Facial Emotion Recognition and Executive Functions in Fibromyalgia

Cristina Muñoz Ladrón de Guevara (MSc),[1] Gustavo A. Reyes del Paso (PhD),[1] María José Fernández-Serrano (PhD)[2] & Stefan Duschek (PhD)[3]

[1] Department of Psychology, University of Jaén, Spain

[2] Department of Psychology, University of Granada, Spain

[3] Institute of Psychology, UMIT - University for Health Sciences Medical Informatics and Technology, Austria

Corresponding author:

Cristina Muñoz Ladrón de Guevara

Department of Psychology

University of Jaén

23071 Jaén, Spain

E-mail: cmladron@ujaen.es

Funding sources: This research was supported by a grant from the Spanish Ministry of Science, Innovation and Universities, co-financed by European Regional Development Fund (Project RTI2018-095830-B-I00) and the Doctoral School of the University of Jaén.

Conflicts of interest: none

Running title: Emotion Recognition and Cognition in Fibromyalgia

Abstract

Objective: The ability to accurately identify facial expressions of emotions is crucial in human interaction. While a previous study suggested deficient emotional face recognition in patients with fibromyalgia, not much is known about the origin of this impairment. Against this background, this study investigated the role of executive functions. Executive functions refer to cognitive control mechanisms enabling implementation and coordination of basic mental operations. Deficits in this domain are prevalent in fibromyalgia.

Methods: Fifty-two fibromyalgia patients and thirty-two healthy individuals completed the Ekman-60 Faces Test, which requires classification of facial displays of happiness, sadness, anger, fear, surprise and disgust. They also completed eight tasks assessing the executive function components of shifting, updating and inhibition. Effects of comorbid depression and anxiety disorders, and medication use, were tested in stratified analyses of patient subgroups.

Results: Patients made more errors overall than controls in classifying the emotional expressions. Moreover, their recognition accuracy correlated positively with performance on most of the executive function tasks. Emotion recognition did not vary as a function of comorbid psychiatric disorders or medication use.

Conclusions: The study supports impaired facial emotion recognition in fibromyalgia, which may contribute to the interaction problems and poor social functioning characterizing this condition. Facial emotion recognition is regarded as a complex process, which may be particularly reliant on efficient coordination of various basic operations by executive functions. As such, the correlations between cognitive task performance and recognition accuracy suggest that deficits in higher cognitive functions underlie impaired emotional communication in fibromyalgia.

Key words: Fibromyalgia, facial emotion recognition, executive functions, emotion, cognition

Introduction

Facial expressions constitute the most important non-verbal channel through which emotional states are communicated; the ability to accurately identify these expressions is crucial in human interaction (1). While this ability varies considerably among individuals, high-level ability is associated with psychosocial benefits including achievement of interpersonal interaction goals, higher relationship quality, and better mental health and general social adjustment (2, 3). In contrast, difficulties in recognizing facial emotion expressions are linked to poorer interpersonal interactions and negative emotions like frustration, anger and anxiety (3, 4). In addition, impairments in facial emotion recognition have been described in clinical conditions including depression (5), anxiety disorders (6), personality disorders (7, 8), somatoform disorders (9) and schizophrenia (10).

A recent study by Weiß and colleagues (11) suggested that poor facial emotion recognition may also be prevalent in chronic pain conditions. Patients diagnosed with fibromyalgia and healthy individuals completed a face recognition task, which required them to classify 30 emotional expressions into happy, anxious, sad, disgusted and neutral categories. Patients made more misclassifications than controls in all emotional categories. Fibromyalgia is a chronic condition of widespread pain accompanied by symptoms such as disturbed mood, fatigue, insomnia and impaired cognitive performance (12). Fibromyalgia symptoms substantially reduce quality of life and psychosocial functioning (13, 14). According to current knowledge, fibromyalgia pain occurs due to hypersensitivity of central nociceptive pathways; this has been demonstrated, for example, in brain imaging studies showing exaggerated activity of the neuromatrix underlying pain (15, 16). In addition, affective factors are implicated in the pathology of the disorder. Experimental studies suggested that fibromyalgia patients are particularly vulnerable to the effects of negative mood on the processing of body-related information. In patients, as compared to healthy controls, induction of aversive emotions led to greater increases in subjective pain responses and central nervous somatosensory processing (17, 18). Evidence also points to exaggerated psychophysiological responses to aversive stimuli (19), selective processing of negative

information (20), increased emotional avoidance (21), and catastrophizing (22). Impaired emotional communication may be another relevant aspect of affective pathology in fibromyalgia. Failure in emotion recognition may contribute to poor social functioning, such as interaction problems, isolation and general lack of social resources, which are frequently observed in fibromyalgia patients (13, 23).

Several psychological mechanisms may mediate the impairment in facial emotion recognition seen in fibromyalgia. Firstly, a role of alexithymia has been suggested (11). Alexithymia refers to a personality trait characterized by difficulty in identifying and describing one´s own feelings, which is highly prevalent in fibromyalgia (24). Negative correlations between alexithymia and emotion recognition task performance suggest that this trait may also interfere with accurate identification of emotions expressed by others (25, 26). Another line of reasoning refers to somatosensory perception, which shows marked abnormalities in fibromyalgia (18, 27). According to current theories of emotion, somatosensory perception plays a key role in affective processing, and alterations therein may alter the experience and communication of emotions (28, 29). Comorbid emotional disorders may also play a role; fibromyalgia is frequently accompanied by depression and anxiety disorders (30, 31), which in turn are associated with impaired facial emotion recognition (5, 6).

In addition to these mechanisms, the cognitive deficits seen in fibromyalgia patients may interfere with the accurate identification of facial emotion expressions. Neuropsychological testing has repeatedly documented poorer performance of fibromyalgia patients in most domains of cognitive functioning (32-34). Moreover, a number of studies of healthy individuals revealed positive correlations between performance on various cognitive tests and facial recognition tasks (3, 35, 36). Recent meta-analyses confirmed the existence of moderate positive associations of facial emotional recognition with abilities like visual-spatial thinking, language processing, memory, processing speed, as well as general intelligence (3, 37). Therefore, it may be that deficiencies in facial emotion recognition in fibromyalgia are related to both the cognitive and emotional impairments that characterize the disorder.

