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Chronic pain patients are impaired on an emotional decision-making task

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Abstract

Chronic pain can result in anxiety, depression and reduced quality of life. However, its effects on cognitive abilities have remained unclear although many studies attempted to psychologically profile chronic pain. We hypothesized that performance on an emotional decision-making task may be impaired in chronic pain since human brain imaging studies show that brain regions critical for this ability are also involved in chronic pain. Chronic back pain (CBP) patients, chronic complex regional pain syndrome (CRPS) patients, and normal volunteers (matched for age, sex, and education) were studied on the Iowa Gambling Task, a card game developed to study emotional decision-making. Outcomes on the gambling task were contrasted to performance on other cognitive tasks. The net number of choices made from advantageous decks after subtracting choices made from disadvantageous decks on average was 22.6 in normal subjects ($n = 26$), 13.4 in CBP patients ($n = 26$), and -9.5 in CRPS patients ($n = 12$), indicating poor performance in the patient groups as compared to the normal controls ($P < 0.004$). Only pain intensity assessed during the gambling task was correlated with task outcome and only in CBP patients ($r = -0.75$, $P < 0.003$). Other cognitive abilities, such as attention, short-term memory, and general intelligence tested normal in the chronic pain patients. Our evidence indicates that chronic pain is associated with a specific cognitive deficit, which may impact everyday behavior especially in risky, emotionally laden, situations.

Keywords: Chronic pain; Depression; Decision-making task

1. Introduction

There is little scientific information about the mechanisms of human chronic pain. On the other hand, animal models of pain developed over the last two decades, have greatly advanced our understanding of underlying peripheral and spinal cord mechanisms providing evidence for extensive neuro-plastic changes (Hunt and Mantyh, 2001; Woolf and Salter, 2000). Human brain imaging studies of acute pain indicate minimal involvement of the prefrontal cortex, and especially the orbitofrontal cortex, in such states (Bushnell et al., 1999; Price, 2000; Treede et al., 1991; Treede et al., 1999). In contrast, our brain imaging studies show the preferential involvement of the prefrontal cortex in chronic pain (Apkarian et al., 2001a–c). Therefore, we surmised that chronic pain should be considered a 'cognitive state', and that it may thus be competing with other cognitive abilities, especially those utilizing cortical circuitry with a major overlap with circuitry of chronic pain, i.e. the orbitofrontal cortex which is shown to be important in emotionally charged cognitive states (Damasio, 1996; Fuster, 2001). There is a large literature regarding the relation between pain and emotion (Keefe et al., 2001). A large part of this literature deals with the effects of enhancing of emotional regulation on pain, and the relation of emotional distress to treatment seeking in persons having pain. Here we take a more modest approach and examine the performance of patients with chronic pain in cognitive tasks. Since the orbitofrontal cortex is essential

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in the generation of emotional overtones (Damasio, 1996; Fuster, 2001), we specifically hypothesize that emotionally driven cognitive states may be impaired in chronic pain conditions.

Bechara et al. (1994) developed a neuropsychological procedure, gambling task, which simulates, in real time, decision-making strategy by factoring the uncertainty of promises and outcomes, as well as reward and punishment. In the gambling task participants choose between decks of cards that yield high immediate gain but larger future losses (bad decks, A and B; Fig. 1a), and decks that yield lower immediate gain but a smaller future loss (good decks, C and D). They are instructed to make choices that maximize their gains, with minimal instructions regarding the rules of the task. Patients with orbitofrontal damage, unlike normal controls, perform defectively in this task (Bechara et al., 1994, 2000). We use this task to examine the cost that chronic pain may impose on emotional decision-making. Performance on the gambling task was compared between normal volunteers, chronic back pain (CBP) and complex regional pain syndrome (CRPS) patients.

2. Methods

All procedures were approved by the Institutional Review Boards of SUNY Upstate Medical University and of Northwestern University. Participants were fully

