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Dissertação apresentada à Universidade Católica Portuguesa para obtenção do grau de mestre em
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Sob orientação de Rita Canaipa, PhD e Roi Treister, PhD

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Abstract

Interoception is currently defined as the conscious and unconscious perception of internal bodily states. Researchers and clinicians have been struggling to fully understand its meaning and how to measure it, thus the investigation on this topic is not yet fully established. It has been suggested that in chronic pain conditions, such as Fibromyalgia, disruption of the interoceptive pathway may contribute to changes in body awareness and some subjective symptoms that these individuals, who experienced long-term pain, complain. Fibromyalgia individuals are also known to have cognitive impairment. Recent studies on interoception suggest that interoception is related to cognitive processes. Based on this knowledge it was hypothesized a relationship between cognitive functioning in Fibromyalgia and Interoception. Thus, the aim of the current study was to investigate perception of body states in Fibromyalgia, more specifically, *Interoceptive Accuracy* and *Interoceptive Sensibility* and its relationship with cognitive functioning in Fibromyalgia. Twenty-nine FM patients were recruited. They were assessed with heartbeat detection task, Multidimensional Assessment of Interoceptive Awareness (MAIA) and neuropsychological memory and attention task, i.e. Digit Span test and Stroop Task. Psychological and Fibromyalgia clinical characteristics were also assessed. The results showed that the individuals less accurate in interoception heartbeat detection task have poorer cognitive performance in short-term memory and cognitive inhibition. Furthermore, increased self-reported ability to regulate body signals was related to a decreased working memory performance. These results suggest the importance of distinguishing the different dimensions of interoception and to discriminate the cognitive resources needed to interoception, as well as the cognitive impact of interoceptive symptom monitoring in chronic pain populations. Due to its possible clinical implications, we believe that this may be an area of interoception research that deserves deepen study in the future.

Keywords: Interoception Accuracy, Interoception Sensibility; Fibromyalgia; Neuropsychological Assessment; Cognitive Function.

Resumo

Atualmente a interoceção é definida como a perceção consciente e inconsciente dos estados corporais internos. Os investigadores e clínicos têm-se esforçado por compreender plenamente o seu significado e a sua forma de medição, pelo que a investigação sobre este assunto ainda não está totalmente estabelecida. Tem sido sugerido que em condições de dor crónica, tais como a Fibromialgia, a perturbação da via interoceptiva pode contribuir para mudanças na consciência corporal e alguns sintomas subjetivos de que estes indivíduos, que sentiram dor a longo prazo, se queixam. Sabe-se também que os indivíduos com Fibromialgia têm dificuldades cognitivas. Estudos recentes sugerem que a interoceção está relacionada com processos cognitivos. Com base neste conhecimento, proposta a hipótese de existir uma relação entre o funcionamento cognitivo na Fibromialgia e a Interoceção. Assim, o objetivo do presente estudo foi investigar a perceção dos estados corporais na Fibromialgia, mais especificamente, a Precisão Interoceptiva e a Sensibilidade Interoceptiva e a sua relação com o funcionamento cognitivo na Fibromialgia. Foram recrutados vinte e nove pacientes com Fibromialgia, que foram avaliados com tarefa de deteção dos batimentos cardíacos, o questionário de Avaliação Multidimensional de Sensibilidade Interoceptiva (MAIA) e tarefas neuropsicológicas de memória e de atenção (Digit Span Test e Stroop Task). Foram também avaliadas as características psicológicas e clínicas da Fibromialgia. Os resultados mostraram que os indivíduos menos precisos na tarefa de deteção dos batimentos cardíacos tinham um desempenho cognitivo inferior na memória a curto prazo e inibição cognitiva. Além disso, o aumento da capacidade autorregulação de sinais corporais estava relacionado com uma diminuição do desempenho da memória de trabalho. Estes resultados sugerem a importância de distinguir as diferentes dimensões da interoceção e de discriminar os recursos cognitivos necessários à mesma, bem como o impacto cognitivo da monitorização dos sintomas de interoceção nas populações de dor crónica. Devido às suas possíveis implicações clínicas, acreditamos que interoceção é uma área de investigação que merece um estudo mais aprofundado no futuro.

Palavras-chave: Precisão Interocetiva, Sensibilidade Interocetiva; Fibromialgia; Avaliação Neuropsicológica; Funcionamento cognitivo.

Contents

List of tables

1. Introduction

Interoception is the conscious and unconscious perception of our internal bodily states (Craig, 2009) and can be described as the cluster of processes by which physiological signals in the body are transmitted back to the brain, allowing the organism to regulate the internal state homeostatically (Cameron, 2001). Interoception processes awareness of several bodily feelings, such as pain, touch, temperature signals, including heartbeats, afferent signaling, central processing, neural and mental representation of internal bodily signals, and the feeling states that they generate (Critchley & Garfinkel, 2017).

Recently, three dimensions of Interoception have been suggested by Garfinkel et al. (2015). The first is *Interoceptive Accuracy (IAc)* that can be described as the ability to accurately perceive changes in the homeostatic function (Calì et al., 2015) or detect internal sensations and signals, such as heart beating, hunger, or thirst (Pollatos & Herbert, 2018). It is usually assessed by measuring the individual's sensitivity to detect their own heartbeats, in the heartbeat detection task (Schandry, 1981). The second is *Interoceptive Sensibility (IS).* It refers to the subjective experience of perceiving and being aware of one's internal body sensations, such as the ability to report bodily states like muscle tension, hunger, dry mouth (Pollatos & Herbert, 2018) and it can be measured with questionnaires such as Multidimensional Assessment of Interoceptive Awareness (Mehling et al., 2018). Finally, the third is *Interoceptive Awareness (IAw*). It is a metacognitive concept that quantifies individuals' explicit knowledge of their interoceptive accuracy (Garfinkel & Critchley, 2013) or the awareness of bodily states through a measure of the confidence in the accuracy of interoceptive states (Pollatos & Herbert, 2018) i.e., how confident is the person on whether he is accurately or inaccurately assessing their heartbeat (Garfinkel et al., 2015). This third Interoception dimension is poorly studied because it refers to a difficult measure: a metacognitive awareness of the individual's interoceptive accuracy.

It has been proposed that a disturbed interoception is associated with a wide range of psychiatric and psychosomatic disorders (Khalsa & Lapidus, 2016) as well as with chronic pain conditions. In other words, individuals who experience pain over a prolonged period and beyond the expected clinical time for healing, such as chronic pain patients, may present abnormalities in processing body-related signals (Solcà et al., 2020). It is known that the representation of the body in the brain is correlated with the integration of multisensory stimuli across several central nervous system (CNS) structures (Suzuki et al., 2013). Insula, which is a key area for interoception and pain processing (Tracey & Mantyh, 2007) is also one of the brain areas that show functional changes associated with chronic pain (Baliki et al., 2011). This may suggest that disruption in the interoceptive pathway may contribute to changes in body awareness in individuals who experienced long-term pain.

Like in most chronic pain conditions, Fibromyalgia (FM) patients have interoception impairment. Borg and colleagues (2015) showed that sensory and affective aspects of pain in FM modulated the perception of bodily sensations. Thus, pain is strongly related to interoception and constitutes, alongside catastrophizing and amplified somatosensory perception, a characteristic of dysfunction in FM (Di Lernia et al., 2016). In these populations, beyond pain and other concomitant disorders, cognitive problems have also been frequently reported. Fibromyalgia (FM) is one chronic pain condition with these attributes. It is a complex and multidimensional disease marked by chronic pain and multiple symptoms with biomedical, psychosocial, and behavioral dimensions (Offenbaecher et al., 2017). Chronic pain is the key symptom of FM (Häuser & Wolfe, 2012; Bennett et al., 2007) resulting in high levels of functional disability (Häuser et al., 2015). On the other hand, cognitive impairment has been investigated: FM patients have memory decline, mental confusion, speech difficulty (Katz et al., 2004), attention impairment, a decline of long-term and working memory, as well as difficulties in shifting and updating executive functions when compared with healthy controls (Tesio et al., 2015). At last, cognitive dysfunction that is reflected on FM patients can be closely related to pain which is modulated by a catastrophizing style (Borg et al., 2015).

More recently, it has been suggested that the relation between cognitive abilities and interoception may be important (Tsakiris & Critchley, 2016) but there is still limited knowledge about this relation. Although the term ‘interoception’ is not frequently used in day-to-day experience, the phenomenon it refers to is one of the most basic human experiences (Ceunen et al., 2016). It guides both emotions and cognitive processes (Dunn et al., 2010). The growing interest in the ability to increase the interoception reporting skills is due to the crucial link known to exist between interoception and other relevant human neurocognitive processes such as memories, decision making, time perception (Ceunen et al., 2016), emotion experience, health, and pain (Craig, 2009). Thus, the identification of the variations on generation and perception of bodily responses, are crucial for the variability in emotion experience. This was found both in central and peripheral processing of emotional stimuli (Pollatos et al., 2012), as well as cognitive abilities like intuition and decision making (Dunn et al., 2010). In other words, this evidence suggests that the more accurate in perceiving bodily activity the individual is, the stronger the relationship between bodily changes and emotional or cognitive processing. Further study of this relationship may increase understanding of the cognitive mechanisms involved in the processing of body signals.

2. Literature Review

2.1. Interoception

Interoception refers to the conscious and unconscious perception of our internal bodily states (Craig, 2009). Internal physiological states (e.g., hunger or thirst) are represented cortically, letting the brain to receive feedback about changes to maintain homoeostasis in the body (Craig, 2002), through change in visceral organs and internal states within the body (Seth, 2013). Accordingly, interoception can be referred as a multimodal construct that combines multisensorial signals processed by internal viscera, baroreceptors, chemosensors (Craig, 2009), surface temperature receptors and nociceptors (Ceunen et al., 2016) through physiological channels (Craig, 2002).