In the present study, the possible role of executive functions in facial emotion recognition was investigated in fibromyalgia. Executive functions refer to complex control mechanisms that facilitate dynamic regulation of human cognition and behavior (38). Using factor analysis and linear structure modeling, Miyake and colleagues (39), identified three main components of executive functions: shifting, updating and inhibition. The shifting component involves processes that enable switching between multiple tasks or mental operations. Updating refers to the monitoring of incoming information, evaluating its relevance to ongoing tasks, and replacing old information in working memory with relevant new information. The inhibition function includes the ability to consciously inhibit or override dominant or automatic responses. Facial emotion recognition is regarded as a complex process, which requires coordination of various basic operations and manipulation of visual, semantic and affective information (40). Therefore, its successful implementation may strongly depend on executive functions. In fact, this has been confirmed by the positive correlations between measures of executive functions and recognition accuracy in patients with schizophrenia and affective disorders (41, 42). Moreover, deficits in executive functions in fibromyalgia have been seen in numerous studies. Patients performed worse than healthy individuals on classical executive function tasks like the Stroop Test (43), n-back task (44), verbal fluency task (44), Wisconsin Card Sorting Test (45) and Iowa Gambling Task (55).

The present study aimed to replicate and extend the finding of Weiß and colleagues of impaired recognition of facially expressed emotions in fibromyalgia (11). In addition to poorer recognition performance in patients, the original study revealed inverse relationships of pain severity, alexithymia, and levels of depression and anxiety with performance. However, the possible relevance of cognitive deficits to the recognition impairment has not been investigated so far. Therefore, in our study a group of fibromyalgia patients and a healthy control group completed a comprehensive battery of tasks assessing the three components of executive functions, in addition to a facial recognition task. Moreover, possible effects of psychiatric comorbidity and medication on facial emotion recognition were evaluated. In

particular, psychoactive drugs such as antidepressants, anxiolytics and opiates may affect cognitive and affective variables in fibromyalgia (46).

Methods

Study Design and Participants

This study was part of a larger project on cognition and emotion in fibromyalgia (44, 47). It was carried out using a cross-sectional design. In total, 52 fibromyalgia patients and 32 healthy control subjects participated. To minimize the likelihood of inclusion of participants with age-related cognitive decline, the age range of both groups was restricted to 18 to 65 years. Only individuals with an education level sufficient to complete the cognitive tasks were included. Due to the higher prevalence of fibromyalgia in women than men, and to avoid potential gender-related confounding factors, the sample was restricted to women. All patients were recruited through the Fibromyalgia Association of Jaen (Spain); they were examined by a rheumatologist and met the 1990 and 2010 American College of Rheumatology criteria for fibromyalgia (12, 48). Exclusionary criteria for the fibromyalgia group comprised neurological disorders (in particular those affecting cognitive performance like brain injury or cerebrovascular disorders), cardiovascular diseases, metabolic abnormalities, and severe somatic (e.g., malignant disease during the past 5 years) or psychiatric (e.g., psychotic disorders, bipolar disorder, obsessive-compulsive disorder or drug addiction) disorders. The control group was recruited from the community via local advertisements and snowball sampling. The same exclusionary criteria were applied to controls as to patients. In addition, controls were required to be free from chronic pain of any kind and to not have a first-degree relative diagnosed with fibromyalgia. However, individuals with transient acute pain (e.g., menstrual pain, pain due to muscle strain or tension) were allowed to participate. Table 1 presents the sociodemographic and clinical data of both study groups. The patients and healthy controls did not differ significantly in terms of age, duration of education or body mass index (BMI).

Table 1

The sample size was estimated based on the two main study aims, i.e. comparison of fibromyalgia patients with healthy individuals in terms of facial emotion recognition and quantification of the associations between executive functions and facial recognition in fibromyalgia patients. The correlations between cognitive performance and facial recognition observed in healthy and clinical samples strongly differed between studies, where most of them were in the medium range (4, 40-42). Assuming a correlation of .4, alpha level of 5% and beta error of 20%, power analysis revealed that a sample size of 49 was required for the patient group. The sample size estimation for the group comparison was based on previous studies comparing patients with fibromyalgia or psychiatric disorders with healthy individuals in terms of facial recognition, which revealed effects sizes (Cohen´s d) typically between .2 and .6 (5, 6, 9-11). Expecting an effect size of .4, an alpha level of 5% and a beta error of 20%, power analysis yielded a total sample size of 78 (Cohen, 1988). Following a somewhat more conservative strategy, we included 52 fibromyalgia patients and 32 healthy controls in the study.

Emotion Recognition Task

The computerized version of the Ekman-60 Faces Test (EK-60 F) (49, 50) was used to assess facial emotion recognition. This task consists of 60 black and white portrait photographs (front view) of 10 professional actors (6 women, 4 men) displaying the six basic emotions of happiness, sadness, anger, fear, surprise and disgust (10 pictures per category). Pictures were presented on the screen in a randomized order for 5 s each. Each picture was followed by a categorization task, where participants had to classify the face into one of the six emotional categories. Responses were made via the computer keyboard without any time limit. After each keystroke, a black screen was shown for 5 s, followed by the next picture. Task performance was indexed by the sum of correct responses per emotional category, in addition to the total number of correct responses.

Cognitive Tests and Clinical Assessment

The following tests were primarily used to assess the executive function of *updating*:

The *Letter Number Sequencing* task is a subtest of the Wechsler Adult Intelligence Scale (WAIS-III) (51), in which the participant is read a list of numbers and letters, and has to recall the numbers in ascending order and the letters in alphabetical order (21 trials). The number of correct responses indicates task performance.

In the *Spatial Span* subtest of the Wechsler Memory Scale (WMS-III) (52), 10 three-dimensional cubes are placed at a table in front of the participant. The experimenter touches several cubes in a set sequence (sequence length, 2 to 9 items); thereafter, the participant is asked to touch the cubes in the same (forward span), or the reverse (backward span), sequence (32 trials). In order to limit the number of variables, and because of the strong correlation between forward and backward span (r = .49), test performance is represented by the sum of all correct responses.

During the *Arithmetic* subtest of the WAIS-III, the participant has to solve 20 story-type arithmetic problems within a restricted time period ranging between 15 and 120 s. Performance is represented by the number of correct answers.

The *Verbal Fluency* task (53) requires production of the largest possible number of words starting with the letters F, A and S (1 min per letter). The total number of words produced indexes task performance.