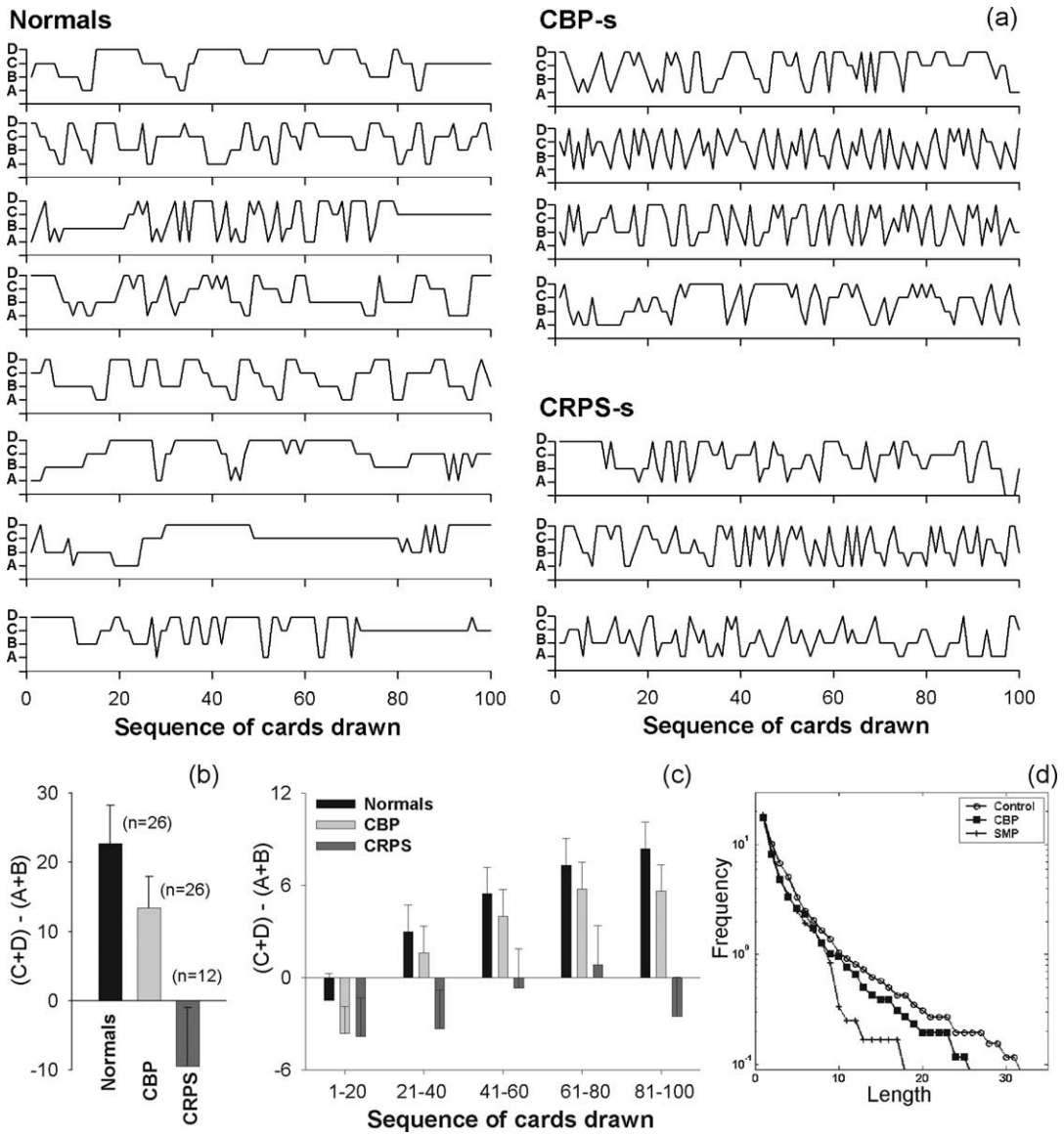

Fig. 1. Performance on the gambling task. (a) Individual subjects' sequences of cards drawn from the four decks (A and B are disadvantageous choices; C and D are advantageous choices) are shown for eight normal subjects, four CBP and three CRPS chronic pain patients. (b) Group-averaged outcomes on the gambling task calculated as net number of choices made from advantageous decks after subtracting choices made from disadvantageous decks: (C + D) − (A + B). (c) Time evolution of choices made. (d) Dynamical properties of performance on the gambling task. 'Persistence', defined as the length of consecutive draws made from the same deck, is more frequently larger in the control subjects as compared to the chronic pain patients.

instructed regarding the experiments, and all signed consent forms. CBP patients were assessed and entered into the study by Harden, Levy, and Fredrickson. CRPS patients were assessed and entered into the study by Thomas, Harden, and Levy. All participants filled medical history and handedness questionnaires. Patients also filled short-form of McGill pain questionnaire (SF-MPQ, Melzack, 1987), and Beck's anxiety and depression questionnaires (Beck and Steer, 1993a,b). The patients' intensity of pain was also assessed on a verbal visual analog scale (0, no pain; 10, maximum imaginable pain) at the start, a quarter of the way, half way, three quarters, and at completion of the game.