The afferent pathways may also transfer sources of information about the state and function of the body that could influence cognition and behavior (Cameron, 2001). Interoceptive signals ascend from the periphery in both spinothalamical and lemniscal tracts (Craig, 2009) and are integrated at multiple levels, whereas the medial and the anterior insular cortex play a primary role (Engström et al., 2015). On the other hand, "Exteroceptive awareness" is the knowledge of one's body in relation to space and movement, such as knowledge of body posture (Valenzuela-Moguillansky et al., 2017) and it can be associated with an 'exteroceptive' somatosensory system (Craig, 2002). On the contrary, "interoception" could be related to one's perception of the internal state (Valenzuela-Moguillansky et al., 2017) where the visceral feelings of vasomotor activity, hunger, thirst, and internal sensations are related with an interoceptive' system (Craig, 2002).

Interoception is a relatively recent construct which began with the concept's proprioception and exteroception during the early 20th century (Ceunen et al., 2016) and its meaning has changed over time and consensus is yet not fully established. Several authors believe that it is still not clear how to differentiate between objective, subjective and metacognitive aspects of interoception. For improving the study and theoretical distinction between different aspects of interoception Garfinkel, Seth, Barrett, Suzuki and Critchley (2015) proposed three distinct dimensions: *Interoceptive Accuracy (IAc), Interoceptive Sensibility (IS)* and *Interoceptive Awareness (IAw):*

Interoceptive Accuracy (IAc) is used to define the process of accurately identifying and tracking internal bodily sensations measured by an objective behavioral tests of heartbeat detection such as the heartbeat perception task (Schandry, 1981). In this task the individual is taught to count the heartbeats they feel within their body in a specific time. The individual's IAc is calculated by comparing the number of heartbeats they perceive with the actual number of heartbeats they had, measured by an electrocardiogram. *Interoceptive Sensibility (IS)* refers to the ability to perceive their own subjective interoceptive abilities/body awareness through self-evaluated assessment. Interviews and questionnaires are used to assess the extent to which individuals can perceive their internal sensations (e.g Multidimensional Assessment of Interoceptive Awareness, MAIA, (Mehling et al., 2018). At last, *Interoceptive Awareness (IAw)* refers to the extent to which an individual's confidence in their performance on an interoceptive task can predict their genuine performance, that is, the metacognitive awareness of the individual's interoceptive accuracy. This dimension is usually obtained immediately after the end of the heartbeat detection task, whereas the subject is asked to rate his confidence in his perceived accuracy response, (e.g. using a paper and pencil marking his response on a continuous visual analogue scale from "No heartbeat awareness" to "Full perception of heartbeat").

2.1.1 Interoception and Cognition

The interest to investigate if interoception is related to cognitive function has grown and several authors have searched for this relation, like Damasio (1996) with his "somatic marker hypothesis". Here he suggested that interoception affects decision-making processes and there is a link between these two constructs indicating that bodily responses are encoded in memory together with information about the event.

Consequently, the awareness of emotional feelings is established on the neural representation of bodily cognitions, with ‘somatic markers’ evoking feeling states that influence cognition and behavior. Therefore, these representations are one crucial requirement for emotional feelings (Damasio, 1996). Also, Craig (2002) have demonstrated that sympathetic nervous activity is a main interoception pathway and these findings indicated that rational decision making was preceded by interoception processing. Thus, cognition may be related to interoception abilities. Accordingly, it can be said that interoceptive signals could guide cognitive processes, with increased interoceptive accuracy being associated with increased intuitive decision making (Dunn et al., 2010). Other perspective found is *Embodied Cognition* that is based on two major assumptions: first, that higher cognitive processes operate on perceptual symbols. And second, that concept use involves reactivations of the sensory-motor states that occur during experience with the world (Niedenthal et al., 2005). Several authors present hypotheses derived from peripheral theories of emotions (e.g.: Craig, 2003; Damasio, 1996) linking Interoceptive Accuracy to differences in the emotional processing. At last, the embodied mind approach to which mind, cognition, and affect (Füstös et al., 2013) strengthens the current view that the body plays an essential role in cognition (Gao et al., 2019). The possible inclusion of interoception within models of embodiment is important because it has been proposed that interoception also can moderate embodiments (Häfner, 2013), that it, bodily perceived feelings related to the body’s internal and external state which offer a sense of our physical and physiological condition (Herbert & Pollatos, 2012), both for health psychology and for theories of cognition (Zhou et al., 2021).

In recent times, some investigators have suggested that activation of interoceptive representations and meta-representations of bodily signals supporting interoceptive awareness are closely related to emotional experience and cognitive functions (Herbert & Pollatos, 2012). Thus, interoceptive signals are increasingly recognized to have a prevalent, yet incompletely described impact on cognition, influencing attention, perception, and emotion processing (Tsakiris & Critchley, 2016).

2.1.1.1 Interoception, Brain Structures and Cognition

Several brain structures are involved in interoceptive processes and cognition: the anterior insula may serve as an integral hub in mediating dynamic interactions between other large-scale brain networks involved in externally oriented attention and internally oriented cognition (Simmons et al., 2013); gut and hippocampal function, which was studied by some authors that tested the hypothesis that specific interoceptive signals are transported via the vagus nerve to the hippocampus to influence memory function (Suarez et al., 2018). Likewise, some episodic memory studies have implicated the hippocampus in the processing of sensory information from the external environment perception and the amygdala with processing of the emotional dimension of episodic memories (Kassab & Alexandre, 2015). More recently, Lathe and colleagues (2020) studied hippocampus at the experimental level and proposed that these structures may have a key role in memory and neuropsychological disorders because they process internal sensing, which they also called interoception. With this information it can be said that Interoception mediated by the hippocampus may thus provide a new dimension to context-dependent memory encoding, extending from 'where' and 'when' to 'how I feel' (Lathe et al., 2020). This may be in accordance with Craig (2002) perspective that implicates cortical regions, limbic brain areas, thalamus, as well as the hypothalamus and brainstem regions, among others, in interoception. Besides, the insula is implicated in motivational feelings, through the integration of interoceptive information regarding the internal state of the body (Critchley & Harrison, 2013), indicating homeostatic adjustments of behavior through midline motor pathways (Jackson et al., 2011). This may suggest that afferent information concerning bodily physiology can indeed influence intentional inhibition decisions, for example via ‘somatic markers’, as already described by Damasio (1996) to guiding human behavior.

Using fMRI methods, other authors described the importance of the insular cortex as part of the processing hub for interoception (Terasawa et al., 2015). Therefore, it would be expected that lesions in this area should have a significant impact on function (Salomon et al., 2018). Consequently, Wang and associates (2019) assessed the involvement of the anterior insular cortex (AIC) in attention processing in healthy and AIC lesion patients. To assess interoceptive attention they used a breath detection task to evaluates interoceptive attention and a dot flash detection task to assess exteroceptive attention on both samples. The results showed that using functional magnetic resonance imaging and examined the requirement of the AIC in interoceptive attention process in patients with AIC lesions, were found evidence of the requirement of the AIC in supporting interoceptive attention by showing reduced behavioral performance on the interoceptive task in patients with focal AIC lesions.

Recent evidence reveals that learning, memory, and other cognitive processes are influenced by interoceptive signaling (Azzalini et al., 2019). So, it is logical to expect that the central neural systems, which receives interoceptive energy status signals, are associated anatomically and functionally with involved structures in remembering and learning about features of the environment (Quigley et al., 2021). Several years ago, two studies have shown how problematic it is, with the current interoceptive methods in humans (Schachter & Singer, 1962), to study the specific impact of interoceptive signals on affective and emotional experience (Mezzacappa et al., 1999). Hence, the functions of interoception may extend from essential bodily functions to high-level cognitive and emotional behaviors.

2.1.2 Interoception assessment controversies

As mentioned, the Schandry's (1981) heartbeat perception task measures Interoceptive Accuracy (IAc). Even though it is a very quick, cheap, and easy to administer task several researchers have raised concerns about its validity (Murphy et al., 2018). This task has face validity because the ability to perceive heartbeats tell us something about individual’s internal life and their capacity to access it (Zamariola et al., 2018) but some believe that it does not allow separating real ability in detecting heartbeats from answering based on previous knowledge about the number of heartbeats (Brener & Ring, 2016). Accordingly, to several authors the heartbeat counts may be more based on beliefs about heart rate than on the real sensations generated by heartbeats (Ring et al., 2015) and the actual tracking of relevant signals (Murphy et al., 2018). Moreover, the individual’s differences in heartbeat accuracy are due to discrepancies in sensitivity to stimuli produced by heartbeat (Ring & Brener, 2018). Therefore, the combination of accurate knowledge of heart rate and inaccurate perception of cardiac activity may originate better results at heartbeat counting task (Brener & Ring, 2016). In Zamariola and colleagues (2018) study it has been shown that high Interoceptive Accuracy do not indicate a high correlation between responses and actual heartbeats, so the authors suggest that participants over-report heartbeat perception. Another concern about this task is that the heartbeat perception may be affected by exteroceptive via such as heart rate variability (Knapp-Kline & Kline, 2005) or several variables, like demographic and domain-general cognitive factors (e.g., executive functioning), which typically modulate any task (Fittipaldi et al., 2020).

Recently, Desmedt et al., (2018) study did an adaptation to the Schandry's original task, where they are requested to only report felt heartbeats in completing the task, instead of telling participants that cannot rely on heart rate estimation. The results showed that Interoceptive Accuracy adapted score reduces compared to the IAc original score and several non-interoceptive processes were used in this adapted task.

2.1.3 Interoception and Chronic Pain

Chronic Pain (CP) is a condition that derives from several pathophysiological mechanisms (Nicholas et al., 2019) and can be described as a persisting pain for at least three months or beyond the expected time for healing (Treede et al., 2019). The main components of the brain network for pain are: thalamus, primary and secondary somatosensory cortices (S1, S2), the insular cortex, the anterior cingulate cortex and prefrontal cortices (Apkarian et al., 2005) that can be called 'pain matrix'(Tracey & Mantyh, 2007). Research demonstrates that structural and functional changes are found in this brain network in association with chronic pain (Ribera d'Alcalà et al., 2015).

