Z=1.575, p=.014) and MPI II "solicitous responses" scores (Z=1.720, p=.005) before treatment. Homogeneity assumption was violated for HAMD (F=5.524, p=.026), MPI I affective distress (F=7.809, p=.009), and PCS (F=4.304, p=.047) scores. Multivariate analyses yielded significant interaction effects for pain measures (VAS pain and MPI "pain severity"), MPI-section II and PVAQ score, while no significant interaction effects for depression and MPI pain impact and activities measures could be found.

Univariate analyses for pain measures revealed significant interaction effects for VAS pain extracted from the patients' pain diary as well as the MPI "pain severity" subscale (see table 2). Inspection of the mean values for the two groups shows that pain scores were reduced to a greater extent in the FG than in the CG (mean and individual pain scores are shown on the left side of fig. 2).

Univariate analyses for MPI section II measures yielded significant interaction effects for "solicitous responses" and "negative responses" scores, while no interaction effect for "distracting responses" could be found. MPI – scores for "solicitous responses" decreased in CG from pre- to posttest while values for the FG remained roughly unchanged, whereas scores for "negative responses" apparently decreased in FG while they increased in CG.

Further, a significant interaction effect for 2-point discrimination threshold could be found. Threshold values decreased for FG while the CG's values stayed almost constant (see table 2 or right side of fig. 2).

No interaction effects indicating impact of feedback treatment on PASS, PCS, BDI and HAMD scores could be found. However, pain-related attention (measured by PVAQ scores) was reduced in FG patients and elevated in CG patients after treatment as the corresponding interaction effect reaches statistical significance.

To determine, whether changes in the solicitous and negative responses as well as in attention to pain might have moderated the effects of the experimental treatment on pain (VAS) and 2-point discrimination threshold, changes (pre-test minus post-test scores) in all of these variables were subjected to correlation analyses.

The corresponding results are shown in table 3. As can be seen there, changes in solicitous responses, negative responses and attention do not seem to be associated with variations in two point discrimination threshold and pain (VAS) and thus cannot be responsible for changes in these variables.

However, a substantial correlation of changes in pain (VAS) and changes in two point discrimination threshold could be found, suggesting that changes in both variables might have been partially due to the same mechanism.

4. Discussion

The results described above indicate that even very brief visual feedback interventions seem to be effective for patients suffering from CLBP with respect to back pain intensity (VAS rating) and somatosensitivity (two-point discrimination threshold). Patients receiving feedback treatment for two weeks in addition to standard rehabilitation therapy showed improvements to a greater extent compared to the control group who received an equal number of sessions but only of standard treatment.

Still, the therapeutic situation for CLBP is disappointing. Evidence-based treatment options provide only small to medium benefits, when compared to sham therapy / placebo. Effect sizes for NSAI drugs, spine manipulation, acupuncture and behavioural therapy - obtained in RCTs - range from .40 to .60. Efficacy estimates decrease substantially when these treatments are compared to other forms of intervention and the majority of studies did not even reach clinically important change scores (often, for example, a reduction of pain symptoms by 30 percent is recommended [46]).

Given the fact, that our participants received only 6 sessions and the total duration of the intervention was not more than two hours, the effect sizes for pain intensity, that are above the average effect range reported for conventional CLBP treatment, are quite impressive. The decrease of about 35% in VAS pain and 29% in MPI “pain severity” is meaningful even in terms of clinically important changes.

The question how these - relative to the therapeutic time and effort - substantial changes in pain intensity could be achieved in our sample will be discussed below.

Interventions targeting cortical reorganisation - a possible option?

Wand and O’Connel [47] have suggested that the unsatisfactory outcome and the finding that there is mainly no difference in the efficacy of uni- and multimodal treatment might be

explained by the assumption that the main problem of CLBP does not lie in the back (as suggested by many treatment rationales) but within the brain and can be framed as a problem of cortical reorganisation and degeneration as a long term effect of chronic pain.

CLBP patients show decreased lumbar tactile acuity measured by TPDT or graphaesthesia while their tactile thresholds were unchanged as compared to healthy control subjects [48]. In our sample we found significant effects of about the same size on TPDT and on pain intensity in the feedback group and - although causality cannot be inferred from correlation – because of the fact that changes in both variables are strongly correlated we may cautiously speculate that the reduction of pain possibly could have been achieved by an improvement in proprioception that might have led to a normalization of somatosensory cortical representation.

