Posttraumatic Stress Disorder and Chronic Lower Back Pain: The Neurological Impacts of a Comorbid Diagnosis and Integrative Treatment

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Abstract

Previous research has indicated a prevalent co-occurrence of chronic lower back pain (CLBP) and Posttraumatic Stress Disorder (PTSD). Though the dual diagnosis of these disorders is prevalent, a cyclical nature of symptomology also exists. With trauma symptoms igniting chronic pain symptoms and bouts of pain engaging trauma symptoms, there continues to be a lack of understanding as to the neurological underpinnings of this phenomena. Further, there has been little exploration into the treatment of said co-occurring disorders. An investigation by Lankster and Williams (2018) recommended the use of Acceptance and Commitment Therapy for individuals triply diagnosed with PTSD, CLBP, and alexithymia. However, the previous study excluded the neurological effects of these disorders, as well as their behavioral and physiological manifestations, which are considered in the current study to develop an intervention with increased efficacy.

The purpose of this systematic review was to investigate the neurological effects of these conditions, the manner in which they overlapped, and the cognitive and behavioral manifestation of dual neurological deficits. A structured psychological treatment, which includes various aspects of neurological, cognitive, behavioral, and somatic interventions with concurrent pharmacological treatment, is developed to holistically address deficits based on combined neurological effects.
Keywords: Neurological Effects, Neurological Deficits, Posttraumatic Stress Disorder, Eye Movement Desensitization and Reprocessing, Chronic Lower Back Pain

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Chronic pain affects over 1.5 billion people worldwide, making it the leading cause of disability in the world (Martucci & Mackey, 2014; Borsook, 2012). This condition is more prevalent than heart disease, cancer, and diabetes combined; and is the most common cause of long-term disability (National Institute of Health, n.d). Previous research has indicated a significant portion of chronic pain sufferers are dually diagnosed with Posttraumatic Stress Disorder (PTSD; Lankster & Williams, 2018).

According to Lankster and Williams (2018), approximately one in five United States military veterans experience co-morbid chronic pain and PTSD. Moreover, in a "study comprised of volunteer firefighters, they found that approximately 50% of those with PTSD also reported a chronic pain issue, versus an estimated 21% of those without PTSD " (Lankster & Williams, 2018 p. 226). Specifically, chronic lower back pain (CLBP) is one of the most common types of chronic pain, and numbers of CLBP cases are steadily increasing (Freburger et al., 2009). As with other types of chronic pain, there appears to be a high prevalence of dually diagnosed patients (Bilic et al., 2013). Individuals suffering with concurrent CLBP and PTSD tend to endure more severe pain than CLBP patients without PTSD, and have poorer treatment outcomes (Bilic et al., 2013).

There are two common theories for the high rates of co-morbid CLBP and PTSD. The first of which, the Shared Vulnerability Model, posits that factors such as avoidance and negative mood and affect predispose some individuals to co-morbidity (Asmundson et al, 2002). Alternatively, the Mutual Maintenance Model hypothesizes that the symptomology of one disorder exacerbates the symptoms of the other causing a cyclical effect (Lankster & Williams, 2018). However, neither of these theories addresses the neurological implications of comorbidity.

Gray Matter and Glucose Metabolism

Gray Matter, also spelled grey matter, was named for its grayish hue. This composition of neuronal cell bodies, glial cells, dendrites, capillaries, and unmyelinated axons in the brain receives and processes sensory input. It then directs the sensory information to the central nervous system (CNS). Overall, gray matter serves to help people perform the functions necessary to sustain life (e.g., simulations speech, memory, muscle control, and cognition; Bohren, 2018). Generally, gray matter develops in a heterogenous manner across most major brain lobes until approximately 11 years of age; however, the temporal lobe continues to develop until about 14 years of age. After a peak in growth, post-pubescent synaptic pruning commences and continues throughout the remainder of one's life. However, there are extraneous variables that can impact the increase and decrease of gray matter beyond that of age differentiation, such as medication, PTSD, CLBP, and other disorders (Gogtay & Thompson, 2010; Dusi et al., 2015; Im et al., 2016; Martucci & Mackey, 2014). Gray matter atrophy adversely impacts cognitive functioning and how the brain processes rewards (specifically with atrophy to the prefrontal cortex; Ramanoël et al., 2018; Parvaz et al., 2012; Brain & Behavior Research Foundation, 2015).

The aforementioned variables also significantly impact glucose (sugar) metabolism (Shimo et al., 2011; Im et al., 2016). According to Rao, Oz, and Seaquist (2006), glucose is the brain's primary source of energy, and it relies on glucose from our blood to maintain normal metabolic function. Therefore, glucose is distributed in the brain via cerebral blood flow and regulated though glucose metabolism. Both process causatum neurological and functional outputs.

Glucose is stored energy obtained from dietary intake. One's glucose levels may fluctuate within a normal range; however, when glucose metabolism is out of this range cerebral blood flow is impacted. Typically, at rest cerebral blood flow is highest in areas of the brain with the

highest glucose metabolism. Functional activation increases cerebral blood flow and usually metabolism increases as well (Mergenthaler et al., 2013). However, this effect slightly varies depending on brain region. For example, in the primary somatosensory cortex decreased blood flow can increase metabolism (Devor et al., 2008). There is an important relationship between glucose metabolism and gray matter. According to the Harvard Mahoney Neuroscience Institute (2019), high blood glucose levels can affect the brain's functional connectivity, which links brain regions that share functional properties, and brain matter. As a result, this can cause the brain to atrophy or shrink (Wand et al., 2011; Mergenthaler et al., 2013). Brain functions such as thinking, memory, and learning are closely linked to glucose levels and how efficiently the brain uses this fuel source (Mergenthaler et al., 2013).