All participants were right-handed, their education, gender and age were documented and compared for appropriate matching between groups. Subjects with a history of neurological disease, head trauma, and psychiatric or developmental disorders were excluded. Patients were instructed to stop use of analgesics for 24 h prior to participation in the study.

2.1. Normal subjects

Twenty-six normal volunteers were tested for cognitive abilities. These subjects were matched with the patients and were contrasted with the patients regarding cognition. Their mean age was 43.6 years, range 25–64, 14 male and 12 female, 6 completed high-school, 16 undergraduate, and 4 graduate education.

2.2. CBP patients

Twenty-six CBP patients were studied. All fulfilled the International Association for the Study of Pain (IASP) criteria for chronic lumbar spinal or radicular pain (Merskey and Bogduk, 1994). Mean duration of CBP was 8.6 years. In 19 CBP patients, there was significant radicular pain involving one or both legs. Mean age was 43.7, range 21–71, 8 males and 18 females, 10 completed high school, 15 undergraduate, and 1 graduate education. Complete drug history was obtained in 17 CBP patients. Of these, 2 did not use any pain medications, 10 used either over the counter medications or cyclooxygenase-2 inhibitors, 6 regularly used anti-convulsants, 2 anti-depressants, 2 opioids, and 4 used a very large array of medications. The CBP patients mean depression score was 13.9, equivalent to minimal depression, and mean anxiety score was 13.9, equivalent to mild anxiety. Verbal visual pain intensity ratings during gambling task were collected in 17 CBP patients. Four were excluded from the pain intensity vs. gambling task performance analysis and from participation in the larger battery of cognitive testing because of high depression index and high drug consumption.

2.3. CRPS patients

Twelve CRPS patients were studied. All fulfilled IASP criteria for having chronic regional pain syndrome of type I, CRPS-type I, also known as reflex sympathetic dystrophy (Merskey and Bogduk, 1994); and ascertained that the pain could be relieved for a limited period by sympathetic blocks. All 12 had unilateral upper extremity chronic pain with or without mechanical allodynia or thermal hyperalgesia. The mean duration of chronic CRPS was 2.4 years. Their mean age was 42.9, range 21–56, 4 males and 8 females, 5 completed high-school and 7 undergraduate education. Complete drug use history was obtained in 6 SMP patients. Of these, 2 did not use any pain medications, 2 used over the counter pain medications, 1 regularly used an anti-depressant, and 1 regularly used an anti-convulsant. The CRPS patients mean depression score was 16.4, equivalent to a mild–moderate level of depression, and mean anxiety score was 13, equivalent to mild anxiety.

Sympathetic blocks were part of the routine therapy for the CRPS patients (Blumberg et al., 1997), who were tested for cognitive abilities before and after sympathetic blocks. Thomas administered the blocks by injecting a local anaesthetic (bupivacaine 0.2% in 20 cm^3 saline) within the axillary space of the painful arm. In all cases the procedure resulted in decreased pain within 15–20 min post-block.

2.4. Cognitive tests

Cognitive tasks were taken directly from the literature and used as described in the original work. (1) Iowa Gambling Task (Bechara et al., 1994, 2000): Designed to evaluate the ability to postpone immediate reward for a longer-term successful outcome, tests emotional decision-making ability. Subjects play a card game under conditions of limited knowledge about reward and penalty. (2) Wisconsin card sorting test (WCST; Heaton et al., 1993): Assesses the ability to solve problems in response to changing stimuli, the ability to shift and maintain set, and utilize feedback. Patients with dorsolateral prefrontal lesions are unable to perform this test correctly (Heaton et al., 1993). Multiple types of scores can be recorded. We concentrate on perseverative errors, which depend on the number of categories completed and trials to complete first category. Perseveration in this task is when the subject persists in responding to an incorrect stimulus characteristic and is unable to relinquish the old category for the new. Errors in non-perseverative responses were also calculated. (3) Digit span from the Wechsler Memory Scale—Revised (Wechsler, 1945; Heaton et al., 1993): It is composed of digits forward and digits backwards that are administered separately. The subject is read number sequences of increasing length, and asked to repeat it from memory either forward or backward. The score indicates the number of correct responses, assessing short-term memory. Vocabulary, similarities and matrix reasoning subtests from

the Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1955): These tests explore vocabulary, verbal knowledge, verbal concept formation, abstract verbal reasoning, and spatial non-verbal fluid reasoning abilities, testing general cognitive abilities such as memory, learning, concept and language development. Raw scores are converted to *T*-scores (mean of 50 and a standard deviation of 10). (5) Stroop: measures a subject's ability to inhibit a response that comes naturally and instead respond to changing task demands in a novel way (Trenerry et al., 1989). Stroop has been associated with functions in the left frontal lobe. The color–word score is the primary score used.