Passive and active lumbar proprioception of CLBP patients also seems to be impaired [49,50] and they experience difficulties to move and position their lumbar spine in a controlled manner [29]. On exteroceptive levels of processing these patients have problems to judge on pictures whether a model's trunk was rotated left or right [51] and their body image may be disrupted because they have difficulties to delineate the outline of their trunk [37]. Moreover, lumbopelvic control and TPDT seem to be correlated in CLBP patients [52] and patients' body image seems to be disrupted in regions with decreased tactile acuity [37].

To target pain-related cortical changes, training of somatosensory acuity and graded motor imagery programs - including imagined movements and mirror therapy - to normalize sensory and motor representations have been recommended in a recent review of therapeutic options in the treatment of pain [53]. Such interventions have been proven effective for phantom limb pain and complex regional pain syndrome but it is still unclear whether they also are an effective treatment for CLBP. Complicating factors are the relatively small representation of the lower back in somatosensory and motor cortex areas, the fact that the back is never seen in

everyday life and the problem that visual feedback of the back can only be taken from an unnatural viewpoint outside and behind the back. However, first empirical evidence including our results points into the direction that visual feedback of the back may nevertheless be helpful: Body position sense is recalibrated by vision [54] and patients further may utilize the additional information provided to monitor movement and thus increase lumbopelvic control. Consequently less post-movement pain and faster "time to ease" could be found when CLBP patients were able to visualize their back during movement by the use of mirrors [33].

In a recent multiple-baseline study of three CLBP patients a 10 weeks graded sensorimotor retraining program consisting of tactile acuity and localization training, imagined and small to full range movements using visual feedback proved effective in the reduction of pain intensity, pain interference and disability [55].

Our findings offer further empirical evidence that interventions combining somatosensory acuity training, movement and visual feedback are a promising option for the treatment of CLBP, even when the intervention is shorter and less intensive.

Was the decrease in TPDT and pain caused by the intervention?

As hypothesised, VAS pain and 2-point-discrimination threshold particularly seem to be affected by the intervention, while other variables affected by chronic back pain like pain anxiety and vigilance, cognitive appraisal to pain, depression and pain coping strategies remain largely unaffected.

The only variables not directly linked with experienced pain that showed differences in changes from pre to post-test between both treatment groups were the levels of "negative" and "solicitous" responses of the MPI Section II as well as the PVAQ total score. While it is unlikely that our intervention has influenced the behaviour of other persons that are significantly related to our patients, the changes in the PVAQ scores might have been due to our intervention and deserve some interpretation.

It is possible that the FG patients reported less pain at the end of our intervention since they had learnt to pay less attention to it, maybe because attention is drawn to the visuo-spatial features of the lower back instead of its painfulness via our experimental procedure, which in turn might have lessened attention to pain. This is inline with a hypothesis raised by Ramachandran [56] how visual feedback of the painful area might counteract pain intensity: As the painful area looks rather unimpaired from the outside and no external cause of back pain can be recognized, nociceptive signals contradicting the visual information might be considered as partly spurious. Another interpretation could be that, since our therapeutic intervention may have led to a more accurate proprioceptive representation of the back, this may have strengthened patients' confidence in the accuracy and predictability of their nociceptive perceptions so that they had to direct less attention to pain sensations.

Shortcomings

Despite these encouraging results, there are several shortcomings that should be mentioned: Our findings are based on a small sample consisting of 30 patients, so the outcome should be interpreted with care and should be confirmed by larger studies that include more subjects. The small sample size may have masked effects that contradict our hypotheses: Although not statistically significant, numerical changes from pre- to posttest might have reached significance levels in a larger sample with higher statistical power. Additionally, for some of the variables subjected to analyses of variance, assumptions concerning normality and homogeneity of variance were not met – although none of the measures for which the hypothesized effects could be found were affected by these violations.

Although exercises where monitored by an experienced physiotherapist, no objective method like ultrasound imaging was used to survey whether the musculus multifidus (MM) was specifically activated by the participants. Choosing MM activation as low back movement

was somewhat arbitrary. While it is known for quite a long time that strengthening superficial trunk and abdominal muscles improves CLBP, deep trunk muscles like the MM and the transversus abdominis have recently come into focus and there is evidence that training of these muscles seems to be even more effective [57]. We have chosen MM activation, as outlined earlier – because movement of the trunk via the MM can be easily learned and performed painlessly in a lying position.