Several authors suggested that chronic pain subjects (e.g. FM, Multisomatoform disorder, Chronic low back pain and somatization disorder) may have changes in interoceptive processing. However, (Schaefer et al., 2012) study was the first used the heartbeat perception task to measure Interoceptive Accuracy in patients with somatoform disorder showed that IAc was not significantly different in chronic pain patients comparing to healthy controls. In the same line, Ribera d'Alcalà et al. (2015) study also used the heartbeat perception task to measure Interoceptive Accuracy and did not found any significant difference in IAc between chronic pain subjects and healthy individuals. Weiss et al. (2014) study uses the heartbeat perception task to measure Interoceptive Accuracy suggested higher IAc was associated with higher self-regulatory capacity. Thus, somatoform patients exhibited a substantially reduced interoceptive accuracy and self-regulation, but pain tolerance was significatively increased in this group as compared to healthy controls. Additional Duschek et al. (2017) study used the same task that Ribera d'Álcalà et al., (2015) but found the inverse results, any significant difference in IAc between chronic pain subjects and healthy individuals, that is, FM patients exhibited a significantly reduced Interoceptive Accuracy and observed an inverse correlation between IAc and symptoms severity. Mehling and colleagues (2013) studying Interoceptive Sensibility with Multidimensional Assessment of Interoceptive Awareness (MAIA) compared chronic low back pain patients with mind–body trained subjects found differences in IS. Borg and colleagues (2015) also using MAIA found contradictory results suggesting no difference in IAs between FM patients and healthy individuals.

More recently, Di Lernia and colleagues (2020) explored the relationship between the three components of interoception comparing CP patients (e.g. chronic primary pain, secondary musculoskeletal pain and chronic neuropathic pain) and healthy controls. They used several methods to measure interoception: heartbeat counting task for Interoceptive Accuracy, Visual Analogue Scale for Interoceptive Confidence and MAIA for Interoceptive Sensibility. Pain and mood questionnaires were also used (e.g. Brief Pain Inventory, Beck Depression Inventory, State-Trait Anxiety Inventory). It was found low interoceptive confidence and accuracy in CP patients compared to the healthy group, suggesting that CP patients are unaware of their impairment in accuracy on the perception of interoceptive sensations. The authors claim that this pattern occurs because CP involves disrupted signaling (i.e. interoceptive accuracy) or integration of body to brain, with subsequently poorer ability to process non-pathological bodily sensations. Moreover, interoceptive and mood variables predicted pain severity in CP patients, with interoceptive accuracy positively predicting and interoceptive confidence negatively predicting pain severity. Also, results suggested that intensity of pain in CP does not result only from interoception but also from comorbid depression and anxiety.

2.2. Pain

According to the International Association for the Study of Pain (IASP), pain refers to "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage". Currently, there is a new pain definition that describes pain as "an aversive sensory and emotional experience typically caused by, or resembling that caused by, actual or potential tissue injury". Pain is a physiological process that contributes to the maintenance of the physical integrity of the human being, causing not only suffering, but when becomes chronic, also the ability to reduce people's quality of life and predisposes the human body to pathophysiological changes that can lead to comorbidities (DGS, 2017). It is a biopsychosocial phenomenon due to the interaction of neuroanatomical and neurochemical systems with various cognitive and affective processes (Garland, 2012).

Finally, pain is a multipart experience, initiated by sensory information conveyed from a noxious stimulus, greatly modified by emotional, cultural, and cognitive perspectives (Bridgestock & Rae, 2013). According to Craig (2003) pain can also be conceptualized as a homeostatic emotion involving both of a sensation and motivation reaction, instead of a previous thought that were an exteroceptive sense or cutaneous sub-modality sensation. Thus, is considered a conscious experience, controlled by (un)conscious responses (Pollatos et al., 2012) and modulated by numerous factors such as sensory, emotional, and cognitive abilities (Craig, 2009) that eventually will affect action, learning and regulatory behaviors (Wiech & Tracey, 2013).

2.3. Fibromyalgia

Based on the notion that interoception represents the understanding of bodily states, soon it was suggested that problems in these representations could be related to several health conditions, particularly in those that are more related to subjective bodily symptoms. This is the case of many chronic pain conditions, such as Fibromyalgia. The interest to investigate whether interoception is altered in persons with Fibromyalgia have grown in recent years (Borg et al., 2018). Fibromyalgia (FM) is a complex and multidimensional disease marked by chronic pain and multiple symptoms (Offenbaecher et al., 2017).

Fibromyalgia is a syndrome characterized by chronic pain with more of three-month duration and traditionally pain in, at least, 11 of 18 tender points. Recently more importance has been given to the presentation of other symptoms, such as joint stiffness, fatigue, sleep disturbance, cognitive dysfunction, and depression (Wolfe et al., 1990). Previous American College of Rheumatology (ACR) classification criteria have been revised and currently, criteria for FM diagnostic is described has: (a) Widespread pain index (WPI) ≥ 7 with score between 0 and 19, symptom severity (SS) scale score ≥ 5 where the score is the sum of the severity of the 3 symptoms (fatigue, waking unrefreshed, cognitive symptoms) plus the severity (0 “no problem” to 3 “severe”) of somatic symptoms in general. The final score is between 0 and 12 or WPI 3–6 and SS scale score ≥9; (b) symptoms have been present for at least 3 months; (c) patient does not have a disorder that would otherwise explain the pain (Wolfe et al., 2010) and (d) presence of generalized pain, in at least 4 of 5 regions (Wolfe et al., 2016).

Moreover, FM is associated with several changes in sensory processing in the brain such as a reduction in the reactivity of the hypothalamus-pituitary axis to stress, an increased activity of pro-inflammatory cytokines (Sommer et al., 2012) and reduced activity of anti-inflammatory cytokines, and neurotransmitter control disorders (e.g., dopamine and serotonin). FM patients often report high levels of functional disability (Häuser et al., 2015). In Portugal, FM prevalence is about 1.7% of all rheumatic diseases (Branco et al., 2016), with most patients being female, between 43 and 60 years of age (Regal Ramos, 2017).

2.3.1 Pain in FM

Once tissue damage or inflammation occurs, signals from nociceptors are brought via nerve cells to the dorsal horn in the spinal cord, from which the information are further transferred to the brain. Interestingly, the brain can also receive pain signals with little or even without nociceptive information, meaning that the patient experiences pain without tissue damage or inflammatory processes (Tracey & Mantyh, 2007). This may be what occurred in FM where the received pain signal may be increased or inhibited, resulting in an amplified or attenuated pain perception (Häuser et al., 2015). Several studies have showed that the central nervous system (CNS) contributes to an effective amplification of sensory stimuli (Staud et al., 2003), leading to an improved response to noxious stimuli and an exaggerated excitability of the neurons in the spinal cord transmitting nociceptive information to the brain (Li et al., 1999).

Patients with FM have a decreased pain threshold, which means that they display increased pain responses to normally nonpainful stimuli (e.g., allodynia) and to normally painful stimuli (e.g., hyperalgesia) (Häuser et al., 2015). The etiology of FM is not yet clear but current models assume a key role of sensitization of central nociceptive pathways in pain genesis (Gracely & Ambrose, 2011). Some studies have demonstrated that several psychological factors are also involved in the process of pain amplification, such as, depressive mood and anxiety which are factors that have been shown to amplify the nociceptive signals in experimental pain (Wiech & Tracey, 2009).

There are two distinct systems to modulate pain - the medial and lateral - whose transmit pain to higher center brain neurons. The medial system is involved in the affective and cognitive dimension of pain, pain memory, and autonomic responses (Fil et al., 2013) and is principally constituted of paleospinothalamic, spinomesencephalic, spinoreticular, spinoparabrachial hypothalamic and spinothalamic tract fibers (Garland, 2012) that travel in caudal and rostral direction to higher centers by terminating in the parabrachial nucleus, reticular formation, mesencephalon, intralaminar and medial thalamic nuclei, thalamic ventral caudal nucleus, the insula, parietal operculum, the secondary somatosensory cortex, the amygdala and hippocampus (Lampl, 2012). The lateral system is important for the sensory-discriminative component of pain since it provides information about pain localization and duration (Steeds, 2013) and is formed by the neospinothalamic, the neotrigeminothalamic, and the cervical bundle and the beam of the dorsal horn that terminate in the lateral thalamus, the primary and secondary somatosensory areas, the parietal operculum and the insula (Wiech et al., 2008).

More important is the descending pain modulatory system that is an anatomical network that enable the regulation of nociceptive processing in several circumstances to produce facilitation or inhibition (Melzack & Wall, 1965). The nucleus raphe magnus (NRM) and the periaqueductal gray (PAG) area has a key role in descending mechanisms that modulate spinal nociceptive activity (Rainville, 2002) because it receives information from the ascending projections from the spinal cord and the descending projections from the cortical areas, as posterior insula, anterior cingulate cortex, pre-frontal cortex, amygdala (Garland, 2012). This system exerts influences on nociceptive input by which the central nervous system inhibits nociceptive signals at the spinal outputs (Tracey & Mantyh, 2007).

As already mentioned, the interoceptive system may be related to these modulatory pain systems. It is constituted by the same key areas, such anterior insular cortex (AIC) also known as the core of the meta-representation that integrates all the active physiological processes inside the organism, the anterior cingulate cortex (ACC), the prefrontal cortices and the somatomotor and somatosensory cortices (Critchley et al., 2004). Interoceptive signals also ascend from the periphery in both spinothalamic and lemniscal tracts (Craig, 2009) after integrated at multiple levels, whereas the medial and the anterior insular cortex play a primary role (Engström et al., 2015). Several studies related pain with Interoception, and it is known that interoceptive sensitivity heighten acute pain sensitivity and decrease pain tolerance (Pollatos et al., 2012).