Gray matter requires significant energy (i.e., glucose) for synaptic transmission, which involves neurotransmitters traveling from a pre-synaptic neuron to a post-synaptic neuron (Attwell & Laughlin, 2001). If there is insufficient glucose in the brain, for example, no neurotransmitters are produced and communication between neurons breaks down. To ensure the delivery of continuous supply of glucose to maintain normal cellular function "Glucose-sensing Neurons" are present (Rao et al., 2006). According to Levin, Dunn, and Routh (2002), these glucose seeking neurons have evolved for the purpose of monitoring and responding to the availability of glucose. However, under certain chronic conditions such as stress and diabetes there is a change in the brain's adaptive response (Rao et al., 2006).

In a research study conducted at Cincinnati Children's Hospital Medical Center (2016), teenagers with type 2 diabetes had significant changes in total gray matter volume and in regions involving seeing and hearing, memory, emotions, speech, decision making, and self-control. Similarly, in a study, Redel, Dolan, DiFrancesco, Vannest, and Shah (2019), found that there was a relationship between less gray matter volume in the brain and the ability to pronounce and sound out unfamiliar words.

Zhang, Zhang, Wang, and Zhang (2018) conducted a study on Chinese Earthquake survivors. Their objective was to detect changes in gray matter volume and their correlation to PTSD symptom severity. They found that the PTSD group had more gray matter in the left middle temporal gyrus and in the right dorsal medial prefrontal cortex, and less gray matter volume in the region of the right temporal pole than the non-diagnosed control group. In addition, a meta-analysis consisting of 319 subjects and various studies of maltreated youths and combat veterans consistently found a reduction in gray matter volume in PTSD groups (Kühn & Gallinat., 2013; Morey et al., 2016; Herringa et al., 2012).

Methods

Objectives

The primary objective of the present study was for researchers to systematically review literature containing Spect MRI data for the purpose of examining effects of PTSD and CLBP on grey matter density and cerebral glucose metabolism in diagnosed patients. Primary outcome measures were the alteration in density and/or metabolism; however, this research also explored the secondary outcome measures of behavioral and physiological expressions of said changes such as: pain, cognitive functioning, and fear avoidance behaviors.

Goal

To develop a structured psychological treatment which includes various aspects of neurological, behavioral, and somatic interventions with concurrent pharmacological treatment that will be efficacious in addressing these neurological effects.

Questions. *What are the impacts of PTSD and CLBP on glucose metabolism and grey matter density? How may these impacts be expressed when PTSD and CLBP are presented as co-morbid? What treatments are efficacious in addressing the co-morbid presentation of these disorders based on the alterations in glucose metabolism and grey matter?*

- *Proposed protocol and registration*. The study inclusion criteria and analysis adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009) and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2021).
- *Information sources*. Studies were found by searching the following electronic databases: MEDLINE, Pubmed, PloS one, JSTOR, ProQuest, Google Scholar, PsychInfo, and EBSCO
- *Electronic search terms/strategies*.

1) Post traumatic Stress Disorder

#1. (Post Traumatic Stress Disorder [MeSH terms] OR (Post-traumatic Stress Disorder) OR (PTSD, trauma) OR (CPTSD, PTSD) OR (Complex trauma) OR (Psychological trauma) OR (Complex PTSD) OR (C-PTSD) OR (Neurological PTSD) OR (Posttraumatic Stress) OR (Complex traumatic stress) OR (Trauma disorder) OR (Post-trauma effects) OR (Complex Posttraumatic Stress Disorder))

2) Chronic Lower Back Pain

#2. (Chronic Lower Back Pain [MeSH terms] OR (CLBP) OR (Chronic Pain Syndrome) OR (Chronic Pain, Lower Back) OR (Lower Back Pain) OR (Lower Back Pain Disorder) OR (Lower Back Pain, Disorders) OR (Lower Back Pain, Muscular) OR (Muscular Lower Back Pain) OR (Muscle or Ligament Strain, Lower Back, Chronic Pain) OR (Bulging Disc, Spine, Chronic Pain) OR (Ruptured Disc, Spine, Lower Back) OR (Osteoporosis, Lower Back, Chronic Pain) OR (Neuropathic Pain, Lower Back) OR (Lumbar Spine Pain) OR (Spinal stenosis) OR (Myofacial Pain Syndrome, Chronic Pain) OR (Chronic Pain Disorders, Lower Back) OR (Arthritis, Lower Back) OR (Arthritis, Chronic Lower Back Pain) OR (Herniated Disc, Lower Back Pain) OR (Low Back Pain) OR (Primary CLBP) OR (Chronic Pain, Back Pain) OR (Fibromyalgia, Lower Back Pain) OR (Chronic Conditions, Back Pain) OR (Chronic Back Pain))

3) Neurological Functioning

#3. (Neurological effects [MeSH terms] OR (Neurology) OR (MRI) OR (SPECT MRI) OR (Cerebral Glucose Metabolism) OR (Gray Matter) OR (Grey Matter) OR (fMRI) OR (PET Scan) OR (Neurological impact) OR (Positron Emission Tomography Imaging) OR (Grey Matter Density) OR (Neuroimaging) OR (SPECT) OR (Neurophysiology) OR (Neurological Functioning) OR (Glucose Metabolism) OR (Neurological Implications) OR (Neurological Connectivity) OR (Neurological Activation) OR (Neurological Deactivation) OR (Functional

Connectivity)).