The *Ruff Figural Fluency Test* (54) involves five different arrangements of dots on a sheet of paper. The participant is asked to draw as many unique designs as possible by connecting the dots in different patterns (60 s per arrangement). Task performance is indexed by the total number of unique figures produced.

In the *Similarities* subtest of the WAIS-III, the participant reads word pairs representing objects or concepts, and has to indicate how these objects/concepts are similar (analogical reasoning). The number of correct responses represents performance.

The following tasks were primarily used to assess the *inhibition* and *shifting* functions:

The *Color Word Interference Test* (*Stroop Test)* (55) consists of four different parts, each comprising 50 items. In Part 1 (color naming), the colors of patches have to be named as quickly as possible; in Part 2 (reading), the words “blue”, “red” and “green”, printed in black, have to be read. In Part 3 (inhibition), these color words are presented in incongruent colors (e.g., red written in blue color) and the participant must name the color while ignoring the word meaning. Part 4 (shifting) is based on the same items as Part 3, but the response mode switches between reading and color naming according to a visual signal. Inhibition performance is indexed by the difference in execution time between the inhibition and color naming conditions (Part 3 vs. Part 1); shifting performance is represented by the time difference between shifting and inhibition (Part 4 vs. Part 3). Lower shifting and inhibition scores reflect better performance.

In the *Five Digits Test* (56), a series of 50 squares are displayed on the computer screen, each of which contains one to five digits or asterisks. In Part 1 (reading), the participant has to read the digits as quickly as possible; in Part 2 (counting), the asterisks must be counted. In Part 3 (interference), the digits are counted. The requirements of Part 4 (shifting) are identical to those of Parts 1 and 2 (reading and counting, respectively); however, the task mode changes between trials according to a visual signal. Inhibition is indexed as the time difference between Part 3 and the mean of Parts 1 and 2; shifting is quantified according to the time difference between Part 3 and the mean of Parts 1 and 2. Lower scores reflect greater inhibition and better shifting performance.

During the *Wisconsin Card Sorting Test* (57), the participant assigns a series of 64 cards displaying different symbols to one of four reference cards. The cards can be matched by the symbols´ number, color or shape. The participant is unaware of the assignment rule

(number, color, shape), but receives feedback after each trial (correct/incorrect). The rule changes after 10 consecutive correct responses, such that the assignment strategy has to be changed accordingly. In this study, shifting performance was indicated by the percentage of perseverative errors, i.e. incorrect responses that would have been correct for the preceding rule.

Mental disorders in both samples were diagnosed using the *Structured Clinical Interview for Axis I Disorders of the Diagnostic and Statistical Manual for Mental Disorders (SCID)* (58). The SCID is an internationally recognized interview guide for diagnosing prevalent psychiatric problems, including affective and anxiety disorders.

Procedure

The study was conducted over two sessions performed on the same day, each of which lasted approximately 2 hours. During the first session, a clinical psychologist conducted the SCID interviews, recorded the prospective patients' sociodemographic and clinical data, and evaluated them in terms of the inclusion and exclusion criteria. Five prospective participants with fibromyalgia had to be excluded for the following reasons: not meeting the age criterion (1 patient), alcohol problems (1 patient), opiate dependence (1 patient), recently diagnosed cancer (1 patient) and semi-illiteracy (1 patient). Five prospective controls we excluded due to alcohol problems (3 individuals), suspected schizophrenia (1 individual) and the existence of a first-degree relative with fibromyalgia (1 individual). Performance testing was conducted during the second session. First, the EK-60 F was completed, followed by cognitive tests presented in the following fixed order: Letter Number Sequencing, Arithmetic, Spatial Span, Verbal Fluency, Similarities, Stroop Test, Five Digits Test and Wisconsin Card Sorting Test. The study was approved by the Ethics Committee for Human Research of the University of Jaén and all participants provided written informed consent.

Statistical Analysis

Emotion recognition was analysed using ANOVA with the between-subjects factor of group (fibromyalgia patients vs. control group) and the within-subject factor of emotional category (happiness, sadness, anger, fear, surprise, disgust). The number of correct classifications in the six categories served as the dependent variable. Furthermore, possible biases related to psychiatric comorbidity and psychotropic medication were tested in the fibromyalgia group by means of a stratified analysis, where patients suffering and not suffering from depression or anxiety disorders and those using and not using antidepressants, analgesics, anxiolytics or opiates, were compared. For this purpose, ANOVA with the between-subjects factors of group (according to diagnosis or medication) and the within-subject factor emotional category was performed on the patients. In cases of violation of the sphericity assumption, the Greenhouse-Geisser correction was applied. The original degrees of freedom and corrected p values are provided. Relationships between executive functions and emotional recognition were quantified in the fibromyalgia group by Pearson correlations, including all of the cognitive test outcome measures and the total number of correct classifications on the EK-60 F. To control for the possible impact of education level on emotion recognition, duration of education was adjusted for when computing the correlations. In addition, multiple regression analysis was computed with the cognitive test outcome measures as predictors and the total number of correct classifications on the EK-60 F as the dependent variable.

Results

Figure 1 shows the numbers of correct classifications in the six emotional categories of the EK-60 F for both study groups. Recognition accuracy was lower overall in the fibromyalgia patients than healthy individuals. ANOVA revealed a main effect of group ($F[1,82] = 13.55$, $p < .001$, $\eta_p^2 = .14$). In addition, a main effect of emotional category was seen, indicating differences in recognition accuracy among the six emotional categories within the whole sample ($F[5,410] = 34.07$, $p < .001$, $\eta_p^2 = .29$). Accuracy was highest for the category of

happiness, followed by disgust, surprise, anger, sadness and fear. The interaction between the factors was not significant, suggesting that the group difference in recognition accuracy did not vary as a function of emotional category (F[5,410] = 1.34, p = .25, η_p^2 = .016).

Figure 1

The stratified analyses in the fibromyalgia group did not reveal differences in the number of correct classifications between patients suffering and not suffering from comorbid depression (group effect: F[1,50] = 0.15, p = .70, η_p^2 = .003), nor between those suffering and not suffering from comorbid anxiety disorders (group effect: F[1,50] = 1.51, p = .23, η_p^2 = .029). Moreover, recognition accuracy did not differ between patients taking antidepressants, anxiolytics, non-opioid analgesics or opiates and those not taking these medications (group effect antidepressant use: F[1,50] = 3.17, p = .081, η_p^2 = .060; group effect anxiolytic use: F[1,50] = 0.33, p = .57, η_p^2 = .007; group effect non-opioid analgesic use: F[1,50] = 0.001, p = .98, η_p^2 < .001; group effect opiate use: F[1,50] = 0.022, p = .88, η_p^2 < .001). While all of these ANOVA models revealed an effect of emotional category (all p < .001), no group by emotional category interactions were seen (all p ≥ .38).