2.3.2 Interoception in FM

The three dimensions of Interoception have been studied in FM patients, but with contrasting findings. Results from Duschek et al. study (2017) which utilized the heartbeat perception task to measure Interoceptive Accuracy, showed us a significantly lower score in FM patients compared to healthy group. In other words, this study suggested that inadequate access to bodily signals may limit patients´ ability to integrate these signals during emotional processing. Borg and colleagues (2018) first aim of the study was to investigate the three dimensions of interoception in a FM sample and results showed no difference between FM patients and healthy group, whatever the dimension. In additionally data, they found that pain, emotions, and anxiety were factors related to FM but also to interoception. In Interoceptive Accuracy, even though there is no difference in heartbeat detection task, the outcomes suggested that the higher the pain-related affect FM patients, the lower their Interoceptive Accuracy.

In Valenzuela-Moguillansky and colleagues (2017) study, the authors compared FM patients and a healthy control group to compare exteroceptive and interoceptive aspects of body awareness. They used several questionnaires to measure clinical characteristics (e.g. Fibromyalgia Impact Questionnaire), Exteroceptive Body Awareness (e.g. body-scaled action task), Interoceptive Sensitivity (e.g. heartbeat detection-task), and Interoceptive Awareness (e.g. MAIA). They found that Interoceptive sensitivity (measured by heartbeat detection-task) did not differ between groups and claim that this dimension is not related to fibromyalgia symptoms. However, concerning mental health data it was found an inverse association: FM patients revealed an inverse association between IS score and depressive symptoms, while the healthy group demonstrated a positive correlation between IS scores and anxiety. The authors suggested that this result could be due to a different emotional-affective background. Concerning MAIA results, both groups did not differ between each other, but FM patients have higher score in MAIA noticing scale, suggesting greater awareness of uncomfortable, comfortable, and neutral body sensations then healthy group. Other result was that for the whole sample, lower interoceptive awareness (measured with MAIA) suggested a higher impact of fibromyalgia/any discomfort symptoms. In summary, they observed a connection between extero- and interoceptive body awareness where the MAIA total score and IS score associated negatively with depression, indicating that these two aspects of interoception decrease with higher depressive symptom burden.

Finally, it should also be mentioned that beyond interoceptive processing, cognitive impairment in Fibromyalgia could also be due to emotional distress (i.e. depression and anxiety). This may affect cognitive function in FM and have been reported to be associated with poor executive function (Gelonch et al., 2017) and attentional function (Miró et al., 2015) or due to a hippocampus dysfunction (Emad et al., 2008). More recently, several studies have revealed difficulty in verbal memory, attention and concentration, and language between FM patients and healthy group (Walitt et al., 2016) and results suggest that more severe emotional distress were associated with a larger difference in cognitive function between individuals with fibromyalgia and healthy controls (Wu et al., 2018). Other finding is that interoceptive inference may affect this condition and is consistent with recent evidence that shows interoceptive influences on cognition and perception (Seth, 2013). This demonstrate that further study of the relationship between chronic pain and cognitive impairment is important due to the neural systems involved in cognitive and pain processing are closely linked and may modulate one another reciprocally (Moriarty et al., 2011).

2.3.3 Cognitive impairment in FM

Several studies have shown that memory impairments, mental confusion, and/or concentration difficulties are reported between 60 and 76% of patients (Leavitt et al., 2002). Other FM patients' complaints about memory decline have been reported in 70% of a studied sample (Katz et al., 2004). About the severity of cognitive symptoms, it is known that 23% of patients complained of mild cognitive failures and 60% reported moderate–severe complaints (Gelonch et al., 2017).

Results from neuropsychological tests shows that FM patients have impairments in working, episodic and semantic memory, likewise in selective attention or focusing and redirecting attention (Glass, 2008). It has been reported a weaker performance on working memory tests (Gelonch et al., 2017) and other tasks assessing attention and executive function such as the Stroop Color Word Test (Glass, 2009).

A recent neuroimaging study from Albrecht and colleagues (2016) found that individuals with FM have differences in brain activations during the performance of working memory tasks compared to healthy individuals. Results show that the brain regions activated in FM subjects were the bilateral parahippocampal regions while in healthy subjects the regions of the circumvolution of the cingulum and amygdala were activated and even lower activation of the girus fusiformis in FM compared to healthy group. In this study, it was also found that the FM group showed significantly lower scores in the digit memory task compared to the control group, although the scores were within normal range.

In recent times, Galvez-Sánchez et al. (2018) reported poor performance in a sample of FM patients *versus* healthy controls on a neuropsychological protocol in processing speed, attention, visuospatial and verbal memory, cognitive flexibility, mental planning, and organizational skills. Likewise, Bell et al. (2018) found differences between these two groups for the domain of inhibitory control which includes measures of selective attention and response inhibition.

3. The present research

It has been described that interoception is a multimodal construct that combines multisensorial signals (Craig, 2009). This is a complex concept and thus, Garfinkel and colleagues (2015) proposed that interoception can be conceptualized in three distinct dimensions: *Interoceptive Accuracy (IAw), Interoceptive Sensibility (IS)* and *Interoceptive Awareness (IAw)* to improve the study and theoretical distinction.

Several studies have suggested that interoception is related to memory and decision making (Tsakiris & Critchley, 2016; Werner et al., 2010). For example, patients with brain lesions in medial temporal lobe show impairment in interoception accuracy tasks (Berriman et al., 2016) and individuals with low cognitive performance may have low interoception abilities (Umeda et al., 2016). Moreover, the neuroanatomic basis of interoception is believed to represents the link for the "body in the mind" and the mechanisms of the embodiment of affective and cognitive functions (Herbert & Pollatos, 2012). Even though this may have relevant theoretical and clinical implications, the knowledge related to this topic is still on its beginning. There is much literature concerning interoception in chronic pain (Di Lernia et al., 2020), particularly on Fibromyalgia (Valenzuela-Moguillansky et al., 2017). Beyond decreased interoceptive ability compared to healthy individuals (Duschek et al., 2017; Borg et al., 2018) concentration and memory problems (Katz et al, 2004), particularly working memory (Cowan et al., 2012), but also attention and executive function (Tesio et al, 2015) are systematically found in these populations, but the relation between interoception and cognition are yet to be understood.

Based on this this, the main aim of the current study was to investigate the two interoceptive dimensions, accuracy and sensibility, and its relations with cognitive ability in a sample of chronic pain patients.

Thus, the first aim of this study was to investigate if there were relations between *Interoception Accuracy* and *Interoception Sensibility* in Fibromyalgia individuals, measured by heartbeat detection task and Multidimensional Assessment of Interoceptive Awareness (MAIA) outcome measures, respectively.

Therefore, the second aim of the current study was to assess if there are relations between *Interoception Accuracy and Interoception Sensibility* and cognitive functioning, specifically *short-term-memory, working memory, selective attention, and response inhibition*.

Finally, the third aim of the current study is to further investigate if these two studied interoception dimensions are related to psychological and clinical characteristics in Fibromyalgia patients. Five self-questionnaires, Fibromyalgia Impact Questionnaire, Brief Pain Inventory, 36-Item Short Form Health Survey, Hospital Depression and Anxiety Scale and Functional Assessment of Chronic Illness Therapy-fatigue were used.

4. Methods

4.1. Participants

The study sample included 30 participants recruited from a Rheumatology Department of a Lisbon Hospital diagnosed with fibromyalgia according to 1990 American College of Rheumatology (ACR) (Wolfe et al., 1990) classification criteria and the more recently proposed by Wolfe et al. (2010) diagnostic criteria. Experiments were conducted in accordance with the Declaration of Helsinki and with the approval of the local Ethical Board. Written informed consent was obtained from each participant before the beginning of the experiment, and afterwards a code number was attributed to each subject. Participants were enrolled onto the study after meeting the following criteria: (1) stable therapy doses four weeks prior to the study; (2) age above 18 years and (3) being capable of providing informed consent. Participants were excluded if: (1) were current pregnancy or breastfeeding; (2) had any persistent or severe infection within 30 days of baseline; (3) had formal diagnosis of psychiatric conditions or any uncontrolled medical condition (e.g. uncontrolled diabetes mellitus, unstable ischemic heart disease; (4) had history of rheumatic disease beyond Fibromyalgia; (5) history or signs of demyelinating disease and (6) were unable to provide informed consent, communicate and understand the purpose and instructions of the study.

4.2. Tools and procedures

4.2.1. Interoception Assessment

4.2.1.1. Interoceptive Accuracy

The *Heartbeat perception task* assesses the individuals' ability to be accurate in the perception of its heartbeat (Schandry, 1981). The subjects were asked to sit still and attend to their heartbeats counting silently, and without manually checking, in three intervals (25, 35 and 45 seconds) while the equipment assessed their true baseline heartbeat, i.e., they sat still for 5 minutes and from that point, when they heard the word "now" they counted the heart beats, and when they heard "stop", they said to the experimenter the counted number. The task was the following order: rest (60s) - perception (25s) – rest (30s) – perception (35s) – rest (30s) – perception (45s) – rest (60s). The subject was unaware to the different length of each round. Heart rate and respiration were assessed using Ag/AgCl electrodes per Einthoven's' triangle and respiratory belts, respectively, connected to the BITalino device hardware (Plux Wireless Biosignals, SA, Lisbon, Portugal). Heartbeat perception accuracy was calculated, for each subject, as an error score between counted heartbeats reported and actual heartbeats obtained by ECG, according to the formula, whereas IA vary between 0 – 1 and higher scores indicate better IAc.:

$$Score = \frac{1}{3}\sum[1 - (\text{recorded heartbeats} - \text{counted heartbeats}) / \text{recorded heartbeats}]$$

4.2.1.2. Interoception Sensibility

The *Multidimensional Assessment of Interoceptive Awareness (MAIA)*(Mehling et al., 2018) is a self-report measure of interoceptive body awareness with 33 items scored on a 6-points Likert scale. Higher subscales score indicates higher levels of positive awareness. MAIA includes 7 subscales: (1) *Noticing*, the awareness of one's body sensations; (2) *Not-distracting*, the tendency not to ignore or distract oneself from sensations of pain or discomfort; (3) *Not-worrying*, the tendency not to experience emotional distress or worry with sensations of pain or discomfort; (4) *Attention regulation*, the ability to sustain and control attention to body sensation; (5) *Emotional awareness*, the awareness of the connection between body sensations and emotional states; (6) *Self-regulation*, the ability to regulate psychological distress by attention to body sensations and (7) *Trusting*: the experience of one's body as safe and trustworthy (3 items). The score for each scale is calculated by averaging the scores of individual items, and thus can range 0–5. Interoceptive awareness was assessed by the Portuguese version of the original scale and this version revealed good psychometric properties (Machorrinho et al., 2019).