2.5. Experimental groups and comparisons

Performance on the gambling task was compared between 26 normal subjects, 26 CBP, and 12 CRPS patients. A sub-population from this pool, 10 normal subjects, 6 CBP, 3 CRPS was also tested on WCST, Wechsler digit span, WASI vocabulary, similarities, and matrix reasoning subtests, and Stroop. To determine the effects of the intensity of chronic pain on performance on gambling task, CRPS patients and normal subjects were tested on this task twice. Seven CRPS patients before and after a sympathetic block, 5 CRPS patients tested twice without sympathetic blocks, and 10 (of 26) normal subjects tested twice to provide a baseline comparison.

2.6. Statistical analysis

The data are expressed as mean ± SEM. Analysis of variance (ANOVA; one or two-way, with or without repeated measures) followed by Tukey's test, one-tailed Student's *t*-test, or Mann–Whitney rank sum test (when the outcome distribution did not pass normality test) were used to determine the effects of presence of chronic pain on cognitive performance. Single input and multiple parameter linear regressions were used to determine the relationships between pain, anxiety, depression and cognitive outcomes. $P < 0.05$ was the level of significance used in this study and Statistica software (kernel version 5.5, StatSoft Inc., Tulsa, OK) was used to perform statistical analysis. A non-linear fit was used to calculate the exponent for the power law description of sequence of choices made on the gambling task (Matlab release 13, The Mathworks, Natick MA).

3. Results

Examination of individual performances on the gambling task (Fig. 1a) reveals that normal subjects more frequently choose cards from the good decks and are more 'persistent', i.e. they tend to draw cards from the same deck for longer number of consecutive draws. The net number of choices made from good decks after subtracting choices made from bad decks (Fig. 1b) was significantly lower in the two patient groups as compared to the normal subjects, and CRPS patients performed worse than CBP patients. One-way ANOVA across the three groups is significant ($F_{2,63} = 6.0$; $P < 0.004$); post-hoc Tukey test ($P < 0.05$) indicates significant differences between all three pair-wise comparisons. The statistical results were not affected with the inclusion or exclusion of CBP patients with high drug consumption. Age, sex, and education were not significantly different between the groups ($P > 0.05$). The evolution of choices made over time was studied by examining average choices made for every 20 draws (Fig. 1c). As the task progresses, normal controls gradually shift their preference toward the good decks and away from the bad decks. CBP patients show a similar but delayed behavior; while CRPS patients show no evidence for improvement in time. Two-way ANOVA for subject groups ($F_{2,319} = 10.9$; $P < 0.001$); for five intervals of cards drawn ($F_{4,319} = 6.9$; $P < 0.001$) are significant. Dynamical properties of gambling task performance were examined by quantifying persistence. We calculated the lengths of consecutive same-deck-selections for each subject, and generated group-averaged frequency plots of persistence (Fig. 1d). Lengths of consecutive same-deck-selections were counted and group averaged. In CRPS patients, maximum length of consecutive cards drawn from the same deck is <20; this value is larger than 30 in normal subjects. Individual subject frequency–length graphs were approximated with a power law $y = x^{-k}$. The decay rate, k was -1.39 ± 0.3 for normal subjects, -2.33 ± 0.5 for CBP patients, and -2.51 ± 0.5 for CRPS patients. Comparing k between normal subjects and CBP + SMP patients shows borderline significance (*t*-test, $P < 0.08$). Thus, chronic pain patients tend to show lower persistence than normal subjects.