Table 2 lists the correlations in the fibromyalgia group between cognitive parameters and the total number of correct classifications, with adjustment for duration of education. All correlations, except Spatial Span and the Shifting index Stroop Test outcomes, reached significance. As higher values on the Stroop Test, Five Digits Test and Wisconsin Card Sorting Test outcome measures indicate lower task performance, all correlations denote associations between higher executive function performance and better facial emotion recognition.

Table 2

Regression analysis in the fibromyalgia group revealed an R value of .67 for the overall model; the beta weights and collinearity statistics (tolerance, VIF) are delineated in Table 3. None of the beta weights reached significance. The correlations between the cognitive test

outcome measures are presented in the Supplementary Material. In total, 44 of the 55 correlations were significant, suggesting close associations between the predictors. Together with the relatively low tolerance and high VIF values for some of the predictors, this suggests the presence of collinearity in the multivariate model.

Table 3

Fibromyalgia patients exhibited poorer performance on most of the cognitive test outcome measures. The results are reported in detail elsewhere (44).

Discussion

This study analyzed the ability of fibromyalgia patients to recognize facially expressed emotions, and the association of this ability with executive functions. Patients made more errors overall in the classification of faces according to their expressions than healthy individuals. Moreover, recognition accuracy correlated positively with performance on executive function tasks. Facial emotion recognition did not vary as a function of comorbid depression or anxiety disorders, or with the use of antidepressants, anxiolytics, analgesics or opiates.

Our finding of impaired emotion recognition replicates that of Weiß and colleagues (11), in which fibromyalgia patients, as compared to healthy controls, exhibited more errors in the classification of images showing happy, angry, anxious, sad, disgusted and neutral faces taken from the Karolinska Directed Emotional Faces Battery (59). The magnitude of the group difference was identical in both studies, at η_p^2 = .14. The lack of an interaction effect in the ANOVA suggested that the patients´ difficulty in identifying the expressions did not vary as a function of emotional category, which is also consistent with the original study. Just as in the present analysis, Weiß and colleagues (11) did not find evidence indicating that psychiatric or psychotropic medication accounts for the impairments.

In this study, correlations between cognitive test scores and correct classifications on the EK-60 F suggested associations between the executive function components of updating, shifting and inhibition with emotional recognition. The inhibition component was represented by the corresponding indices of the *Stroop Test* and *Five Digits Test*, which were related to classification accuracy. Perseverative errors on the *Wisconsin Card Sorting Test* reflect shifting ability, that is, the ability to flexibly switch between different task rules. In addition to this parameter, the shifting index of the *Five Digits Test* also predicted correct classifications. The *Letter Number Sequencing* task requires the retention and manipulation of information in working memory, such that the correlation obtained for this parameter suggests an association of the updating component with emotional recognition. This is also supported by the correlations of the *Arithmetic*, *Verbal Fluency*, *Ruff Figural Fluency* and *Similarities* tasks with correct classifications. Although the requirements of these tasks are more heterogeneous, they all exhibit high load on the updating component (for a detailed discussion pertaining to the assignment of the tasks to the three executive function components, see (44)). It is important to note that fibromyalgia patients performed worse than healthy individuals on almost all of the tasks (44). As such, the data support the hypothesis that deficiencies in executive functions are associated with the difficulty in identifying emotional expressions experienced by fibromyalgia patients. However, it must be acknowledged that the shifting index of the *Stroop Test* and the *Spatial Span* task were unrelated to classification accuracy, which somewhat restricts our ability to draw conclusions regarding the role of shifting and updating in emotional recognition.

Regression analysis revealed an R value of .67 for the overall model, suggesting that the cognitive test scores together explained a substantial proportion (45%) of the variance in facial recognition performance. In contrast, none of the beta weights of the predictors reached significance. This may mainly be ascribed to the substantial correlations between the predictors (multicollinearity) in the multiple regression model. However, the correlations are consistent with current theories of executive functions such as Miyake´s model (39), which our classification is based on. Factor analysis and structural equation modelling

suggested that updating, shifting, and inhibition constitute dissociable latent variables; nevertheless, these three components are closely associated with each other (39). Regression analysis is the method of choice to quantify the degree to which a specific variable predicts a criterion, independent of other variables. However, in our study it could not be hypothesized that the cognitive test scores would be independent predictors of facial recognition performance, so the relationships between executive functions and emotion recognition are better reflected by the first order correlations.

Identification of emotions expressed by the human face constitutes a complex ability comprising several stages of information processing, which may be affected by the cognitive deficits associated with fibromyalgia (3, 40) (see Figure 2). The early stages involve the encoding of visual information, which mainly requires basic perceptual and attentional skills. Deficits in basic attentional functions, which are prevalent among fibromyalgia patients, may interfere with these processes (32, 60, 61). During later stages, the encoded information is integrated with preexisting semantic and affective knowledge about facial expressions, which enables identification of a particular emotion. By definition, executive functions are crucial to the latter processes. To ensure their successful implementation, information from the seen face, and information retrieved from long-term memory, have to be maintained and monitored in working memory (updating); relevant subtasks have to be coordinated while the cognitive focus switches between them (shifting). In addition, confounding effects of irrelevant information have to be controlled (inhibition). In our study, the correlations for most of the cognitive test scores were in the medium range, which may indicate that the three functional components contribute to facial emotion recognition to similar extents.

Figure 2

Previous studies revealed evidence of the implication of executive functions in impaired facial emotion recognition in schizophrenia (10, 62). For example, Lee and colleagues (41) reported that the number of perseverative errors on the Wisconsin Card Sorting Test accounted for 25% of the variance among patients in performance on a facial recognition

task. In addition, the speed of performance on the test, indexed by the total number of correct responses and the number of categories completed, predicted recognition accuracy (63, 40). Moreover, correlations between the variables of the Wisconsin Card Sorting Test and facial emotion recognition were seen in patients with bipolar disorder (42). In healthy individuals, associations between cognition and emotion recognition have mainly been studied using intelligence tests. Moderate positive correlations were seen for measures of fluid and crystalized intelligence (see (3) for an overview). Although they are concerned with different psychological constructs, most of the applied tasks have a high load on executive functions.