Although, as pointed out above, it may make sense to combine activation, 2-point-discrimination training and visual feedback to maximise effects, it is questionable whether a combination of all of these factors was necessary. Albeit some empirical evidence that MM activation leads to a reduction of pain in CLBP patients [57] , in our sample it seems unlikely, that MM activation alone has caused the effects described above because this exercise is routinely taught all patients of our rehabilitation ward and thus patients of both groups daily trained their capability to activate their MM.

While tactile acuity seems to be very responsive to training and it has been shown that TPDT training alone is an effective method to reduce pain levels in patients suffering from CPRS and phantom limb pain [25] , to our knowledge, no studies that examine the effects of solely TPDT-training on CLBP intensity have been published so far. One trial including a sensory discrimination training based on 16 vibrators applied to the lumbar spine, which can be controlled by a handheld subject interface, failed to demonstrate superiority over a TENS device with respect to reduction of low back pain [58]. Unfortunately, the authors only reported pain intensity scores and no tactile acuity scores, so maybe tactile acuity also remained unchanged. Moreover, more than half of the participants reported faults of their devices during the intervention period, so it cannot be definitely inferred from these data that sensory acuity training alone does not affect pain intensity in CLBP.

Therefore, although we assume that there may be some kind of synergy between controlled movement, TPDT and visual feedback with respect to pain reduction and normalisation of the

lower back's somatosensory representation that adds on putative direct effects of each component, this assumption is speculative and cannot be inferred from our data.
Finally subjects received a very brief intervention of 6 sessions of 30 minutes each in 2 weeks. This is owed to our limited time in therapy: Patients stayed in our ward only for an average of 3 to 4 weeks, while the first week was needed for recruiting. Nonetheless, it would be very interesting to investigate whether effects could be enhanced by more extensive feedback training and how stable these effects on pain intensity are over the long term.

To conclude, a short intervention utilising visual feedback, TPDT training and MM activation increased tactile acuity and decreased pain perception in our sample. Further studies should explore, whether similar interventions could be a "cheap and easy to realize" supplement to standard treatment in CLBP.

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characteristic	Feedback group (n=15)		Control group (n=15)	
	N	**%**	**N**	**%**
gender				
male	10	66.7	9	60.0
female	5	33.3	6	40.0
Disk surgery up to 12 months ago	4	26.7	6	40.0
Painmedication	6	40.0	6	40.0
Partnership	15	100.0	11	73.3
	Mean	**SD**	**Mean**	**SD**
Age	45.53	7.05	40.60	10.67
Years of education	12.87	2.46	13.47	2.57
Duration of pain (months)	46.87	46.22	30.47	47.57
Weeks since disk surgery (in case of surgery)	3.50	1.00	4.67	1.75
IQ (measured by MWT-B)	102.40	9.72	107.33	14.88