We assessed the relationship between intensity of chronic pain and performance on the gambling task. In CBP patients, there was a strong negative correlation between gambling performance outcome and reported intensity of chronic pain, as assessed on the verbal pain intensity scale during task performance (mean verbal pain intensity 4.4 ± 0.6; $r = -0.75$; $P < 0.003$; Fig. 2a). This relationship was preserved after correcting for age and for duration of chronic pain. Multiple regression analysis with age and duration of chronic pain as confounders results in a $\beta = -0.76$ for dependence of task performance on pain intensity ($P < 0.03$). The CRPS patients afforded the opportunity to examine performance on the gambling task before and after temporary decrease, or cessation, of the chronic ongoing pain by sympathetic blocks ($CRPS_1$; $n = 7$). This was compared to CRPS patients who did not receive blocks but performed the task twice ($CRPS_2$; $n = 7$), and to normal subjects who also performed the task twice ($n = 10$; Fig. 2b). There was a significant difference between subject groups, and between first and second testing for all three groups. Two-way repeat-measures

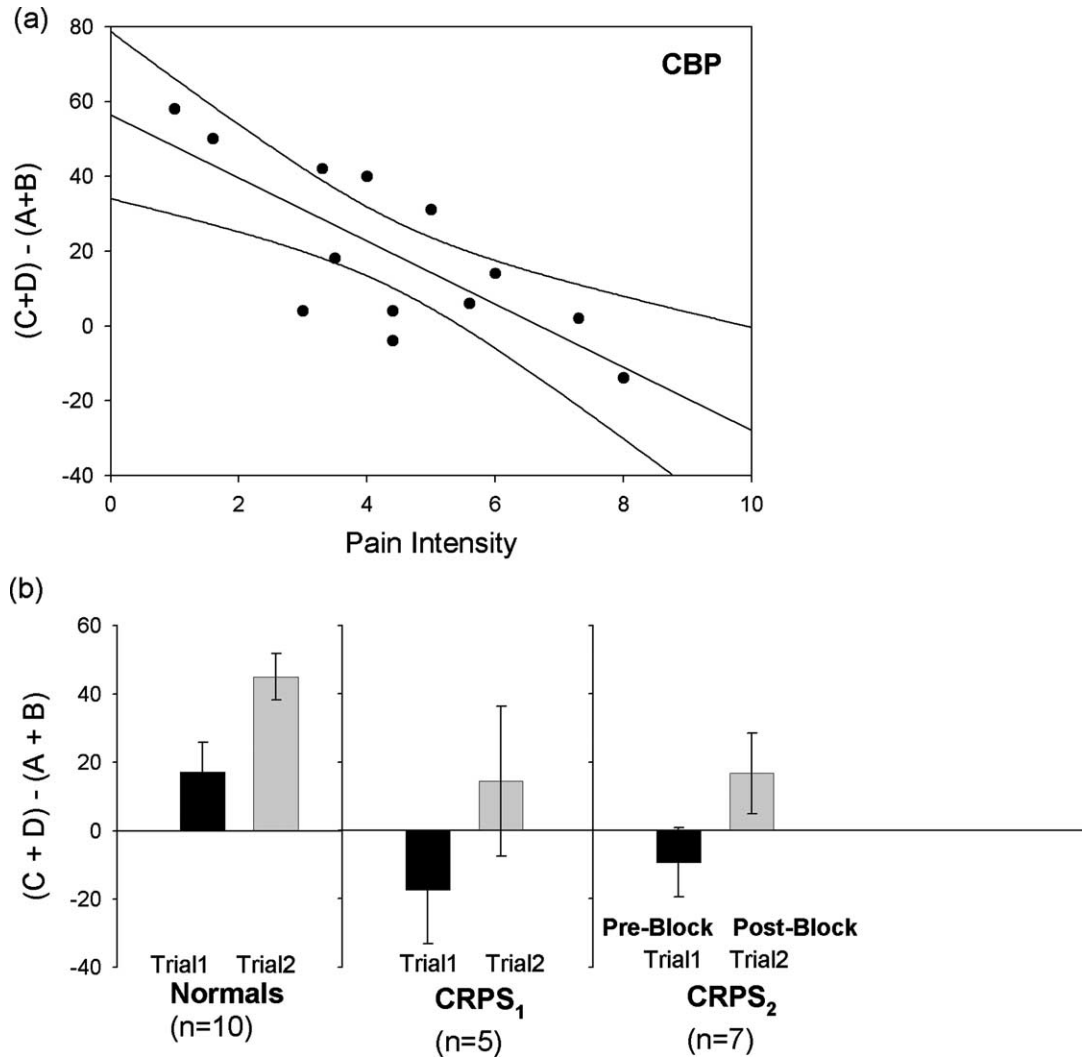

Fig. 2. Dependence of gambling task performance on intensity of chronic pain. (a) In CBP patients performance on the gambling task is negatively correlated with intensity of chronic pain ($r = -0.75$). (b) Performance on gambling task as a function of repetition and chronic pain intensity in CRPS patients. Gambling task is administered twice in normals and in two groups of CRPS patients. Between task repetitions, $CRPS_2$ patients received a local anaesthetic injection to block sympathetic efferents of the chronically painful hand, temporarily decreasing the pain. Performance after the block was not different from repeat performance in $CRPS_1$ patients that did not receive the block, even though the pain was much lower in $CRPS_2$ during Trial2.