In central nervous system information processing, the interactions of pain experience, executive functions and emotion recognition may involve a network of cortical and limbic structures. The prefrontal cortex, which is the core neuroanatomical correlate of executive functions, also plays a key role in decoding facial expressions (64, 65). For example, impaired emotion recognition in schizophrenia has been related to blunted prefrontal activity (40, 66). In addition, the amygdala and insula are implicated in emotional recognition. According to neuroimaging studies, the amygdala is sensitive to the valence of facially expressed emotions (65, 67). Moreover, impairments in emotion recognition are accompanied by reduced activity in the insula (68, 69). Therefore, networks within the prefrontal cortex, and connections with limbic structures, may mediate the dependence of emotional face recognition on executive functions. Another possible causal pathway refers to interference of pain processing with both cognition and emotional communication. A neuromatrix of pain has been identified, which includes structures such as the somatosensory and prefrontal cortices, the anterior cingulate, insula, amygdala and thalamus (70). This matrix partially overlaps with the aforementioned networks; specifically, the prefrontal cortex, amygdala and insula also mediate executive functions and/or emotional recognition. Exaggerated activity in the pain neuromatrix is widely acknowledged as the core pathogenic factor in the hyperalgesia characterizing fibromyalgia (16). This implies increased demand on the prefrontal cortex and limbic structures, and thus reduced processing

resources for executive function and emotional recognition, which may interfere with optimal performance.

It is evident that additional mechanisms that do not significantly depend on higher cognitive processes also contribute to facial emotion recognition and impairments in this ability. As initially stated, alexithymia may link fibromyalgia pain with deficient emotional communication (11). Moreover, mechanisms of emotional contagion may play a role. In terms of emotional mimicry, the perception of an affective expression leads to automatic imitation of the expression by the observer (71). Afferent feedback, in turn, triggers the experience of the affective state that is being mimicked (72). Accordingly, observing an emotional face expression is associated with activation in neural structures that are also active during first-hand experience of this emotion (73). Emotional contagion is considered important in empathy and compassion, but it may also facilitate identification of others´ emotional states (74). However, abnormalities in emotional processing related to fibromyalgia, such as negativity bias, emotional avoidance or alexithymia, as well as negative emotions like depression and anxiety, may interfere with these processes, leading to misinterpretation of the facial expressions of others.

The study used a cross-sectional design and some relevant variables may not have been assessed; therefore, the putative causal pathways between fibromyalgia, executive functions and emotional face recognition must remain hypothetical and alternative explanations cannot be ruled out. Face recognition and executive functions are both affected by mood impairments and anxiety (5, 6, 75, 76). Considering this, the associations between cognitive performance and recognition accuracy to some degree may be due to third variable effects of mood impairments and anxiety. In future research, causal relationships could be explored by intervention studies. Executive functions can be improved by training, and by pharmacological agents such as methylphenidate (77-79). It has also been reported that methylphenidate reduced perceived interference of fibromyalgia pain with concentration, energy and mood (80). To establish the causal role of poor executive functions in deficient emotional recognition in fibromyalgia, whether such interventions also enhance recognition

performance could be examined. In addition, studying the possible effects of interventions targeting emotional processing on executive functions and emotional face recognition may be worthwhile (81, 82). For example, emotional awareness and expression therapy proved beneficial for reducing pain, emotional symptoms and subjective cognitive impairments in fibromyalgia (82). Through such interventions, the causal role of emotional dysregulation in executive function impairments and poor emotional identification could be investigated in fibromyalgia patients.

The comparison of patient subgroups distinguished according to psychiatric comorbidities did not indicate a substantial role of depression and anxiety disorders in the recognition impairment; however, this analysis was limited in scope by the relatively small size of the subgroups, leading to low power of the statistical tests. The group comparison does not provide information concerning the role of comorbidities and medication use, because the groups were not matched in terms of these variables. Another limitation was the restriction of the cognitive assessments to executive functions; it is evident that attentional processes also play a role in facial emotion recognition, in particular during its early stages (3, 40). Moreover, the exclusive use of executive function tests precludes inference regarding the degree to which executive function deficits specifically contribute to impaired facial emotion recognition in fibromyalgia. To obtain further information concerning this matter, future studies should use cognitive parameters that are explicitly hypothesized not to correlate with recognition performance; assessment of general intelligence may also be useful. Another constraint relates to the Ekman-60 Faces Test; a ceiling effect arose in the happiness category, where both study groups identified nearly all expressions correctly. In addition, some of the applied cognitive tasks, especially the WAIS-III and WMS-III subtests, cannot be considered “state-of-the-art” and may be inferior to more recently developed computerized tests. Finally, as only women participated in the study, the generalizability of the findings to male fibromyalgia patients remains unknown.

Conclusions

In conclusion, this study provides further support for the notion of impaired emotional face recognition in fibromyalgia. As a complex process, facial emotion recognition may rely heavily on efficient coordination by executive functions. The association between cognitive test performance and recognition accuracy, together with the executive function deficit in fibromyalgia, implicates higher cognitive functions in the observed impairment. While accurate interpretation of the facial expressions of our fellow human beings facilitates emotional connections and interpersonal communication, impairments may negatively affect relationships and social wellbeing. Interpersonal difficulties such as communication problems with friends and family, conflicts or social isolation are prevalent in fibromyalgia patients (13). In turn, such interaction problems and poor social resources are believed to play a role in pain chronification (83). This may also be relevant with respect to the optimal psychological therapy for the disorder. The inclusion of measures aimed at improving affective decoding and general emotional communication in cognitive-behavioral and emotional awareness programs of pain management might be useful (82, 84).

Conflict of Interest: The authors have no conflict of interest to report.

Access to research data: The research data of the study is available to the public via the repository Open Science Framework (OSF: https://osf.io/fw54p/).