4.2.2. Neuropsychological Assessment

4.2.2.1. Digit Span test

Digit span is a subtest of the Wechsler Memory Scale battery – Third Edition (Wechsler, 1997) which is validated for the Portuguese population and has been widely used in the evaluation of cognitive functions (Wechsler, 2008). This battery focuses on memory measurement, considering the sensory mode in which the material is presented. The inverse Digit span was applied because is a representative measure of memory, which requires the storage of some data while they are manipulated mentally, appealing to the proper functioning of the working memory. Thus, the task consisted of repetition in reverse order of the digit series, of increasing size, distributed by items. Each item corresponds to a different sequence length. The test ended when the subject missed both tests of the same item. The total task score consists of the maximum number of correctly repeated digits. Thus, the higher the score, the better the capacity of the working memory (Wechsler, 2008).

4.2.2.2. Stroop Test (Color Word Interference Test)

This test consists of three different parts, each containing 100 items. In Part 1 (Stroop color naming), the colors of patches must be named as quickly as possible; in Part 2 (Stroop word reading) the words red, blue, and green, printed in black, must be read aloud. In Part 3 (Stroop color-word inhibition), these color words are presented in incongruent colors (e.g., the word red written in blue color); the participant is asked to name the color while ignoring the word meaning (Stroop, 1935). The test evaluates the selective attention, which is the capacity to inhabit irrelevant data, the inhibition, the capacity to suppress a behavioral response tendency, cognitive flexibility, processing speed, IQ, and semantic memory (Lezak et al., 2012; Strauss et al., 2006). The test ended when passed 45 second for each part. The Portuguese version of Stroop test has demonstrated good psychometric properties (Fernandes, 2013).

4.2.3. Clinical Assessment

4.2.3.1. Sociodemographic Characteristics

Subjects were asked to indicate their age at study inclusion, height, weight, marital state, educational level (years of schooling), duration of disease (period, in years), duration of symptoms, medication and the types of treatments they have received.

4.2.3.2. Fibromyalgia impact questionnaire (FIQ)

The Fibromyalgia impact questionnaire (FIQ) is used to assess the health problems related to Fibromyalgia (FM) and its impact on daily living (Burckhardt et al., 1991). It comprises information about function, overall Impact, and symptoms. The FIQ physical functioning domain is based on the patient answers to 11 items, rated on a 4-point scale ranging from "Always" to "Never". The overall impact is calculated from 2 items that ask about the number of days in the last week during which the patients felt good and was able to work. The symptoms domain measures the presence of 10 symptoms on a 0 to 10-point scale. Accordingly, FIQ total score can score up to a maximum of 100. Higher scores indicate higher burden of FM in the patient's life. The Portuguese version of FIQ has demonstrated good psychometric properties (Rosado et al., 2013).

4.2.3.3. Brief Pain Inventory

The Brief Pain Inventory (BPI) is a self-administered generic pain questionnaire for other chronic pain conditions (Cleeland & Ryan, 1994). The BPI gives two main scores: a pain severity score and a pain interference score; the pain severity score is calculated from the four items about pain intensity. Each item is rated from 0, no pain, to 10, pain as bad as you can imagine, and contributes with the same weight to the final score, ranging from 0 to 40, and the pain interference score corresponds to the item on pain interference. The Portuguese version of BPI (P-BPI) reveals good psychometric properties with a Cronbach alpha of .91 (Azevedo et al., 2007).

4.2.3.4. 36-Item short form health survey

The 36-Item short form health survey (SF-36) is used to measures participants' perception of general health (Ware & Sherbourne, 1992) and consists of 36 items measuring eight health domains: physical function, limitations related to physical health problems, bodily pain, general health, vitality, social functioning, limitations related to emotional problems and emotional well-being. Based on these scores, two subscales can be obtained: physical component summary and the mental component summary, ranging from 0 to 100, where higher scores indicate better health state and quality of life perceived by the patient. The Portuguese version of SF-36 reveals good psychometric properties with a Cronbach alpha of .60 for Physical Component Summary and .87 for Mental Component Summary (Pais-Ribeiro, 2005).

4.2.3.5. Hospital depression and anxiety scale

The Hospital depression and anxiety scale (HADS) is quite used to assess anxiety and depression in physically ill populations (Zigmond & Snaith, 1983) and it consists of two subscales, one measuring anxiety, with seven items, and another one measuring depression, with seven items, which are scored separately. Each item was answered by the patient on a 4-point (0-3) Likert scale response. Higher score in each subscale indicates higher depression and/or anxiety (Snaith & Zigmond, 1994). The validated

Portuguese version of this instrument was considered adequate with a Cronbach alpha of .81 for Depression and .76 for Anxiety (McIntyre et al., 1999).

4.2.3.6. Functional Assessment of Chronic Illness Therapy-fatigue

The *Functional Assessment of Chronic Illness Therapy-fatigue (FACIT fatigue)* was developed in 1997 to measure fatigue in oncology patients (Yellen et al., 1997) and is a self-reported questionnaire, used to measure the individual's perception and severity of fatigue, one of the several symptoms present in patients with chronic diseases, and its impact on daily activities (Acaster et al., 2015). FACIT Fatigue scale (version 4) is composed of 13 items and each item is measured on a 4-point Likert scale. The total score ranges from 0 to 52, where less fatigue is demonstrated by giving high score on the scale (Chandran et al., 2007). Patients scoring below the cutoff point of 43 points were considered to have clinically relevant fatigue (Cella et al., 2002). The version 4 of the FACIT-fatigue scale was translated to Portuguese by the FACIT.org and reveals good psychometric properties (Al-shair et al., 2012).

4.2.3.7. Medication consumption.

Participant's medication (and dosage) regimen was registered and organized according to 4 categories: (1) Pain (e.g. non-steroidal anti-inflammatory, analgesic, opioids); (2) Psychotropics (e.g. anticonvulsants, antidepressants, anxiolytics, antipsychotics, amphetamines); (3) Rheumatic (e.g. antirheumatic, biological, corticosteroids) and (4) Hormonal (e.g. thyroid-related, oral contraceptives, menopause-related).

4.3. Procedures

This is a retrospective study based on data collected in 2018 at the Rheumatology Department in accordance with the Declaration of Helsinki and approved by the local Ethical Committee. The recruitment plans involved providing adequate information about the participation requirements to the Rheumatology department to identify, by the help of the physicians, the potential subjects and help establish interest in this study: 30 patients met the participation criteria and were invited to take part in the study. Each subject attended a single laboratory experimental session at the hospital with 2 hours duration where all subjects signed an informed consent before they started the assessment. At the beginning of the experimental session, the subject was asked to fill the questionnaires and neuropsychological tasks. Then, the investigator explained the general instructions of the interoception protocol, and the tasks was performed.

4.4. Statistical Analysis

Data was collected and processed via Excel (Microsoft Corp, Redmond, WA, USA), and was analyzed by using the SPSS software version 26 (IBM Corp., 2015, Chicago, IL, USA). Descriptive statistics were applied for analyzing demographic and baseline characteristics. Spearman’s correlations were used to assess relations between the interoception measures (e.g. heartbeat detection task and MAIA) and neuropsychological measures (e.g. digit span test and Stroop task), as well associations with pain-related and Fibromyalgia psychological questionnaires (e.g. FIQ, HADS, BPI, SF36 and FACIT-fatigue). Since some data failed normality test regarding One -Way ANOVA, it was analyzed with ANOVA welch, a parametric test robust to this statistical violation. Post-hoc analysis (e.g. Scheffée and Tamhane's T2 test) were used to assess relation between the interoceptive dimensions and sociodemographic characteristic of the sample. In all figures, data presented as mean ± SD unless specified otherwise. Statistical significance was defined as $P \leq 0.05$.

5. Results

Participants sociodemographic characterization

The study sample recruited was 30 females, diagnosed with FM, but one subject was excluded because, due to personal restraints, she was not able to finalize the experimental pain protocol. Thereby, the final sample included 29 Fibromyalgia patients ranging in age from 30 to 76 (mean ± SD = 50.41; SD = 10.34) where the most of them were married (65.5%). The beginning of the symptoms occurred between 2 to 46 years (mean ± SD= 13.96; SD=11.21) and the number of years since the FM diagnose was 5.70±4.96 years on average.

Concerning the educational level, 27.6% of the participants have a high school education while 44.8% did not and only 24.1% followed a high education. Table 1 depicts the sociodemographic data of the entire sample and medication information is presented in Table 2. At last, 79.3% of the participants were using pain medication.

Table 1

Study sample sociodemographic data (n=29)

Characteristics	Mean ± SD	Frequency (%)	Min-Max
Age	50.41±10.34		30-76
BMI (kg/m²)	27.03±4.33		20.6-36.1
Years of symptoms	13.96±11.21		2-46
Years of Fibromyalgia diagnose	5.70±4.96		0-17
Education			
Intermediate and primary school		13 (44.8%)	
High School		8 (27.6%)	
High Education		7 (24.1%)	
Marital Status			
Single		2 (6.9%)	
Married		19 (65.5%)	
Unmarried		4 (13.8%)	
Separated/divorced		3 (10.3%)	

Note. SD = standard deviation

Table 2

Participants' Medications

Medications	Fr	%
Pain	23	79.3
Psychotropics	15	51.7
Rheumatic	3	10.3
Hormonal	3	10.3

Note. Medications: pain (non-steroidal anti-inflammatory, analgesic, weak opioids), psychotropics (anticonvulsants, antidepressants, anxiolytics, antipsychotics, amphetamines), rheumatic (anti-rheumatic, biological, corticosteroids), hormonal (thyroid-related, oral contraceptives, menopause-related); Fr = frequency; % = percentage.