Eligibility criteria

Types of studies. Neuroimaging studies of individuals diagnosed with CLBP, PTSD, or CLBP and PTSD were included. Studies with greater than five participants were included. Language restrictions, publication date, and publication type were not enacted, but preference and priority were made for studies conducted in the past five years and published in English.

Types of participants. All studies included individuals aged 18+ with a diagnosis of PTSD, CLBP, or PTSD and CLBP. CLBP was defined in this systematic review as pain which continues, either constantly or intermittently, for a minimum of three months. PTSD is defined according to DSM-5 criteria for the disorder. Randomized Controlled Trials (RCTs) that reported data for participants with a medical diagnosis, signs, or symptoms of mixed chronic pain disorders and/or multiple confounding mental health diagnoses were excluded from the systematic review.

Types of intervention. As the primary purpose of most studies was exploratory, many contained no interventions. Some studies included pharmacological, neurological (selective stimulation of brain regions), and/or psychological (e.g., art therapy, EMDR, mindfulness, ACT, etc.) interventions. No restrictions on intensity or frequency or duration of treatment were in place.

- **Comparison groups.** Control group/ General population
- **Types of outcome measures.**
  - Primary outcome:
    - Rate of glucose metabolism
    - Grey matter density
    - Global well-being
  - Secondary outcomes:
    - PTSD severity
    - CLBP severity
    - Collateral effects

- *Data collection process*
  - **Inclusion Criteria.**
    - RCTs and
    - Individuals aged 18+ years, and
    - PTSD and
    - CLBP exercise and
    - Neuroimaging
  - **Exclusion Criteria.**
    - NOT RCT
    - Individuals under 18 years of age
    - NOT PTSD
    - Mixed chronic pain conditions (e.g., migraine + chronic back pain)
    - NOT Neuroimaging
    - Mixed psychological disorders (e.g., PTSD + Borderline Personality Disorder)

- NOT CLBP
- NOT glucose metabolism
- NOT gray matter density

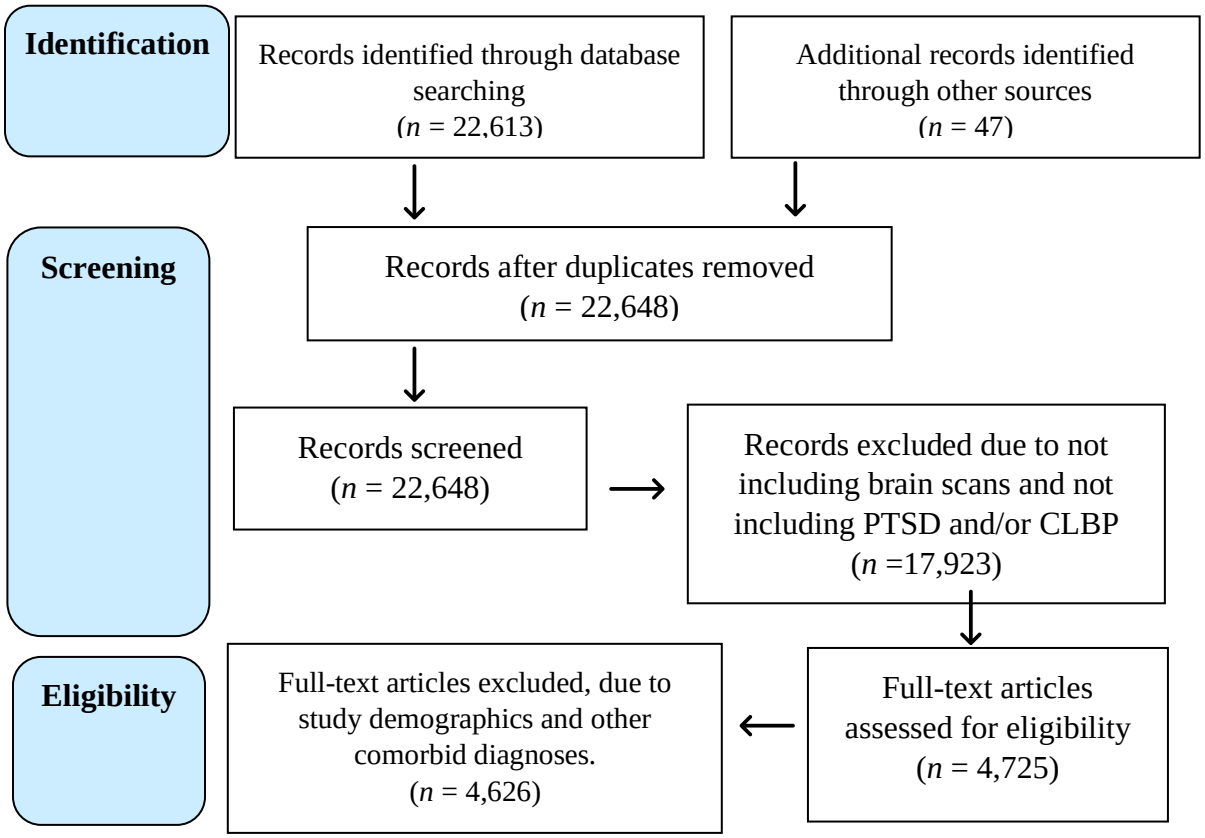
❖ **Reviewers.** Three reviewers independently selected the articles to be considered in this review. To assess agreement between primary reviewers, researchers randomly select five to 10 studies for inclusion. In an effort to ensure accuracy of data extraction from the selected articles and to ascertain as to whether additional information was needed, reviewers contacted authors of original papers selected for inclusion into the systematic review. Differences in data extraction were resolved by reference to original articles and discussion to establish consensus. No review template prepared.