ANOVA for subject groups (normals vs. $CRPS_1$ vs. $CRPS_2$ $F_{1,18} = 3.9$; $P < 0.04$) and for task repetition (Trial1 vs. Trial2 $F_{1,18} = 12.9$; $P < 0.002$) are significantly different. Performance improvement with repeat testing was similar in $CRPS_1$ and $CRPS_2$ groups, indicating that the decrease in chronic pain intensity did not contribute to improved performance. There was no difference between $CRPS_1$ and $CRPS_2$ in Trial1 ($P > 0.67$) or Trial2 ($P > 0.93$), although the blocks decreased verbal pain intensity (in $CRPS_2$ from a pre-block value of 5.6 ± 1.5 to a post-block value of 1.3 ± 0.9; in comparison in $CRPS_1$ verbal pain intensity was 4.7 ± 1.3 in Trial1 and 5.5 ± 1.0 in Trial2; with a significant difference in pain intensity between $CRPS_2$ post-block Trial2 and the other three CRPS trials, $P < 0.006$). Moreover, there was no significant relationship between the ratings of the intensity of chronic pain and performance on the gambling task in the CRPS patients ($r = 0.18$, $P > 0.4$). Thus, task performance in CRPS patients seems independent of chronic pain intensity. However, the CRPS patients did exhibit the ability to learn the task since their performance in the second trial was better than in the first. There was a significant difference between task repetitions in CRPS patients (paired *t*-test Trial1 vs. Trial2 for all CRPS patients $t = -2.6$, $P < 0.03$). Note that such patients showed no evidence for learning the task in a single trial (Fig. 2c). There were no significant relationships between performance on gambling task and Beck's depression and anxiety scores, or sensory and affective components of SF-MPQ, in both CBP and CRPS patients, even when these parameters were combined in multiple-regression models.

Poor performance on the gambling task may be a specific cognitive deficit that chronic pain patients exhibit. Alternatively it may simply be a reflection of a more general cognitive dysfunction reflecting inability to attend to any

cognitive demand. To distinguish between these alternatives we compared performance of a subgroup of normal volunteers ($n = 10$) and CBP patients ($n = 6$) on the gambling task to four other cognitive tests, which assess cognitive abilities and are not thought to rely upon orbitofrontal functioning (Fig. 3). There were no differences between normals and CBP patients on: (1) WCST (ability to solve problems in response to changing stimuli; Heaton et al., 1993), in incorrect, ambiguous, and perseverative responses; (2) Digit span (short-term memory; Wechsler, 1945), forward, backward and total scores; (3) WASI (general intelligence; Wechsler, 1955), in vocabulary, similarities, and matrix reasoning subtests; (4) Stroop test (shift attention away from automatized responses; Trennery et al., 1989), for items completed, incorrect responses, and color–word score. This sub-group of CBP patients, however, performed worse on the gambling task as compared to the normal control subjects (Mann–Whitney rank sum test, $P < 0.03$). We also have preliminary observations in three CRPS patients, who seem normal on Stroop, digit-span, WASI vocabulary, similarities, and matrix reasoning subtests, and yet perform poorly on the gambling task.