Interoception assessment

Descriptive statistics of *Interoceptive Accuracy* are described in Table 3. The mean heartbeat perception score was 0.53 (range 0.00–0.98), with median score of 0.51. This wide range of scores suggests that patients differ in their *Interoception Accuracy*, as assessed by the heartbeat detection task.

Table 3

Interoceptive Accuracy Outcome

	Mean (SD)	Median	Minimum	Maximum
Heartbeat perception task	0.530 (0.29)	0.51	0	0.98

Descriptive statistics of the MAIA outcomes are described in Table 4. All subscales indicated that subjects' *Interoceptive Sensibility* were widely distributed.

Table 4

MAIA outcomes

	Mean (SD)	Median	Minimum	Maximum
Noticing	4.080 (0.71)	4.33	2.67	5

Not-distracting	1.120 (0.94)	1.00	0	3
Not-worrying	2.544 (0.60)	2.50	0.75	3.50
Attention regulation	2.915 (1.12)	3.00	0	4.71
Emotional Awareness	3.971 (0.93)	4.10	0.40	5
Self-regulation	2.704 (1.16)	2.86	0.43	5
Trusting	2.435 (1.54)	2.00	0	5

Neuropsychological assessment

Descriptive statistics of the Digit span test outcomes are described in Table 5. Direct digit span revealed a minimum score of 4 and a maximum of 12, which represent a 7-digit length response, with an average performance of M=8.14 and SD=2.17. Furthermore, Inverse digit span revealed a mean performance of M=5.25 and a SD=1.85 with a minimal score of 2 and maximal of 8 which represent 5-digit length response. At last, digit span total showed a minimum score of 8 and a maximum of 20, which represent the sum of the two subscales, with an average performance of M=13.38 and SD=3.31 All subscales indicated that subjects' *short-term and working memory* were widely distributed.

Table 5

Digit span test outcomes

	Mean (SD)	Median	Minimum	Maximum
Direct digit span	8.137 (2.17)	8.00	4	12
Inverse digit span	5.241 (1.85)	6.00	2	8
Digit span total	13.379 (3.31)	14	8	20

Descriptive statistics of the Stroop Task outcomes are described in Table 6. Stroop Word revealed a minimum score of 55 and a maximum of 107 words correctly said, with an average performance of M=78.07 and SD=14.59. Likewise, Stroop Color revealed a mean performance of M=61.08 and a SD=11.37 with a minimal score of 42 and maximal of 87 words and color correctly said. At last, Stroop Color-Word showed a minimum score of 20 and a maximum of 47 word correctly said, with an average performance of M=29.50 and SD=7.63. All subscales indicated that subjects' *selective attention and inhibition response* were widely distributed.

Table 6

Stroop Task outcomes

	Mean (SD)	Median	Minimum	Maximum
Stroop Word	78.074 (14.59)	79.00	55	107
Stroop Color	61.076 (11.37)	60.50	42	87
Stroop Color-Word	32.307 (7.63)	29.50	20	47

Clinical Assessment

A set of 5 questionnaires were administered in the study, including FIQ (*Fibromyalgia Impact Questionnaire)*, BPI (*Brief Pain Inventory*), SF-36 (*36-Item Short Form Health Survey*), HADS (*Hospital Anxiety and Depression Scale*) and FACIT-fatigue (*Functional Assessment of Chronic Illness Therapy-fatigue*). Descriptive statistics of the scales and subscales used to assess psychological characteristics can be found in table 7.

Table 7

Clinical Characteristics Main Outcome

Questionnaires	Mean ± Standard Deviation
FIQ	64.29±17.32
BPI	
Severity Score	5.51 ± 1.99
Interference Score	5.81 ± 2.26
SF36	
Physical functioning	37.77 ± 24.2
Limitations due to physical	18.51 ± 32.22

health	
Bodily Pain	29.17 ± 26.44
Vitality	31.79 ± 23.57
Emotional well being	49.63 ± 22.72
Social functioning	50 ± 23.26
Limitations due to emotional problems	41.03 ± 44.53
General health	37.78 ± 24.51
HADS	
HADS Anxiety	11.46 ± 3.86
HADS Depression	8.5 ± 3.88
HADS Total	19.96 ± 7.11
FACIT- fatigue	32.10 ± 11.12

Correlations between Interoception measures

No correlation was found between MAIA subscales – *Interoceptive Sensibility* and *Interoceptive Accuracy*.

Correlation between Interoceptive Accuracy (IAc) and Neuropsychological Assessment

Correlations between Interoceptive Accuracy (IAc) and Neuropsychological assessment measures can be found in Table 8. The results showed a positively correlation between *Digit Span Direct*, *Digit Span TOTAL*, *Stroop Word*, *Stroop Color* and *Stroop Color-Word*. Thus, subject with higher performance in those memory and attention task had higher accuracy in reporting their own heartbeat. No correlation was found between Digit Span Inverse and Interoceptive Accuracy.

Table 8

Spearman correlation between Interoceptive Accuracy (IAc) and Neuropsychological Assessment

	Digit Span Inverse	Digit Span Direct	Digit Span TOTAL	Stroop Word	Stroop Color	Stroop Color-Word
Interoceptive Accuracy	0.338	0.489**	0.541**	0.455*	0.532**	0.695**

Note. *p<0.05; **p<0.01

Correlation between Interoceptive Accuracy (IAc) and Clinical Characteristics

No correlation was found between Interoceptive Accuracy and all clinical characteristics.

Correlation between Interoceptive Accuracy (IAc) and sociodemographic characteristics

No correlations were found between *Interoceptive Accuracy* and ‘age’, ‘years of symptoms’ and ‘body mass index’ variables.

Correlations between Interoceptive Sensibility (IS) - MAIA subscales outcomes and Neuropsychology Assessment

Negative correlations were found between MAIA subscales outcome measures and Digit Span test, specifically the Inverse Digit Span outcome and MAIA *Attention Regulation* subscale (Spearman’s r= -0.541, p=0.004), meaning that people more able to sustain and control attention to body sensations, have reduced working memory ability; MAIA *Self-regulation* subscale (Spearman’s r= -0.434, p=0.021), suggest that people with higher ability to use awareness of those sensations to reduce distress, have reduced working memory ability; MAIA *Trusting* subscale (Spearman’s r= -0.458, p=0.019), meaning that patients with higher sense of trust in one’s own body revealed, have reduced working memory ability. Digit Span Total measure also correlates with MAIA *Attention regulation* subscale (Spearman’s r= -0.415, p=0.031), meaning that patients more able to sustain and control attention to body sensations, have less memory ability. There were no correlations between MAIA subscales and Stroop Task. Table 9 depicts the outcomes.

Table 9

Spearman correlation between MAIA subscales and Neuropsychological Assessment

MAIA Subscales	Digit Span Direct	Digit Span Inverse	Digit Span TOTAL	Stroop Word	Stroop Color	Stroop Color-Word
Noticing	-0.054	0.051	0.017	0.028	-0.114	-0.091
Not-distracting	0.069	0.205	0.136	0.290	-0.028	0.072
Not-worrying	-0.104	-0.061	-0.050	0.159	0.080	0.285

Attention regulation	-0.217	-0.541**	-0.415*	-0.230	-0.111	-0.203
Emotional Awareness	0.009	-0.344	-0.173	-0.060	-0.087	-0.081
Self-regulation	-0.071	-0.434*	-0.268	-0.062	-0.152	0.019
Trusting	-0.194	-0.458*	-0.352	-0.228	-0.170	-0.163

Note. *p<0.05; **p<0.01

Correlations between Interoceptive Sensibility - Multidimensional Assessment of Interoceptive Awareness (MAIA) subscales outcomes and Clinical Characteristics

Correlations between MAIA subscales outcome and clinical characteristics can be found in Table 10. Regarding Brief Pain Inventory (BPI), that is a self-administered generic pain questionnaire for other chronic pain conditions, was negatively related to Interoceptive Sensibility in *MAIA Trusting* subscale, meaning that patients with higher sense of trust in one's own body revealed, have less impact on daily activities due to pain. Concerning Hospital depression and anxiety scale (HADS) used to assess anxiety and depression in physically ill populations were negatively related to Interoceptive Sensibility in five scales, being them: *MAIA Noticing* subscale correlates with *HADS Anxiety & Depression* subscale, proposed that higher awareness of uncomfortable, comfortable and neutral bodily sensations, less anxiety and depressive symptoms; *MAIA Not-worrying* subscale relates with *HADS Anxiety*, exposed that higher emotional distress or worry with sensations of pain or discomfort, results in less anxiety symptoms; *MAIA Attention regulation* subscale correlates with *HADS Anxiety* & Depression subscale, meaning that people more able to sustain and control attention to body sensations, have reduced anxiety and depressive symptomology; *MAIA Self-regulation* subscale correlates with *HADS Anxiety & Depression* subscale, suggested that people with higher ability to use awareness of those sensations to reduce distress, have less anxiety and depression; at last, *MAIA Trusting* subscale correlates with *HADS Anxiety & Depression* subscale, suggest that patients with higher sense of trust in one's own body revealed, have anxiety and depression symptoms reduced.

Regarding Fibromyalgia impact questionnaire (FIQ) used to assess the health problems related to Fibromyalgia and its impact on daily living, was negatively related to Interoceptive Sensibility in three MAIA subscale, being them: *MAIA Attention regulation* subscale meaning that people more able to sustain and control attention to body sensations, have reduced health problems and impact on daily living due to Fibromyalgia; *MAIA Self-regulation* subscale proposed that people with higher ability to use awareness of those sensations to reduce distress, have less health problems and impact on daily living due to Fibromyalgia; al last, *MAIA Trusting* subscale propose that patients with higher sense of trust in one's own body revealed, have health problems and impact on daily living due to Fibromyalgia reduced. Also, Functional Assessment of Chronic Illness Therapy-fatigue used to measure the individual's perception and severity of fatigue was negatively related to Interoceptive Sensibility in *MAIA Trusting subscale,* meaning that patients with higher sense of trust in one's own body revealed, have less impact on daily activities due to fatigue.