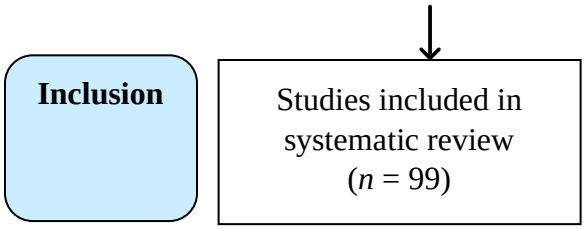
❖ **Risk of Bias.** All included papers were subjected to an assessment of risk of bias based on guidelines outlined by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2021). All review co-authors were provided materials that standardized reporting of specific domains to identify potential areas of bias as part of their evaluation of study quality.

- *Planned Methods of Analysis*.

❖ **Outcome measures.** Researchers performed a systematic review on available data related to PTSD and CLBP. The primary comparisons were of the functional and neurological differences in the primary outcome measures in the diagnosed group versus control group.

Figure 1
Prisma Flow Chart





Results

Tables one through five provide the results of this analysis indicating the neurological impact of each diagnosis on the included brain structures. For each brain region the structures studied are delineated. Each structure has the neurological impact of PTSD and CLBP with the citations for each data. The researchers have also provided a brief description detailing the function of this brain structure.

Table 1

Frontal Lobe: Diagnostic impact of PTSD and chronic lower back pain on various brain regions

Brain Region	Neurological Impact	Author(s)	Description
Anterior cingulate gyrus	PTSD: Reduced metabolism of glucose CLBP: Increase in activity with symptoms of provocation.	Gogtay & Thompson, 2010 Martucci & Mackey, 2014; Apkarian et al., 2004; Gold et al., 2011	Has six functional areas: executive area. becomes active prior to the execution of willed movements and voluntary saccades), pain perception area, emotional area (lies close to the pain perception area), a bladder control area (activated when bladder is full), vocalization area (active during decision making about speech activity), and an autonomic area (which elicits autonomic, visceral, and respiratory responses). (FitzGerald, Gruener, & Mtui, 2012).
Left inferior frontal gyrus	PTSD: Decreased activity with symptoms of provocation CLBP: Increased activity.	Huang et al., 2019 Kong et al., 2010	This produces speech and is also called Broca's motor speech area. While present in both hemispheres, the left one is responsible for the formation of meaningful language for most right-handed persons (Poritsky & Freeman, 2003).
Left middle frontal gyrus	PTSD: Decrease in the volume of gray matter CLBP: Generalized increased activity	Gold et al., 2011 Shimo et al., 2011	Located in the posterior end of the middle frontal gyrus and is responsible for voluntary conjugate eye movements, especially in the

			horizontal plane (Poritsky & Freeman, 2003).
Left supplementary motor area	PTSD: Decrease in the volume of gray matter CLBP: Increased activity with symptoms of provocation	Rabellino et al., 2018 Puri et al., 2010	Responsible for co-ordination of gross voluntary motor activity (Poritsky & Freeman, 2003).
Medial frontal gyrus	PTSD: Decreased cerebral blood flow and glucose metabolism with symptoms of provocation CLBP: Decreased gray matter	Im et al., 2016; Gold et al., 2011 Aupperle et al., 2012	*See Left middle frontal gyrus*
Middle cingulate gyrus	PTSD: Increased activity CLBP: Decreased in the volume of gray matter	Karim et al., 2017 Yu et al., 2018; Lloyd et al., 2012	*See Anterior cingulate gyrus*
Orbitofrontal cortex	PTSD: Reduced grey matter CLBP: Increased functional connectivity with left amygdala and subgenual cingulate cortex	Im et al., 2016 Cheng et al., 2018	The orbitofrontal cortex mediates the conscious perception of smell and plays a role in affective behavior and memory (Fix, & Brueckner-Collins, 2009).
Right supplementary motor area	PTSD: Decreased gray matter CLBP: Increased activity	Sussman et al., 2016; Smallwood et al., 2013 Harri Jenkins et al., 2000	Responsible for gross coordination of voluntary motor activity (Poritsky & Freeman, 2003).

Table 2

Temporal Lobe: Diagnostic impact of PTSD and chronic lower back pain on various brain regions

Brain Region	Neurological Impact	Author(s)	Description
Amygdala	PTSD: Increased metabolism of glucose with symptoms of provocation CLBP: Increase in the metabolism of glucose with	Im et al., 2016; Sussman et al., 2016 Martucci & Mackey, 2014;	Regulates emotional interpretation of the environment and internal stimuli primarily to fear and anger. Stimulation may

	symptoms of provocation. Decreased connectivity compared to general population	Apkarian et al., 2004	produce a rage response, whereas removal of the amygdala (bilaterally) results in docility (Morey et al., 2016)
Left amygdala	PTSD: Increased cerebral blood flow with provocation CLBP: Increased activity with provocation and decreased gray matter.	Im et al., 2016 (Meier et al., 2016)	*See Amygdala*
Right amygdala	PTSD: Increased metabolism of glucose with symptoms of provocation and increased in the volume of gray matter CLBP: Decreased volume of gray matter.	Im et al., 2016; Sussman et al., 2016 Meier et al., 2016	*See Amygdala*
Right borderline amygdala	PTSD: Decrease in the volume of gray matter which is negatively correlated with severity of severity of traumatic events and severity of the symptomology CLBP: Decreased volume of gray matter.	Drevets et al., 2002 Ung et al., 2014	*See Amygdala*
Hippocampus	PTSD: Decreased metabolism of glucose with symptoms of provocation, and at rest. Decreased grey matter. CLBP: Increased activity with symptoms of provocation.	Shimo et al., 2011; Im et al., 2016 Abdallah and Geha, 2017; Kregel et al., 2015	The hippocampal complex is important in preservation and consolidation of memory traces. The left anterior hippocampus encodes novel information involving language function. Right hippocampus is activated during spatial tasks. There is evidence of anteroposterior functional specialization with regard to the experiences of novelty versus familiarity which plays a role in encoding material into long term memory (Aupperle et al., 2012).
Left Hippocampus	PTSD: Increased activity at rest, with symptoms of	Im et al., 2016	*See Hippocampus*