Table 1: Sample characteristics

measure	FG (n=15) pretest mean (SD)	FG (n=15) posttest mean (SD)	CG (n=15) pretest mean (SD)	CG (n=15) posttest mean (SD)	main effect "group" $F_{(2/27)\ mv.}$ $F_{(1/28)\ uv.}$	main effect "group" p	main effect "time" $F_{(2/27)\ mv.}$ $F_{(1/28)\ uv.}$	main effect "time" p	interaction "time x group" $F_{(2/27)\ mv.}$ $F_{(1/28)\ uv.}$	interaction "time x group" p	Effect size d FG alone	Effect size d CG alone	Effect size d FG vs. CG
Pain (multivariate)					**.198**	**.822**	**11.156**	**<.0005**	**4.830**	**.016**			
VAS pain	*3.89 (1.82)*	*2.53 (1.82)*	*3.13 (1.80)*	*3.09 (1.49)*	*.029*	*.866*	*8.806*	*.006*	*7.723*	*.010*	*-.71*	*-.02*	*-.71*
MPI "pain severity"	*2.90 (0.93)*	*2.07 (1.12)*	*2.43 (1.28)*	*2.17 (1.13)*	*.220*	*.643*	*20.715*	*<.0005*	*5.497*	*.026*	*-.84*	*-.19*	*-.50*
2-point discrimination threshold (cm)	**5.13 (1.53)**	**3.17 (1.58)**	**4.90 (1.09)**	**4.60 (1.06)**	**2.258**	**.144**	**16.439**	**<.0005**	**8.888**	**.006**	**-1.21**	**-.26**	**-1.13**
Depression (multivariate)					**.059**	**.943**	**2.574**	**.095**	**1.174**	**.324**			
BDI depression	*7.60 (5.62)*	*5.87 (5.76)*	*7.67 (4.76)*	*6.80 (3.73)*	*.082*	*.777*	*5.323*	*.029*	*.591*	*.448*			
HAMD depression	*2.60 (2.41)*	*2.00 (2.45)*	*2.27 (1.44)*	*2.47 (1.64)*	*.009*	*.925*	*.600*	*.445*	*2.400*	*.133*			
MPI Section I - Pain Impact (multivariate)					**1.543**	**.220**	**2.575**	**.062**	**.441**	**.778**			
"Interference"	*3.19 (1.40)*	*2.46 (1.32)*	*2.59 (1.61)*	*2.26 (1.12)*	*.726*	*.401*	*8.740*	*.006*	*1.260*	*.271*			
"Life Control"	*4.35 (1.07)*	*4.65 (.85)*	*4.25 (1.15)*	*4.30 (.92)*	*.453*	*.506*	*1.307*	*.263*	*.667*	*.421*			
"Affective Distress"	*2.88 (1.04)*	*2.62 (.83)*	*2.42 (.88)*	*2.42 (.36)*	*1.480*	*.234*	*1.251*	*.273*	*1.251*	*.273*			
"Support"	*4.80 (1.29)*	*4.47 (1.44)*	*4.18 (1.19)*	*4.11 (1.25)*	*1.227*	*.277*	*1.397*	*.247*	*.621*	*.437*			
MPI Section II – Response by significant others (multiv.)					**1.634**	**.159**	**1.265**	**.307**	**3.748**	**.023**			
"negativeresponses"	*.80 (1.52)*	*.47 (.99)*	*.56 (.77)*	*.78 (.81)*	*.008*	*.929*	*.222*	*.642*	*5.538*	*.026*	*-.21*	*.27*	*-.44*
"solicitousresponses"	*4.47 (1.19)*	*4.72 (1.00)*	*4.15 (.99)*	*3.73 (1.16)*	*3.385*	*.076*	*1.350*	*.255*	*6.098*	*.020*	*.20*	*-.40*	*.60*
"distracting responses"	*3.48 (1.43)*	*3.93 (1.43)*	*2.68 (1.26)*	*2.75 (1.33)*	*4.532*	*.042*	*2.070*	*.161*	*1.139*	*.295*			
MPI Section III - activities (multivariate)					**.366**	**.831**	**.515**	**.725**	**.805**	**.534**			
"Household chores"	*3.37 (1.34)*	*3.53 (1.24)*	*3.42 (1.27)*	*3.18 (1.67)*									
"Outdoor work"	*2.17 (1.60)*	*2.20 (1.70)*	*1.80 (1.41)*	*1.67 (1.56)*									
"Activities away from home"	*3.85 (1.18)*	*3.60 (1.03)*	*3.43 (1.03)*	*3.28 (1.73)*									
"Social Activities"	*2.83 (1.10)*	*3.02 (.96)*	*3.00 (.87)*	*2.82 (1.07)*									
PASS total	*80.13 (36.53)*	*71.20 (42.51)*	*62.80 (29.32)*	*64.20 (27.27)*	*1.018*	*.322*	*1.115*	*.300*	*2.099*	*.159*			

PCS total	*19.53 (12.02)*	*15.60 (13.21)*	*17.47 (11.71)*	*15.60 (9.29)*	*.064*	*.803*	*6.361*	*.018*	*.808*	*.377*			
PVAQ total	*47.33 (13.06)*	*43.53 (11.00)*	*44.67 (13.24)*	*47.73 (10.90)*	*.034*	*.855*	*.058*	*.812*	*5.054*	*.033*	*-.28*	*.22*	*-.51*

Table 2: Mean values and results of repeated measures analyses of variance: pain, discrimination threshold and symptom measures

measure	Δ 2pdt	Δ VAS	Δneg	Δ sol	Δattp
Changes in 2-point-disc.-threshold (Δ 2pdt)	1.000	**.425 (.019)**	-.195 (.301)	.018 (.927)	.224 (.233)
Changes in VAS pain (Δ VAS)		1.000	-.275 (.141)	.056 (.770)	-.032 (.868)
Changes in MPI scale „negative responses“ (Δ neg)			1.000	-.198 (.294)	.067 (.727)
Changes in MPI scale „solicitousresponses“ (Δ sol)				1.000	.161 (.396)
Changes in PVAQ scale „attention to pain“ (Δattp)					1.000

Table 3: Pearson correlation coefficients of changes in pain, 2-point-discrimination-threshold and selected pain related measures (n = 30)

Figure 1: Feedback configuration

Figure 2: Mean values and individual measures of self reported pain (visual analogue scale) and 2-point-discrimination threshold scores (threshold distance in cm) for the two groups receiving multichannel feedback (FG) and standard treatment (CG).