References

1. Calvo MG, Nummenmaa L. Perceptual and affective mechanisms in facial expression recognition: An integrative review. Cogn Emot 2016; 30: 1081-1106.
2. Elfenbein HA, Foo MD, White J, Tan HH, Aik VC. Reading your counterpart: The benefit of emotion recognition accuracy for effectiveness in negotiation. J Nonverbal Behav 2007; 31: 205–223.
3. Schlegel K, Palese T, Schmid-Mast M, Rammsayer TH, Hall JA, Murphy NA. A meta-analysis of the relationship between emotion recognition ability and intelligence. Cogn Emot 2020; 3: 329-351.
4. Schlegel K, Witmer JS, Rammsayer TH. Intelligence and sensory sensitivity as predictors of emotion recognition ability. J Intell 2017; 5:35.
5. Gollan JK, Pane H, McCloskey MS, Cocarro EF. Identifying differences in biased affective information processing in major depression. Psychiatry Res 2008; 159: 18-24.
6. Jarros RB, Salum GA, Belem da Silva CT, Toazza R, de Abreu Costa M, Fumagalli de Salles J, Manfro GG. Anxiety disorders in adolescence are associated with impaired facial expression recognition to negative valence. J Psychiatr Res 2012; 46: 147-151.
7. Hastings M, Tangney JP, Stuewig J. Psychopathy and identification of facial expressions of emotion. Pers Individ Dif 2008; 44: 1474-1483.
8. Marissen MA, Deen ML, Franken ICH. Disturbed emotion recognition in patients with narcissistic personality disorder. Psychiatry Res 2012; 198: 269-273.
9. Pollatos O, Herbert BM, Wankner SM, Dietel A, Wachsmuth C, Henningsen P, Sack M. Autonomic imbalance is associated with reduced facial recognition in somatoform disorders. J Psychosom Res 2011; 71: 232-239.
10. Barkl SJ, Lah S, Harris AWF, Williams LM. Facial emotion identification in early-onset and first-episode psychosis: A systematic review with meta-analysis. Schizophr Res 2014; 159: 62-69.

11. Weiß S, Winkelmann A, Duschek S. Recognition of facially expressed emotions in patients with fibromyalgia syndrome. Behav Med 2013; 39: 146-154.
12. Wolfe F, Clauw DJ, Fitzcharles MA, Goldenberg DL, Katz RS, Mease P, Russell AS, Russell IJ, Winfieled JB, Yunus MB. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res 2010; 62: 600-610.
13. Arnold LM, Crofford LJ, Mease PJ, Burgess SM, Palmer SC, Abetz L, Martin SA. Patients perspectives on the impact of fibromyalgia. Patient Educ Couns 2008; 73: 114-120.
14. Galvez-Sánchez CM, Duschek S, Reyes del Paso GA. Psychological impact of fibromyalgia: current perspectives. Psychol Res Behav Manag 2019; 12;117-127.
15. Duschek S, Mannhart T, Winkelmann A, Merzoug K, Werner NS, Schuepbach D, Montoya, P. Cerebral blood flow dynamics during pain processing in patients with fibromyalgia syndrome. Psychosom Med 2012; 74: 802-809.
16. Gracely RH, Ambrose KR. Neuroimaging of fibromyalgia. Best Pract Res Clin Rheumatol 2011; 25: 271-284.
17. Davis MC, Zautra AJ, Reich JW. Vulnerability to stress among women in chronic pain from fibromyalgia and osteoarthritis. Ann Behav Med 2001; 23: 215-226.
18. Montoya P, Sitges C, Garcia-Herrera M, Izquierdo R, Truyols M, Blay N, Collado D. Abnormal affective modulation of somatosensory brain processing among patients with fibromyalgia. Psychosom Med 2005; 67: 957-963.
19. Rhudy JL, Delventura JL, Terry EL, Bartley EJ, Olech E, Palit S, Kerr KL. Emotional modulation of pain and spinal nociception in fibromyalgia. Pain 2013; 154: 1045-1056.
20. Duschek S, Werner NS, Limbert N, Winkelmann A, Montoya P. Attentional bias towards negative information in patients with fibromyalgia syndrome. Pain Med 2014; 15: 603-612.

21. van Middendorp H, Lumley MA, Jacobs JW, van Doornen LJ, Bijlsma, JW, Geenen R. Emotions and emotional approach and avoidance strategies in fibromyalgia. J Psychosom Res 2008; 64: 159-167.
22. Geisser ME, Casey KL, Brucksch CB, Ribbens CM, Appleton BB, Crofford LJ. Perception of noxious and innocuous heat stimulation among healthy women and women with fibromyalgia: association with mood, somatic focus, and catastrophizing. Pain 2003; 102: 243-250.
23. Boehm A, Eisenberg E, Lampel S. The contribution of social capital and coping strategies to functioning and quality of life of patients with fibromyalgia. Clin J Pain 2011; 27: 233-239.
24. Montoro CI, Reyes del Paso GA, Duschek S. Alexithymia in fibromyalgia syndrome. Pers Individ Dif 2016; 102: 170-179.
25. Lane RD, Sechrest L, Riedel R, Shapiro DE, Kaszniak AW. Pervasive emotion recognition deficit common to alexithymia and the repressive coping style. Psychosom Med 2000; 62: 492-501.
26. Parker JD, Taylor GJ, Bagby RM. Alexithymia and the recognition of facial expressions of emotion. Psychother Psychosom 1993; 59: 197-202.
27. Duschek S, Montoro, C, Reyes del Paso GA. Diminished interoceptive awareness in fibromyalgia syndrome. Behav Med 2017; 43: 100-107.
28. Craig AD. The sentient self. Brain Struct and Funct 2010; 214: 563-577.
29. Damasio A. The Feeling of What Happens: Body, Emotion and the Making of Consciousness. London: Vintage; 2000.
30. Ghiggia A, Torta R, et al. Pschosomatic syndromes in fibromyalgia. Clin Exp Rheumatol 2017; 105: 106-111.
31. Torta R, Pennazio F, Ieraci V. Anxiety and depression in rheumatologic diseases: the relevance of diagnosis and management. Reumatismo 2014; 66: 92-97.
32. Dick BD, Verrier MJ, Harker KT, Rashiq S. Disruption of cognitive function in fibromyalgia syndrome. Pain 2008; 139: 610-616.