	provocation and increased cerebral blood flow at rest CLBP: Increased activity with symptoms of provocation.	Martucci & Mackey, 2014; Gold et al., 2011	
Left inferior temporal gyrus	PTSD: Decrease in the volume of gray matter. CLBP: Increased activity at rest and with provocation	van der Kolk, 2000 Shimo et al., 2011	The middle and inferior temporal gyri are engaged with learning and memory. Olfaction sensations are mediated through this structure as well as emotional/affective behaviour (Dade, Zatorre, & Jones-Gotman, 2002).
Fusiform cortices	PTSD: Decrease in the volume of gray matter. CLBP: Increase in the volume of gray matter with increased activity with symptoms of provocation	Zhang et al., 2018 Meier et al., 2016; Ung et al., 2014	The exact function of this structure is unknown. It is theorized that it is involved in color sensing, face and body recognition (right fusiform gyrus), and word recognition (left fusiform) (Rypma et al, 2015; Hubbard & Ramachandran, 2005).
Left middle temporal gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increase in the volume of gray matter, with increased activity with symptoms of provocation	Sussman et al., 2016 Meier et al., 2016	*See Left inferior temporal gyrus*
Left precentral gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increased gray matter	Sussman et al., 2016 Qi et al., 2014	This governs motor activity in the corticospinal tract to the trunk and limbs and the corticonuclear tract to head and neck (Poritsky & Freeman, 2003).
Right precentral gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increase in activity with symptoms of provocation	Sussman et al., 2016 Graff-Guerrero et al., 2008; Lloyd et al., 2012	*See Left precentral gyrus*
Left superior temporal gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increased gray matter	Zhang et al., 2018 Ung et al., 2014	The posterior part of the superior temporal gyrus is responsible for the comprehension of spoken

			language. The auditory cortex (Heschl's gyrus) is in the upper surface of the superior temporal gyrus. The dominant hemisphere is important for hearing language (Poritsky & Freeman, 2003; Carter, 2019).
Right inferior temporal gyrus	PTSD: Decrease in the volume of gray matter. CLBP: Decreased functional connectivity with the posterior cingulate cortex and the right parahippocampal gyrus.	Sussman et al., 2016 Liu et al., 2018	*See Left inferior temporal gyrus*
Right middle temporal gyrus	PTSD: Decreased functional connectivity CLBP: Increase in the volume of gray matter and an increase in activity with symptoms of provocation.	Cheng et al., 2018 Meier et al., 2016; Smallwood et al., 2013	*See Left inferior temporal gyrus*
Right superior temporal gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increased activity	Puri et al., 2010 Harri Jenkins et al., 2000	*See Left superior temporal gyrus*
Temporal lobe	PTSD: Decreased metabolism of glucose with symptoms of provocation. There is also increased activity at rest with reduced cortical thickness CLBP: Decrease in the volume of gray matter	Im et al., 2016 Ong et al., 2018	*See Left inferior temporal gyrus*

Table 3

Occipital Lobe: Diagnostic impact of PTSD and chronic lower back pain on various brain regions

Brain Region	Neurological Impact	Author(s)	Description
Occipital lobe	PTSD: increased metabolism of glucose at rest CLBP: Increased activity	Im et al., 2016 Meier et al., 2016	Occipital lobe is the primary visual area. The cuneus receives input from the inferior half of the visual field. The lingual gyrus receives input from the superior half of the visual field. The left hemisphere receives input from the right

			visual field, and right hemisphere receives from the left visual field (Poritsky & Freeman, 2003).
Left inferior occipital gyrus	PTSD: Decreased volume of gray matter CLBP: Decreased connectivity with the Left insula	Sussman et al., 2016 Kong et al., 2010	*See Occipital lobe*

Table 4

Parietal Lobe: Diagnostic impact of PTSD and chronic lower back pain on various brain regions

Brain Region	Neurological Impact	Author(s)	Description
Parietal cortex	PTSD: Decrease in the metabolism of glucose with symptoms of provocation CLBP: Decrease in the volume of gray matter	Im et al., 2016 Apkarian et al., 2004	This structure includes: the post central gyrus (a sensory cortex for the appreciation of posture, touch, and passive movement), supramarginal and angular gyri (makes up part of Wernicke's speech area. This is the perceptive language area where auditory and visual aspects of comprehension are integrated), the dominant lobe is involved in the skills of comprehending numbers/calculations, and visual pathways (the fibers of the optic radiations [lower eye fields] pass deep through the parietal lobe) (Poritsky & Freeman, 2003; Siddiqui et al., 2008; FitzGerald, Gruener, & Mtui, 2012).
Left secondary somatosensory cortex	PTSD: Lack of responsiveness CLBP: Increase in the volume of gray matte	Badura-Brack et al., 2015 Ung et al., 2014	Located in the superior parietal lobule, this structure is responsible for the perception of shape, size and texture and the identification of objects by feel-stereognosis. Specifically, sensory information, for goal directed voluntary movements and the manipulation of objects. It is also involved in the integration of visual and somatosensory stimuli and is essential in the synchronization

			of the eyes and hands in visually guided movements (Poritsky & Freeman, 2003).
Left parietal lobe	PTSD: Decrease in the volume of gray matter CLBP: Increased in activity with symptoms of provocation, there is increased activity at rest and decreased connectivity	Im et al., 2016 Martucci & Mackey, 2014; Shimo et al., 2011	*See Parietal lobe*
Right superior parietal lobe	PTSD: Increased cerebral blood flow at rest CLBP: Global increased activity	Puri et al., 2010 Meier et al., 2016	*See Parietal lobe*