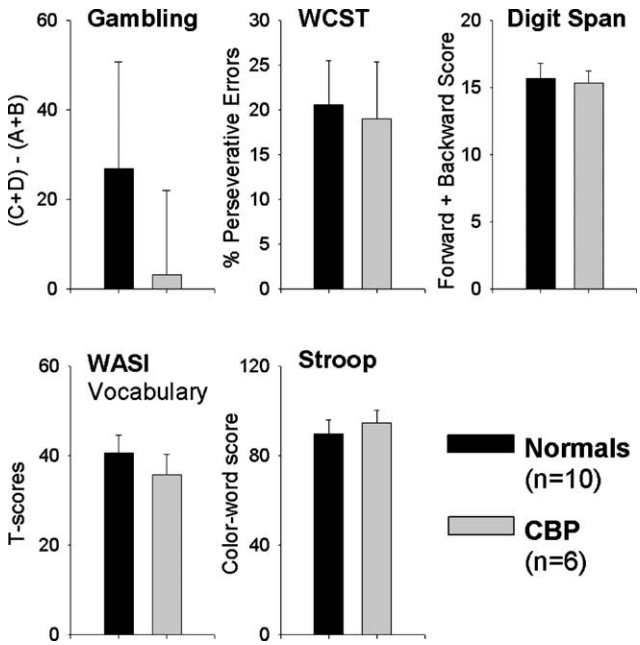

Fig. 3. Performance of CBP patients compared to normal subjects on five standardized neuropsychological tests (mean and SE). Only performance on gambling task was different between normals and CBP patients (see Fig. 1 legend). WCST assesses ability to adapt to changing stimulus conditions, percent perseverative errors are shown. Digit span tests for short-term memory, total correct score for forward and backward tests is shown. WASI-vocabulary measures general verbal intelligence. *T*-scores show normalized score of performance. Stroop tests for attentional shifts. Color–word raw scores are shown.

4. Discussion

The main result of this study is that, compared to matched control subjects, chronic pain patients are impaired on the decision-making task. Specifically, patients failed to adopt the pattern quickly learned by control subjects, which leads to the most profitable outcome. Additionally, patients were less persistent in their choices since they switched more often between decks, and thus exhibited a more random behavior for choices. Even though anxiety and depression were higher than expected in normal subjects, the cognitive impairment was not related to either, implying that their contribution is at least weaker than that of the intensity of chronic pain. In a separate study, we have examined the effects of acute thermal painful stimuli on the gambling task in normal volunteers (Apkarian et al., 2002). Initial results indicate that the presence of painful thermal stimuli, at intensities comparable to that reported by the patients in this study, did not impact gambling task outcomes, implying that the specifics of the pain (e.g. type or duration) are important determinants for affecting gambling task performance.

These findings are consistent with the notion that chronic pain engages the prefrontal cortex (Apkarian et al., 2001a–c), because earlier studies (Bechara et al., 1994, 2000) indicate that lesions limited to this portion of the cortex disrupt performance on the gambling task. The specificity of the cognitive impairment as compared to other cognitive abilities also points to the preferential involvement of the orbitofrontal cortex in chronic pain, in contrast to other prefrontal regions (Stuss et al., 2002). Even though these results are consistent with the premise of the involvement of the orbitofrontal cortex in chronic pain, we emphasize that the details of this involvement, resulting in decision-making deficits, remains unclear. The orbitofrontal cortex serves as a link between multiple brain regions with distinct roles in emotional assessments: (1) regions that hold various categories of memory (e.g. lateral prefrontal areas), (2) effector structures in the brainstem that produce emotional responses, and (3) brain substrates of feelings (e.g. insula, amygdala; Bechara, 2002; Craig, 2002; Fuster, 1997; Mesulam, 1998; Saper, 2002). The interaction between these regions is thought to be coordinated through the orbitofrontal cortex (Bechara, 2002; Fuster, 1997). However, impairment on emotional decision-making task may arise from abnormal activation of multiple components as well as through abnormal interactions across the multiple components that comprise this emotional network. Therefore, the specifics of the impact of chronic pain on the brain network that underlies emotional decisions remain to be elucidated.

The results of our study can also be viewed in the context of the expanding literature on neuropsychological functioning and chronic pain. Studies in this field view patients with chronic pain as active processors of information with pain imposing a negative bias on behavior and cognition.

Experiments have explored biases in attention, interpretation, and memory, including recall, recognition, and autobiographical memory. Except for some tautological results, such as patients with chronic pain exhibiting fear of pain, worry of injury, and better recall for pain-related words, the results are weak and equivocal, see review (Pincus and Morley, 2001). Therefore, our negative results with Stroop test, WCST, short-term memory, and general intelligence agree with this literature. Attention bias due to presence of chronic pain is studied using mainly variants on Stroop task, and show variable and non-significant trends (Pincus and Morley, 2001). One study examined attention using a test battery designed to probe for everyday events, and showed that chronic pain patients were mildly impaired, although this deficit was not related to pain intensity, depression, or anxiety (Dick et al., 2002). Another study showed memory deficits in chronic pain patients in a word-stem completion task, and the deficit was related to pain catastrophizing and fear appraisal but unrelated to pain intensity (Grisart and Van der, 2001). It is not clear if there is a relationship between the deficits we observe on the gambling task and the attentional and memory deficits observed in these studies, especially since the patient groups are diverse between the studies.