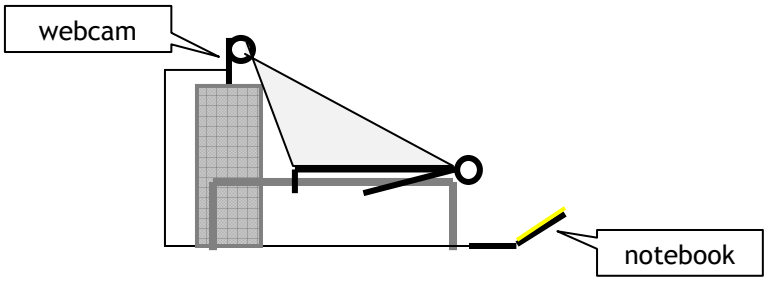

Figure 1

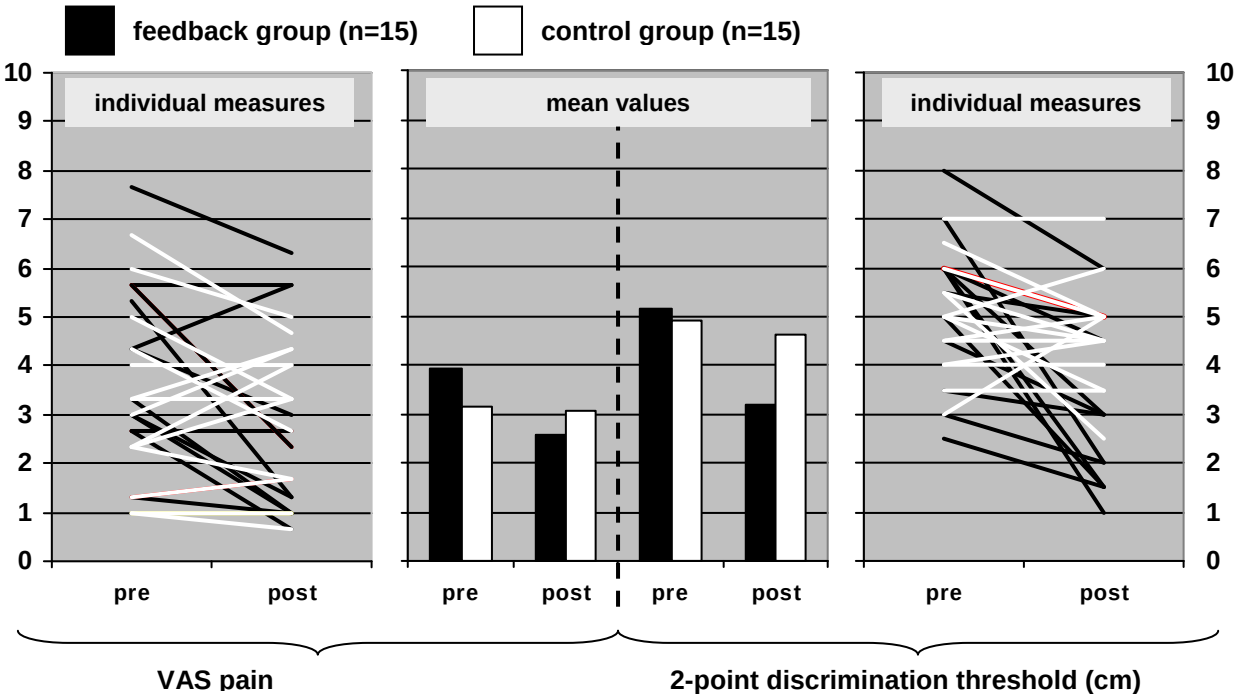
feedback group (n=15)
control group (n=15)
individual measures
mean values
individual measures
10
9
8
7
6
5
4
3
2
1
0
pre
post
pre
post
pre
post
pre
post
VAS pain
2-point discrimination threshold (cm)

Figure 2