Table 5

Structures that span across lobes: Diagnostic impact of PTSD and chronic lower back pain on various brain regions

Brain Region	Neurological Impact	Author(s)	Description
Cerebellum	PTSD: Increased metabolism at rest CLBP: Increased activity with provocation	Im et al., 2016 Shimo et al., 2011; Kregel et al., 2015	Three functional lobes are A: Vestibulocerebellum which is the functional part of the cerebellum responsible for balance and gait. B: Spinocerebellum is concerned with coordinating the activities of the limb musculature. Part of its role is to act as a comparator between the intended and the actual movements. C: Neo- or cerebrocerebellum. is involved with the overall coordination of voluntary motor activities and is also involved in motor planning (Poritsky & Freeman, 2003).
Insula	PTSD: Decreased metabolism of glucose at rest CLBP: Increased activity with	Shimo et al., 2011; Im et al., 2016; Chen et al., 2009 Apkarian et al., 2004; Lloyd et al., 2012	Cortical center for pain presumed to participate in emotional responses, perhaps in the context of pain evaluation (FitzGerald, Gruener, & Mtui, 2012).

	symptoms of provocation		
Left fusiform gyrus	PTSD: Decrease in the volume of gray matter CLBP: Increased in activity with symptoms of provocation, there is increased activity at rest and decreased connectivity	Im et al., 2016 Martucci & Mackey, 2014; Shimo et al., 2011	*See Parietal lobe*
Thalamus	PTSD: Decrease in the volume of gray matter CLBP: Decrease in the volume of gray matter	Im et al., 2016 Martucci & Mackey, 2014; Lamm et al., 2011	Responsible for relaying information from the sensory receptors to proper areas of the brain where it can be processed. It analyzes sensory information being transmitted to the brain (auditory, visual, tactile, and gustatory signals) and directs the sensory information to various lobes of the cortex (Poritsky & Freeman, 2003; FitzGerald, Gruener, & Mtui, 2012)

Tables six through 10 provide the results of this analysis indicating the functional impact and the recommended treatment(s). For each brain region the structures studied are delineated. Each structure has the functional impact of PTSD and CLBP with the citations for this data, and the implicated treatment.

Table 6

Frontal lobe: Analysis of Results

Brain Region	Functional Impact	Author(s)	Treatment
Anterior cingulate gyrus	PTSD: Increased depression CLBP: Increased depression	Derbyshire et al., 2002 Derbyshire et al., 2002	EMDR and Medication (EMDR International Association, n.d., Peres et al., 2007)
Left inferior frontal gyrus	PTSD: Somatization CLBP: Abnormal decision making, anxiety, and loss of cognition.	van der Kolk, 2000 Huang et al., 2019	Psychotherapy not specified, EMDR (Rabellino et al., 2018; EMDR International Association, n.d.)
Left middle frontal gyrus	PTSD: Somatization CLBP: Blunting of affect, poverty of speech	van der Kolk, 2000 Shimo et al., 2011	EMDR and Art therapy (EMDR International Association, n.d.)

	and thought, apathy, anhedonia, reduced social drive, loss of motivation, lack of social interest, and inattention to social or cognitive		
Medial frontal gyrus	PTSD: Decreased emotional responses to stressful stimuli that are not associated with the trauma	Im et al., 2016; Gold et al., 2011	DLS training (Jenkins et al., 2000)
	CLBP: Adjustment disorder	Aupperle et al., 2012	
Middle cingulate gyrus	PTSD: Increased activity	Karim et al., 2017	EMDR (EMDR International Association, n.d.)
	CLBP: Increased insomnia and depression	Yu et al., 2018; Lloyd et al., 2012	
Orbitofrontal cortex	PTSD: Increased depression and insomnia	Yu et al., 2018	Psychotherapy not specified, EMDR (Rabellino et al., 2018; EMDR International Association, n.d.)
	CLBP: Increased depression	Cheng et al., 2018	

Table 7

Temporal lobe: Analysis of Results

Brain Region	Functional Impact	Author(s)	Treatment
Amygdala	PTSD: Increase in depressive symptoms. Increased fight/flight/freeze reaction, increased anger/rage	Rabellino et al., 2018	EMDR (EMDR International Association, n.d.)
	CLBP: Increase in depressive symptoms. Increased fight/flight/freeze reaction, increased anger/rage	Drevets et al., 2002	
Left amygdala	PTSD: Increased in depressive symptoms. Increased fight/flight/freeze reaction, increased anger/rage	Rabellino et al., 2018	CBT/ ACT (Lankster & Williams, 2018; Lamm et al., 2011)
	CLBP: Negative affective such as anger, anxiety, and negative affective states	Yang et al., 2019	
Right amygdala	PTSD: Increased in depressive symptoms. Increased fight/flight/freeze reaction, increased anger/rage	Rabellino et al., 2018	EMDR/ CBT/ACT (Lankster & Williams, 2018; Rabellino et al., 2018;