Proper performance on the gambling task requires the generation of autonomic responses, signaling emotional identification of choices made and the rewards and penalties received based on the choices (Bechara et al., 2000). Thus, our results suggest that in chronic pain the presence of ongoing unpleasant emotions interferes with the emotional evaluation of other conditions, like evaluating the emotional significance of choices on the gambling task. Performance on the gambling task was distinct between the two patient groups. CRPS patients performed worse than CBP patients on the gambling task. There is evidence that neurocognitive performance decreases when pain intensity levels are high (Eccleston, 1995; Iezzi et al., 1999). Mean pain intensity was similar between our CRPS and CBP patients. Thus, pain intensity cannot account for the performance difference between the patient groups, neither does their chronicity of pain since CBP patients were in pain for more years than CRPS patients. Other pain-related parameters, like catastrophizing and fear appraisal, may explain these differences but we did not document them.

The performance of our normal subjects on the gambling task is similar to that reported in the past (Bechara et al., 1994). More importantly, deficit of CRPS patients on the gambling task is of the same magnitude as that of patients with orbitofrontal lesions, yet CRPS patients improve performance with repeat testing while patients with orbitofrontal lesions do not (Bechara et al., 2000). It is noteworthy that we have no direct evidence that chronic pain patients make bad choices in real life situations. We surmise, however, that examining their everyday behavior might reveal defects in emotional decision-making and perhaps even in appropriate social behavior, as commonly observed in patients with orbitofrontal lesions (Bechara et al., 2000; Berthoz et al., 2002; Stuss et al., 2002).

Anxiety and depression were higher in our chronic pain patients than in normal subjects. It seems surprising that these measures were not predictive of performance on the gambling task while pain intensity had a strong relationship to gambling in CBP patients. One explanation may be that the specific patient group studied exhibited minimal depression and mild anxiety. Moreover, there is evidence suggesting that anxiety and depression may influence gambling behavior in opposite directions since sad individuals seem biased in favor of high-risk/high-reward options, whereas anxious individuals are biased in favor of low-risk/low-reward options (Raghunathan and Pham, 1999). Thus, the opposing effects of anxiety and depression may have cancelled each other. Moreover, we did not see a relationship between gambling task outcomes and sensory and affective components of chronic pain as measured by SF-MPQ, although we observe a strong relationship between gambling outcome and verbal pain scores during the task. The tight temporal relationship between the latter measure and the task may have been critical.

Limitations of the study include the fact that medication use remains an important confounder. To reduce the effects of this confound we selected a patient population with minimal consumption of analgesics. This study concentrated on examining cognitive abilities in two specific chronic pain conditions, both of which have a significant neuropathic component. Thus, it is not clear whether these findings generalize, for example, to chronic pain conditions with minimal neuropathic pain. We should also emphasize that the number of subjects studied in each group is relatively small. Thus, emotional decision-making abilities need to be studied in a more natural setting, in a larger cohort, and in other chronic and acute pain conditions.

Overall, we conclude that chronic pain is more emotional in nature than acute pain; as a result it interferes with the emotional decision-making task. Price (2000) recently proposed to subdivide the emotional component of pain into pain unpleasantness and secondary pain affect, where unpleasantness is related directly to the immediate unpleasant emotional feelings and secondary affect is based on meanings such as interference with one's life and implications for the future. He further proposed that unpleasantness is mediated through the anterior cingulate and secondary affect through prefrontal circuits. The present findings extend this idea by implying that chronic pain preferentially enhances the secondary affective component, rendering the condition more emotional. Chronic pain is then interpreted as a consequence of peripheral and central reorganization that leads to a switch from a bottom-up condition, where nociceptive inputs dominate, to a more top-down state where pain behavior is controlled by emotional and cognitive values (Fuster, 2001; Miller and Cohen, 2001), which then engages and disturbs processes identified to be critical for the somatic marker hypothesis

(the hypothesis that conscious and covert 'biomarker' signals, like emotions, influence the processes of response to stimuli; Damasio, 1996). The specificity of the cognitive deficit exhibited in this study implies that the task may have clinical utility, and suggests that cognitive treatments should pay special attention to its emotional aspects.

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