33. Duschek S, Werner NS, Winkelmann A, Wankner S. Implicit memory function in fibromyalgia syndrome. Behav Med. 2013; 39: 11-16.
34. Park DC, Glass JM, Minear M, Crofford LJ. Cognitive function in fibromyalgia patients. Arthritis Rheum. 2001; 44: 2125-2133.
35. Castro VL, Boone RT. Sensitivity to spatiotemporal percepts predicts the perception of emotion. J Nonverbal Behav 2015; 39: 215-240.
36. Palermo R, O'Connor KB, Davis JM, Irons J, McKone E. New tests to measure individual differences in matching and labelling facial expressions of emotion, and their association with ability to recognise vocal emotions and facial identity. PloS one 2013; 8(6), e68126.
37. Murphy NA, Hall JA. Intelligence and interpersonal sensitivity: A meta-analysis. Intelligence 2011; 39: 54-63.
38. Diamond A. Executive functions*.* Ann Review Psychol 2013; 64: 135-168.
39. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex ''frontal lobe'' tasks: a latent variable analysis. Cognitive Psychol 2000; 41: 49-100.
40. Yang, C., Zhang, T., Li, Z. et al. The relationship between facial emotion recognition and executive functions in first-episode patients with schizophrenia and their siblings. BMC Psychiatry 2015; 15: 241.
41. Lee SJ, Lee HK, Kweon YS, Lee CT, Lee KU. The impact of executive function on emotion recognition and emotion experience in patients with schizophrenia. Psychiatry Investig 2009; 6: 156–62.
42. David DP, Soeiro-de-Souza MG, Moreno RA, Bio DS. Facial emotion recognition and its correlation with executive functions in bipolar I patients and healthy controls. J Affect Disord 2014; 152-154: 288-294.
43. Gelonch O, Garolera M, Valls J, Rosselló L, Pifarré J. Executive function in fibromyalgia: Comparing subjective and objective measures. Compr Psychiatry 2016; 66: 113-122.

44. Muñoz Ladrón de Guevara C, Fernández-Serrano MJ, Reyes del Paso GA, Duschek S. Executive function impairments in fibromyalgia syndrome: Relevance of clinical variables and body mass index. PLoS ONE 2018; 13(4): e0196329.
45. Verdejo-García A, López-Torrecillas F, Calandre EP, Delgado-Rodríguez A, Bechara A. Executive function and decision-making in women with fibromyalgia. Arch Clin Neuropsychol 2009; 24: 113-122.
46. Reyes del Paso GA, Pulgar A, Duschek S, Garrido S. Cognitive impairment in fibromyalgia syndrome: The impact of pain, emotional disorders, medication, and cardiovascular regulation. Eur J Pain 2012; 16: 421-429.
47. Galvez-Sánchez CM, Reyes del Paso GA, Duschek S. Cognitive impairments in fibromyalgia syndrome: Associations with positive and negative affect, alexithymia, pain catastrophizing and self-esteem. Front Psychol 2018; 9: 377.
48. Wolfe F, Smythe H, Yunus M, et al. The American College of Rheumatology 1990 Criteria for the Classification of Fibromyalgia. Report of the Multicenter Criteria Committee. Artritis Rheum 1990; 33: 160-172.
49. Ekman P, Friesen W. Pictures of facial affect. Palo Alto, CA: Consulting Psychologists Press; 1976.
50. Young A, Perrett D, Calder A, Sprengelmeyer R, Ekman P. Facial Expression of Emotion: Stimuli and Tests (FEEST). Thames Valley Test Company. Bury St Edmunds; 2002.
51. Wechsler D. Wechsler Adult Intelligence Scale, 3rd Edition. The Psychological Corporation. San Antonio, Texas; 1997.
52. Wechsler D. Wechsler memory scale, 3rd Edition. The Psychological Corporation. San Antonio, Texas; 1997.
53. Lezak, MD. Neuropsychological Assessment. New York: Oxford University Press; 2004.
54. Ruff, R.M. Ruff Figural Fluency Test: Professional Manual. Psychological Assessment Resources Lutz, Florida; 1996.

55. Delis DC, Kaplan E, Kramer JH. Delis-Kaplan Executive Function System (D-KEFS). San Antonio, TX: The Psychological Corporation; 2001.
56. Sedó M. Test de los Cinco Dígitos. Madrid: T.E.A. Ediciones; 2007.
57. Grant DA, Berg EA. Wisconsin Card Sorting Test. Los Angeles, CA: Western Psychological Services; 1993.
58. First M, Spitzer R, Gibbon M, Williams J. Entrevista Clínica Estructurada para los Trastornos del Eje I del DSM–IV (SCIDI). Barcelona, Spain: Masson; 1999.
59. Lundqvist D, Flykt A, Ohman A. The Karolinska Directed Emotional Faces (KDEF). Karolinska Institute: Department of Clinical Neuroscience, Psychology Section; 1998.
60. Harker KT, Klein RM, Dick B, Verrier MJ, Rashiq S. Exploring attentional disruption in fibromyalgia using the attentional blink. Psychol Health 2011; 26: 915-929.
61. Reyes del Paso GA, Montoro CI, Duschek S. Reaction time, cerebral blood flow, and heart rate responses in fibromyalgia: Evidence of alterations in attentional control. J Clin Exp Neuropsychol 2015; 37: 414-428.
62. Sachs G, Steger-Wuchse D, Kryspin-Exner I, Gur RC, Katschnig H. Facial recognition deficits and cognition in schizophrenia. Schizophr Res 2004; 68: 27-35.
63. Bryson G, Bell M, Lysaker P. Affect recognition in schizophrenia: a function of global impairment or a specific cognitive deficit. Psychiatry Res 1997; 71: 105-113.
64. Kawasaki H, Kaufman O, Damasio H, Damasio AR, Granner M, Bakken H, et al. Single-neuron responses to emotional visual stimuli recorded in human ventral prefrontal cortex. Nat Neurosci 2001; 4: 15-16.
65. Vuilleumier P, Armony JL, Driver J, Dolan RJ. Distinct spatial frequency sensitivities for processing faces and emotional expressions. Nat Neurosci 2003; 6: 624-631.
66. Edwards J, Pattison PE, Jackson HJ, Wales RJ. Facial affect and affective prosody recognition in first-episode schizophrenia. Schizophr Res 2001; 48: 235-253.
67. Sambataro F, Dimalta S, Di Giorgio A, Taurisano P, Blasi G, Scarabino T, Giannatempo G, Nardini M, Bertolino A. Preferential responses in amygdala and

insula during presentation of facial contempt and disgust. Eur J Neurosci 2006; 24: 2355-2362.