	CLBP: Impaired perception of anger, fear, anxiety, and depressive symptoms	Drevets et al., 2002	EMDR International Association, n.d.)
Right borderline amygdala	PTSD: Decrease in the volume of gray matter which is negatively correlated with severity of severity of traumatic events and severity of the symptomology	Drevets et al., 2002	ACT/ EMDR (Lankster & Williams, 2018; EMDR International Association, n.d.)
	CLBP: Impaired perception of anger, fear, anxiety, and depressive symptom	Drevets et al., 2002	
Hippocampus	PTSD: Increased in Stress or Fear, difficulties storing and recalling information. Deficits in memory function (Declarative memory and short-term verbal)		EMDR (EMDR International Association, n.d.)
	CLBP: Depression, impaired contextual fear and impaired emotional decision making.	Martucci & Mackey, 2014	
Left Hippocampus	PTSD: Increased in Stress or Fear, difficulties storing and recalling information. Deficits in memory function (Declarative memory and short-term verbal).	Im et al., 2016	Psychotherapy (modality not specified) and EMDR (EMDR International Association, n.d.)
	CLBP: Depression, impaired contextual fear and impaired emotional decision making.	Martucci & Mackey, 2014	
Left inferior temporal gyrus	PTSD: Learning and memory deficits	Sussman et al., 2016	Psychotherapy (modality not specified) and EMDR (Rabellino et al., 2018; EMDR International Association, n.d.)
	CLBP: Disturbance of memory/learning	Shimo et al. 2011	
Left middle temporal gyrus	PTSD: Learning and memory deficits	Kregel et al., 2015	CBT, ACT, Peer assisted learning (Lankster & Williams, 2018; Lamm et al., 2011)
	CLBP: Low fear avoidance, fear anticipation, anxiety, and depression	Kregel et al., 2015	
Left precentral gyrus	PTSD: Increase motor activity causing monoplegia or hemiplegia	Smallwood et al., 2013	Medication and CBT (Lamm et al., 2011)
	CLBP: Increased depression and anxiety	Qi et al., 2014	

Right precentral gyrus	PTSD: Increased motor activity on the opposite side of the body CLBP: Increased risk of depression	Sussman et al., 2016 Kong et al., 2010	Psychotherapy not specified, EMDR (Rabellino et al., 2018; EMDR International Association, n.d.)
Left superior temporal gyrus	PTSD: Deficits in spoken and written language is affected causing aphasias to occur CLBP: Fibromyalgia type symptoms	Hölzel et al., 2009 Lami et al., 2013	Medication and CBT (Lamm et al., 2011)
Right inferior temporal gyrus	PTSD: Deficits in learning and memory CLBP: Impacts memory retrieval of unpleasant experiences, anxiety, anticipation of pain	 Fallon et al., 2016	Daily Living Skills training and EMDR (Rabellino et al., 2018; EMDR International Association, n.d; Cheng et al., 2018)
Right middle temporal gyrus	PTSD: Increased risk of depression CLBP: Anxiety, increased depression, fear anticipation	Ung et al., 2014 Hasler et al., 2007	CBT and Art therapy (Lamm et al., 2011)

Table 8

Occipital lobe: Analysis of Results

Brain Region	Functional Impact	Author(s)	Treatment
Occipital lobe	PTSD: Mild cognitive impairment CLBP: Increased anger, fight/flight/ freeze response to visual stimuli	Sanabria-Diaz et al., 2013 Vrana et al., 2015	Daily Living Skills training (Jenkins et al., 2000)

Table 9

Parietal lobe: Analysis of Results

Brain Region	Functional Impact	Author(s)	Treatment
Parietal cortex	PTSD: Mild cognitive impairment CLBP: Mild cognitive impairment	Kantarci et al., 2010 Kantarci et al., 2010	Psychotherapy (Seminowicz et al., 2011)
Left parietal lobe	PTSD: Spatial processing deficits CLBP: Spatial processing deficits	Fein et al., 2009 Fein et al., 2009	CBT/ Art therapy (Lamm et al., 2011)
Right superior parietal lobe	PTSD: High risk of anxiety disorder		CBT and Art therapy (Lamm et al., 2011)

	CLBP: High risk of anxiety disorder	Hasler et al., 2007	
Motor and posterior cingulate cortices	PTSD: Increased visual task related readiness/visual hypervigilance, functional readiness	Shimo et al., 2011	CBT and Psychotherapy (Seminowicz et al., 2011)
	CLBP: Deficits in executive functioning, processing speed, and memory	Leech & Sharp, 2014	

Table 10

Structures than span across lobes: Analysis of Results

Brain Region	Functional Impact	Author(s)	Treatment
Cerebellum	PTSD: Deficits in cognition, affect, and motor function	Im et al., 2016	Medication (Lamm et al., 2011)
	CLBP: Motor dysfunction	Gaura et al., 2017; Vrana et al., 2015; Dusi et al., 2015	
Insula	PTSD: Deficits in attentive and emotional responses	Im et al., 2016	ACT and CBT (Lankster & Williams, 2018; Lamm et al., 2011; Seminowicz et al., 2011)
	CLBP: Increased propensity for anxiety like worry	Karim et al., 2017; Kong et al., 2013	
Left fusiform gyrus	PTSD: Inability to recognize face, body, or words. Can lead to possible "face blindness" or dyslexia	Im et al., 2016	CBT (Lamm et al., 2013)
	Face blindness and deficits in reading and spelling.	Yang et al., 2019	
Thalamus	PTSD: Decreased in episodic memory and executive functions including speed of information processing, directed attention, and working memory positively correlated to the amount of atrophy	Fama et al., 2015	Psychotherapy modality not specified, Habituation, CBT/ cognitive support, and EMDR (Rabellino et al., 2018; EMDR International Association, n.d.; Lamm et al., 2011)
	CLBP: Decreased in episodic memory and executive functions including speed of information processing, directed attention, and working memory positively	Fama et al., 2015	

	correlated to the amount of atrophy

Discussion

This study was to investigate the cognitive, neurological, and behavioral manifestation of the dual diagnoses of PSTD and CLBP for the purposes of developing a psychological treatment to address resulting effects. Based on the findings, there is a compounded impact in several areas of the brain when co-morbid CLBP and PTSD occurs. The most common functional result of the neurological alterations that occur with these diagnoses were anxiety and depression (American Academy of Neurology, 2017; Apkarian et al., 2004; Fallon et al., 2016).