Table 10

Spearman correlation between MAIA subscales and Clinical Characteristics

	BPI Pain Severity	BPI Pain Interference	HADS Anxiety	HADS Depression	HADS Total	FACIT - fatigue	FIQ
Noticing	-0.227	0.039	-0.378*	-0.507**	-0.473*	-0.052	-0.341
Not-distracting	0.164	0.308	0.348	0.297	0.371	0.233	0.397
Not-worrying	-0.334	0.186	-0.482*	-0.358	-0.474*	-0.006	-0.343
Attention regulation	0.006	-0.295	-0.580**	-0.460*	-0.551**	-0.335	-0.532**
Emotional awareness	0.079	0.019	-0.209	-0.216	-0.221	-0.096	-0.190
Self-regulation	0.033	-0.131	-0.576**	-0.503**	-0.563**	-0.264	-0.472*
Trusting	-0.150	-0.482**	-0.639**	-0.522**	-0.613**	-0.513**	-0.602**

Note. *p<0.05; **p<0.01

At last, results from the *36-Item short form Health Survey,* used to measures participants' perception of general health, was related with *MAIA* in seven scales, being them: MAIA *Not distracting* subscale correlates negatively with SF36 *Limitations due to physical health* subscale, meaning that higher tendency to not ignore or distract from sensations of pain or discomfort, more limitation in daily activities or work performance due to physical health problems; MAIA *Noticing* subscale correlates positively with SF36 *Emotional well-being* subscale, proposed that higher awareness of uncomfortable, comfortable and neutral bodily sensations, results in a better emotional capacity; MAIA *Not-worrying* subscale relates positively with SF36 *Limitations due to emotional problems* subscale, exposed that higher emotional distress or worry with sensations of pain or discomfort, results in less limitations in work performance or daily activities due emotional difficulties; MAIA *Attention regulation* subscale correlates positively with SF36 *Limitations due to physical health* subscale, suggested that people more able to sustain and control attention to body sensations, have less limitations in work performance or daily activities due physical health; At last, MAIA *Trusting* subscale associates positively with SF36 *Physical functioning, Bodily Pain, Vitality, Emotional well-being, Social functioning,* meaning that higher sense of trust in one's own body revealed better physical and social function where individuals feels vitality and emotional well-being in their life and without feeling any kind of pain or limitation. Table 11 depicts the results.

Table 11

Spearman correlation between MAIA subscales and SF36 health survey

	SF36 Physical function	SF36 Limitat physical health	SF36 Bodily Pain	SF36 Vital	SF36 Emotion well-being	SF36 Social function	SF36 Limitat. Emotion problem	SF36 General health
Noticing	0.129	0.070	0.082	0.017	0.390*	0.122	0.055	0.265
Not-distracting	-0.270	-0.488*	-0.100	-0.218	-0.292	-0.234	-0.379	-0.285
Not-worrying	0.336	0.037	-0.017	0.063	0.322	0.087	0.417*	0.213
Attention regulation	0.362	0.526**	-0.173	0.279	0.361	0.266	0.263	0.206
Emotional awareness	0.148	0.314	-0.117	-0.088	0.097	-0.046	-0.020	0.089

Self-regulation	0.349	0.331	0.214	0.236	0.337	0.297	0.027	0.210
Trusting	0.570**	0.393	0.506**	0.456*	0.529**	0.585**	0.232	0.375

Note. *p<0.05; **p<0.01

Correlation between Interoceptive Sensibility (IS) and sociodemographic characteristics

No correlations were found between *MAIA* and 'age', 'years of symptoms' and 'body mass index' variables.

Correlations between Neuropsychological assessment and Clinical characteristics

Positive correlations were found between Stroop, specifically the Stroop Color outcome measure and SF36 *Limitations emotional problems* subscale (Spearman's r = 0.438, p=0.036), meaning that higher attention selective ability, less functioning limitations due to emotional problems. In other words, individual do not have any limitation on their daily activities or work. No other correlation was found. Table 12 depicts the results.

Table 12

Spearman correlation between Neuropsychological Assessment and Clinical Characteristics

	Digit Span Direct	Digit Span Inverse	Digit Span TOTAL	Stroop Word	Stroop Color	Stroop Color-Word
BPI Pain Severity	-0.005	0.008	-0.005	-0.139	-0.140	-0.330
BPI Pain Interference	0.005	0.111	0.043	-0.076	-0.224	0.060
HADS Anxiety	-0.060	0.184	0.017	0.011	-0.141	-0.030
HADS Depression	-0.102	0.130	-0.030	-0.215	-0.026	-0.220
HADS Total	-0.143	0.138	-0.067	-0.130	-0.130	-0.181
FACIT fatigue	0.004	0.128	0.045	-0.161	-0.247	-0.099

FIQ	-0.077	0.065	-0.64	-0.265	-0.252	-0.155
SF36 Physical functioning	0.268	-0.238	0.087	0.357	0.315	0.287
SF36 Limitation physical health	-0.053	-0.359	-0.190	-0.077	0.123	-0.095
SF36 Bodily Pain	0.182	-0.007	0.135	0.280	0.109	0.198
SF36 Vitality	-0.052	-0.084	-0.069	0.073	0.321	0.114
SF36 Emotional well-being	0.086	-0.013	0.092	0.267	0.294	0.240
SF36 Social functioning	-0.048	-0.163	-0.114	0.047	0.083	0.209
SF36 Limitation Emotion problem	-0.069	-0.141	-0.088	0.237	0.438*	0.198
SF36 General health	0.232	0.041	0.210	0.358	0.398	0.355

Note. *p<0.05; **p<0.01

Relationship between Neuropsychological assessment and sociodemographic characteristics

Concerning to short-term memory, One-Way ANOVA results shown that "Digit Span Direct" differs significantly between education level, more specifically among Intermediate, primary school and High Education (F (2,25)=7,897, p=0.002) where the results of high education patients is significantly higher (M=10.14; DP=1.46) to the results of intermediate and primary school patients (M=6.92; DP=1.71). The "Digit Span TOTAL" differs significantly between education level, more specifically among Intermediate and primary school, High School and High Education (F (2,25)=6,950, p=0.004) where the results of high education patients is significantly higher (M=15.86; DP=2.27) to the results of high school patients (M=14.75; DP=2.87) and intermediate and primary school patients (M=11.46; DP=2.90). At last, 'body mass index' have been negatively correlated with Digit Span Direct, meaning that individuals with higher IBM, have reduced short-term memory.

About selective attention and response inhibition our One-Way ANOVA results have shown that the "Stroop Word" differs significantly between education level, more specifically among Intermediate, primary school and High Education (F (2,23)=5,994, p=0.008), where the results of high education patients is significantly higher (M=89.67; DP=15.20) to the results of intermediate school patients (M=70; DP=12.74) and finally "Stroop Color- Word" differs significantly between education level, more specifically among Intermediate and primary school, High School and High Education (F_W (2,11.116)=8,768, p=0.005) where the results of high education patients is significantly higher (M=39.17; DP=6.11) to the results of high school patients (M=35.43; DP=6.78) and intermediate and primary school patients (M=27.33; DP=5.52).

No other correlations were found between Neuropsychological assessment and sociodemographic characteristics, such as 'age' and 'years of symptoms'.

6. Discussion

The present dissertation investigated the perception of body states in Fibromyalgia, more specifically, *Interoceptive Accuracy (IAc) and Interoceptive Sensibility (IS),* and cognitive functioning in a chronic pain population (Fibromyalgia).

It was found that there are relations between the two interoception components (Accuracy and Sensibility) and cognitive performance in working memory and inhibitory control tasks. Specifically, by examining the relationships between IAc outcomes and the neuropsychological test (Stroop and Digit Span) used in the current study, we found further support that higher interoceptive accuracy is related to better cognitive performance in short-term memory and cognitive inhibition. On the other hand, increased self-reported ability to regulate body signals is related to a decreased working memory performance. Furthermore, subjects that report having higher interoception sensibility, specifically self-regulation, and control, describe the presence of less clinical symptoms, like anxiety, depression, or physical limitations. The main results also indicated that there is no association between *Interoceptive Accuracy* and *Interoceptive Sensibility.*

More importantly, Interoception refers to the processing of internal bodily signals, including heartbeats, encompassing afferent signaling, central processing, neural and mental representation of internal bodily signals and the feeling states that they engender (Critchley & Garfinkel, 2017). Interoceptive abilities can be defined according to complementary dimensions of objective accuracy, subjective sensibility, and metacognitive awareness (Garfinkel et al., 2015). According to the current results, both accuracy and sensibility can be related to cognitive performance.

Relations between Interoceptive Accuracy and Interoceptive Sensibility in Fibromyalgia individuals

According to the first aim of the study, we intended to measure the relation between the distinct dimensions of interoception in a Fibromyalgia sample.

Concerning *Interoceptive Accuracy*, results revealed a wide range of scores, which suggests that patients differ in their interoception accuracy. The mean interoceptive accuracy of 0.53 (range 0.00–0.98) was considerably lower than the mean interoceptive accuracy score of 0.92 reported by Stern et al., (2017). This difference is most likely explained by the fact that Stern and colleagues presented with participants several selection options for heartbeat counts during the heartbeat detection test, while the current study used a response paradigm (i.e., individuals were simply asked to estimate their heartbeat count). Results showed that *Interoceptive Accuracy* and *Interoceptive Sensibility* did not have any relationship, supporting the notion that these are distinct constructs which should be measured separately to assess their unique relationships with other psychological variables and cannot be generalized across components or inferred from one component to another. Craig's (2003) perspective argues that although interoception integrates several different bodily sensations into the same neuronal pathways, interoception is a general homeostatic function. However, using the proposed conception of different interoception components, it is difficult to integrate them under the notion of a measurable general interoception ability. These results are consistent with previous research findings, where a correlation between *Interoceptive Sensibility* and *Interoceptive Accuracy* was not found (e.g. Ceunen et al., 2016). Thus, this observation is in line with the theoretical model proposed by Garfinkel and colleagues (2015) that suggests that *Interoceptive Sensibility,* the subjective self-evaluated trait assessed by questionnaires (e.g. MAIA) does not correlate with *Interoception Accuracy*, which is an objective measure (Calì et al., 2015).