68. Vuilleumier P, Pourtois G. Distributed and interactive brain mechanisms during emotion face perception: Evidence from functional neuroimaging. Neuropsychologia 2007; 45: 174-194.
69. Apkarian AV, Bushnell MC, Treede RD, Zubieta JK. Human brain mechanisms of pain perception and regulation in health and disease. Euro J Pain. 2005; 9: 463-484.
70. Singer T. The neuronal basis and ontogeny of empathy and mind reading: Review of literature and implications for future research. Neurosci Biobehav Rev 2006; 30: 855-863.
71. Preston SD, de Waal FBM. Empathy: Its ultimate and proximate bases. Behav Brain Sci 2000; 25: 1-72.
72. Hatfield E, Cacioppo JT, Rapson RL. Emotional contagion. New York, NY. Cambridge University Press; 1994.
73. Singer T, Lamm C. The social neuroscience of empathy. Ann NY Acad Sci 2009; 1156: 81-96.
74. Adolphs R. The social brain. Neural basis of social knowledge. Annu Rev Psychol 2009; 60: 693-716.
75. Hoffmann A, Ettinger U, Reyes del Paso GA, Duschek, S. Executive function and cardiac autonomic regulation in depressive disorders. Brain Cogn 2017; 118: 108-117.
76. Ferreri F, Lapp LK, Peretti CS. Current research on cognitive aspects of anxiety disorders. Curr Opinion Psychiatry 2011; 24: 49-54.
77. Dahlin E, Nyberg L, Bäckman L, Neely AS. Plasticity of executive functioning in young and older adults: Immediate training gains, transfer, and long-term maintenance. Psychol Aging 2008; 23: 720-730.
78. Nandam LS, Hester R, Wagner J, Cummins TD, Garner K, Dean AJ, Kim BN, Nathan PJ, Mattingley JB, Bellgrove MA. 2011. Methylphenidate but not

atomoxetine or citalopram modulates inhibitory control and response time variability. Biol Psychiatry 2011; 69: 902-904.

79. Salminen T, Strobach T, Schubert T. On the impacts of working memory training on executive functioning. Front Hum Neurosci 2012; 6: 166.
80. Katz RS, Bond H, Leavitt F. Methylphenidate improves concentration, energy and mood in fibromyalgia. Arthritis Rheum 2013; 65(Suppl): S470.
81. Hsu MC, Schubiner H, Lumley MA, Stracks JS, Clauw DJ, Williams DA. Sustained pain reduction through affective self-awareness in fibromyalgia: A randomized controlled trial. J Gen Int Med 2010; 25: 1064-1070.
82. Lumley MA, Schubiner H, Lockhart NA, Kidwell KM, Harte SE, Clauw DJ, Williams DA. Emotional awareness and expression therapy, cognitive behavioral therapy, and education for fibromyalgia: a cluster-randomized controlled trial. Pain 2017; 158: 2354-2363.
83. Flor H, Turk DC. Cognitive and learning aspects. In: McMahon SB, Koltzenburg M, eds. Textbook of Pain. Amsterdam: Elsevier; 2006: 241-258.
84. Thieme K, Turk DC. Cognitive-behavioral and operant-behavioral therapy for people with fibromyalgia. Reumatismo 2012; 64: 275–285.

1. **Table 1.** Demographic and clinical characteristics of the study population; values of t[82] or x^2 and p of the group comparison (M = mean, SD = standard deviation).

	Fibromyalgia patients (N = 52)	**Control group (N = 32)**		
	M ± SD / N (%)	M ± SD / N (%)	t[82] / x^2	p
Age (years)	51.25 ± 8.67	52.94 ± 6.59	-0.95	.35
Duration of education (years)	9.27 ± 3.52	10.59 ± 3.64	-1.65	.10
BMI (kg/m^2)	28.29 ± 4.49	26.49 ± 4.36	1.80	.075
Depression (N, %)	22 (42.30 %)	2 (6.25 %)	12.62	<.001
Anxiety disorders (N, %)	25 (48.08 %)	7 (21.88 %)	5.77	.016
Antidepressant medication (N, %)	27 (51.92 %)	2 (6.26 %)	18.28	<.001
Anxiolytic medication (N, %)	35 (67.31 %)	8 (25.00 %)	14.19	<.001
Non-opioid analgesic medication (N, %)	45 (86.5 %)	8 (25.00 %)	32.22	<.001
Opiate medication (N, %)	23 (44.2 %)	0 (0.00 %)	16.49	<.001

Note: Anxiety disorders include panic disorder, generalized anxiety disorder, phobias and adjustment disorder.

Table 2. Partial correlations between cognitive test parameters and the total number of correct classifications on the EK-60 F, controlling for duration of education, in fibromyalgia patients.

Test	r	P
Letter Number Sequencing	.26	.034
Arithmetic	.43	.001
Spatial Span	.16	.14
Verbal Fluency	.41	.001
Ruff Figural Fluency Test	.34	.007
Similarities	.40	.002
Stroop Test: Inhibition	-.24	.043
Stroop Test: Shifting	-.16	.14
Five Digits Test: Inhibition	-.30	.015
Five Digits Test: Shifting	-.41	.002
Wisconsin Card Sorting Test	-.35	.006

Note: Higher scores on the Stroop Test, Five Digits Test and Wisconsin Card Sorting Test indicate lower task performance; higher scores on all other tests indicate better task performance.

Table 3. Regression analysis in the patient sample for the prediction of the total number of correct classifications on the Ekman-60 Faces Test by the cognitive test parameters.

Test	Standardized beta	p	Tolerance	VIF
Letter Number Sequencing	-.13	.53	.36	2.78
Arithmetic	.15	.44	.39	2.59
Spatial Span	-.18	.32	.42	2.36
Verbal Fluency	.22	.22	.47	2.14
Ruff Figural Fluency Test	.17	.37	.42	2.38
Similarities	.27	.16	.39	2.57
Stroop Test: Inhibition	.04	.87	.21	7.76
Stroop Test: Shifting	-.11	.55	.44	2.29
Five Digits Test: Inhibition	-.20	.38	.27	3.72
Five Digits Test: Shifting	-.03	.89	.28	3.57
Wisconsin Card Sorting Test	-.19	.23	.57	1.75

Note: VIF = variance inflation factor

Figure legends

Figure 1. Number of correct classifications of emotional face displays (bars indicate standard errors of the mean)

Figure 2. Processes involved in facial emotion recognition and possible interference by cognitive impairments in fibromyalgia