Relations between Interoceptive Accuracy and Interoceptive Sensibility with Neuropsychological Assessment, specifically short-term memory, working memory, selective attention, and response inhibition

According to the second aim of the study, we intended to measure the relation between the distinct dimensions of interoception and cognitive functioning.

The neuropsychological memory and attention task were correlated to *Interoceptive Accuracy and Interoceptive Sensibility.* This result suggests, that in Fibromyalgia patients, short-term memory, selective attention, and response inhibition are related with a higher *Interoceptive Accuracy*. Some studies found a better memory performance in greater heartbeat perceivers in comparison to poor heartbeat perceivers: in Pollatos & Schandry (2008) study, they investigated the association between cardiac perception and memory recall of emotional pictures, which evaluates explicit memory and in Werner and associates (2010) study through a wordstem completion task, they pretend to investigate implicit memory. Our study suggests that a greater autonomic response and improved access to bodily information provide facilitating signals for memory retrieval (Critchley & Harrison, 2013). The current results suggest that the task of accurately counting the own heartbeats may be easier for patients that have increased cognitive abilities in the measured variables. The reason for this relation is yet to be found, but eventually the heartbeat task may be a cognitive demanding task for the chronic pain patients, because they need to maintain attention to their body signals and to memorize the counting. If this explanation is true, there are important confounding variables in this task and maybe it is too dependent on cognitive abilities. Concerns about the real construct measures by interoception tasks has been recently detailed in a recent works (Zamariola et al., 2018; Murphy et al, 2019). Another possibility is that a better interoception ability may be related to an increased ability to regulate attention and to respond to cognitive challenges (Zamariola et al., 2019).

Interestingly, increased self-reported interoception abilities, as measured by MAIA, were on the opposite direction concerning working memory. One possible explanation is that the resources dedicated to internal state may compete with resources needed to manipulate external stimulus in this cognitive task, particularly in a high demanding task as inverse digit span. Recent findings showed that representation of internal physiological state may emerge as a sensory experience center (e.g., pain) that can dominate individuals' attention, disrupting thoughts or feelings and compete with other cognitive processes (Critchley & Harrison, 2013), like those involved in working memory tasks. Other explanation for these differences could be an eventual relation between extroversion-introversion personality (Moradi et al., 2019) because the mental performance is affected during exposure to external stimulus and in introverts were found higher levels of psychophysiological activity than in extroverts (Belojevic et al., 2001). This could explain why individuals with increased self-reported ability to regulate body signals revealed a decreased working memory performance.

Relations between Interoceptive Accuracy and Interoceptive Sensibility with clinical and sociodemographic characteristics.

The third goal of the present dissertation was to study psychological factors underlying mechanisms for the distinct interoception dimensions.

No correlations were found between Interoception Accuracy and any clinical or sociodemographic characteristic, suggesting that the ability to be more precise detecting the own heartbeat is not related to any specific clinical domain. As far as we know this challenges the view that interoceptive accuracy may be a good measure of the ability to perceive the body function with relevant clinical outcomes (Garfinkel et al., 2015). On the other hand, the current study found correlations between Interoception Sensibility, measured using MAIA and clinical characteristics, specifically with Depression and Anxiety and with some scores of physical and functional parameters measured by FIQ and SF36.

Results from the *36-Item short form Health Survey* used to measures participants' perception of general health were related with *Interoceptive Sensibility* where higher sensibility scores result on a better social and physical functioning where the individuals do not show limitation to their daily activities and/or work performance and they show positive feelings about their life. Concerning *Hospital depression and anxiety scale (HADS)* used to assess anxiety and depression in physically ill populations were negatively related to *Interoceptive Sensibility* meaning that higher sensibility ability corresponds to less anxiety or depression symptoms. These results are in the same line of study where research suggests that diminished interoception associated with depression (Pollatos et al., 2009). Also, fibromyalgia has been related to traits such as anxiety and depression, each associated with heightened and diminished *Interoceptive*

Sensibility, respectively (Valenzuela-Moguillansky et al., 2017). Furthermore, *Functional Assessment of Chronic Illness Therapy-fatigue,* used to measure the individual's perception and severity of fatigue, were negatively related to *Interoceptive Sensibility* meaning that individuals showed less impact on daily activities due to fatigue when they had higher sensibility. Regarding *Fibromyalgia impact questionnaire* (FIQ) used to assess the health problems related to Fibromyalgia and its impact on daily living, presented have reduced health problems and impact on daily living due to Fibromyalgia; Finally, *Brief Pain Inventory (BPI)* is a self-administered generic pain questionnaire for other chronic pain conditions were negatively related to *Interoceptive Sensibility* suggested that patients with sensibility ability, have less impact on daily activities due to pain.

As expected, it was also found that more educational status facilitates the cognitive performance, where individuals with more years of schooling have better short-term memory and attention abilities. According to Zahodne and colleagues (2019) education may influence cognitive functioning through mechanisms involving brain maintenance or cognitive reserve. On the other hand, increased higher body mass index was related to a decreased short-term memory performance. This result is corroborated by Steenbergen & Colzato (2017) where structural differences associated with elevated BMI are correlated with decreased cognitive functioning.

6.1. Limitations

The current study has also limitations that should be addressed in further studies. One of the main limitations is that correlations used in this study do not allow an understanding of the directionality of the results, i.e., whether cognition explains poor interception or vice-versa. Also saying that the lack of interoceptive awareness consists in the most prevalent limitation to this research. The recruited sample represents a single hospital since all the recruited subjects were current patients treated in that medical facility. To overcome this limitation in future research, recruitment from other clinical facilities would enlarge the scope of our conclusions made on Fibromyalgia patients. One more limitation of the current study is the small sample size and the lack of a control non-fibromyalgia group requested to compare differences between baseline scores and correlations between the study tasks. An additional limitation is related to the fact that the sample was exclusively made of females, which restricted the generalizability of the results. Another issue that increases the difficulties in comparing accuracy in a clinical sample is due to little knowledge of interoception and some of the processes underlying the experiences of people in chronic pain, specifically in fibromyalgia.

6.2. Future research directions

Studying the same relations on a larger FM sample should be the next step of the current study. Also, the use of a control heathy group would allow further comparisons that might elucidate better distinctive features between FM patients and normal population. It will be also important to enlarge the sample size and replicate the study in different cultural and clinical conditions to investigate the presence of any significant differences in the results between different Chronic pain populations. Also, is needed to do further research that allows to determine which measures are most suitable, where methodological enhancements would remove any ambiguity regarding which dimension of interoception is being measured by each task. Other interesting direction is the necessity to manipulate interoceptive signal processing under experimentally controlled conditions and to investigate its effects on emotional and cognitive functions. Therefore, replicating the study in different contexts will, in turn, increase our knowledge towards the role of cultural and environment differences on pain reporting experience. It will therefore contribute a better understanding of the mechanisms of the syndrome and, consequently, help to develop interventions aimed at reducing the suffering of these patients. To overcome this limitation using a similar clinical sample with more interoceptive knowledge could, thus add new insights on these relations.

7. Conclusions

The main finding of this study was that *Interoceptive Accuracy* is related to the cognitive performance in Fibromyalgia patients, where individuals less accurate in interoception heartbeat detection task have poorer cognitive performance in short-term memory and cognitive inhibition. Furthermore, increased self-reported ability to regulate body signals was related to a decreased working memory performance.

Our results show there are no relations between *Interoceptive Accuracy* and *Interoceptive Sensibility*, suggesting that interoception is not sufficiently described as one homogeneous concept, but it rather consists of distinct facets, which need to be studied separately. According to neuropsychological assessment findings highlight the need of further investigation of cognition mechanisms involved in Interoception, where it is important to understand the directionality of the results. The importance of distinguishing the different dimensions of interoception and to discriminate the cognitive resources needed to interoception, as well as the cognitive impact of interoceptive symptom in chronic pain populations is much needed. Relations between interoception and psychological characteristics show a pattern of consistent correlations.

Finally, correlations between interoception sensibility and clinical characteristics shows a tendency for better emotional (depression and anxiety) and physical functioning in that which report increased ability to perceive internal bodily states. Due to its possible clinical effects, we believe that this may be an area of interoception research that deserves intensified study in the future.

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APÊNDICES

Questionário Sócio Demográfico

ID: __________

Sexo:

☐ Masculino ☐ Feminino

Idade: __________

Peso atual: _________________ Altura: _____________________

Nível educacional: qual o grau de ensino que completou?

Nenhum ☐ 4ºano ☐ 6ºano ☐ 9º ano ☐ 12ºano ☐ licenciatura ☐

mestrado ☐

Estado Civil:

Solteiro ☐ casado/união facto ☐ separado/divorciado ☐ viúvo ☐

Data de início dos sintomas de Fibromialgia:

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Data do diagnóstico de Fibromialgia:

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Medicação que toma habitualmente:

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Medicação tomada nas últimas 48h:

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Outras patologias diagnosticadas:

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Tarefa de perceção do batimento cardíaco

Schandry (1981)

Tarefa	**Tempo início**	**Tempo decorrido após a tarefa**	**NOTAS**	**Nº Batimentos reportado**	**Grau de confiança na sua precisão nos batimentos (0-10)**
5 minutos baseline	**0**min	**5**min	**AVISAR AOS 4min** que estamos prestes a começar		
60 segundos	**5**min	**6**min	Repouso		
10 segundos	**6**min	**6** min **10**seg	Treino		
60 segundos	**6**min **10**seg	**7**min **10**seg	Repouso		
25 segundos	**7**min **10**seg	**7**min **35**seg	**CONTAR**		
30 segundos	**7**min **35**seg	**8**min **5**seg	Repouso		
35 segundos	**8**min **5**seg	**8**min **40**seg	**CONTAR**		
30 segundos	**8**min 40seg	**9**min **10**seg	Repouso		
45 segundos	**9**min **10**seg	**9**min **55**seg	**CONTAR**		