Anxiety and Depressive Symptoms

Overall findings support that when CLBP and PTSD occur the right amygdala, amygdala, anterior cingulate gyrus, middle cingulate gyrus, orbitofrontal cortex, right middle temporal gyrus, and superior parietal lobe, insula, left hippocampus and hippocampus incur alterations in grey matter density and/or glucose metabolism resulting in depression and/or anxiety symptoms (Lee et al., 2010). These symptoms can further impact the medial frontal gyrus exacerbating deficits in emotional adaptability. In addition, the left inferior frontal gyrus and the middle frontal gyrus also are affected by CLBP and PTSD due to somatization, which results in increased chronic pain. This causes cyclical emotional dysregulation and deficits in cognitive functioning (Lankster & Williams, 2018).

Furthermore, alterations in amygdala structures caused increased symptoms associated with PTSD; specifically, an increase in the fight/flight/freeze response, and increased emotions such as anger and rage. It is recommended that these symptoms are treated to address both physical and mental health conditions utilizing Eye Movement Desensitization and Reprocessing (EMDR), Psychotherapy, and Acceptance Commitment Therapy (ACT).

Psychomotor Agitation and Motor Coordination

Psychomotor agitation is another symptom that results from neurological deficits in the cerebellum, left middle temporal gyrus, left/right precentral gyrus, left superior gyrus, and left/right supplementary motor area due to combined CLBP and PTSD. (Gold et al., 2011). Findings indicate Psychotropic Medication and Cognitive Behavioral Therapy (CBT) are beneficial to treat this symptom.

Cognitive Functioning, Memory, and Learning

In addition, the combination of CLBP and PTSD affects learning, memory, and cognitive functioning (Buckalew et al., 2020; Lee et al., 2010). Based on the systematic review conducted the thalamus and right thalamus experience atrophy. These areas are responsible for episodic memory, executive functioning, attention, and speed, and when atrophy occurs these functions are adversely impacted. Glucose metabolism changes in the superior frontal gyrus, insula, and insular cortex all similarly result in inattention, cognitive dysfunction, and deficits in information processing, and the left inferior temporal gyrus experiences memory and learning disturbances (Gu et al.,2012). Also, evidence from studies examining memory led to the conclusion that the right inferior temporal gyrus deficits are due to retrieval of unpleasant memories caused by trauma.

To address increased deficits in episodic memory, executive functioning, attention, and speed research recommends the use of EMDR and CBT (Qin et al., 2012; Chacko et al., 2013). Taken together, these findings support that a structured psychological treatment, consisting of various aspects of neurological, behavioral, and somatic interventions, with concurrent pharmacological treatment will be efficacious in addressing the neurological effects identified above (Chen et al., 2017).

Treatment

Protocol

To therapeutically address the array of aforementioned neurological and functional outcomes of these comorbid disorders, the following treatment protocol is proposed. This protocol is to be administered by licensed mental health professionals preferably in collaboration with, or as a part of a treatment team. However, it may be adjusted to accommodate an independent (private) practice, forasmuch as appropriate referrals and consultations are conducted (Bennabi et al., 2013). This protocol was developed by integrating the previously mentioned evidence-based treatments recommended for the various impairments resulting from changes in glucose metabolism and grey matter density.

First, the patient should be medically examined and adhere to medical and prescription interventions throughout this treatment course. Upon the completion of medical examination and medication management, a therapeutic intake is conducted, psychoeducation on the therapeutic processes is provided, and the patient is assessed for the severity of pain, quality of life, and trauma symptoms. Suggested assessment measures include: The Clinician Administered PTSD Scale-DSM 5, Battery for Health Improvement-2, Multidimensional Pain Inventory, McGill Pain Questionnaire, MMPI-3, and Assessment of Quality of Life. Supplementary informal assessments such as the Tree of Life may be used as well. Those assessments will be utilized as a baseline to measure patient outcomes. In addition, the use of these assessments provides the clinician with an in-depth view of the patients' symptoms, which are associated with changes in their glucose metabolism and grey matter density.

Secondly, based on the information provided, coping skills training begins. This training includes restorative, maintenance, autoplastic and alloplastic interventions. Restorative coping skills are used to increase psychological resiliency when the individual is functioning at a deficit due to experiencing increased stress (e.g., a vacation). On the other hand, maintenance skills are used daily to maintain a baseline. External methods are alloplastic interventions used for both restorative and maintenance, and internal methods are autoplastic interventions (See Table 11).

Table 11
Types of Coping Skills

	Internal (I)	External (E)
Restorative (R)	I-R	E-R
Maintenance (M)	I-M	E-M

The external methods for restorative and maintenance are daily living skills which are incorporated into the individual's daily life using a calendar/planner. As previously stated, individuals with CLBP and PTSD often have difficulty navigating daily life which increases

stressors and impairs functioning (Lankster & Williams, 2018; Bremner, 2002). Internal coping skills may include practices such as grounding, mindfulness, and thought stopping etc. All coping skills are re-assessed and adjusted appropriately throughout the course of treatment (Hölzel et al., 2009).

Additional internal coping skills, also referred to as resources, are gathered during the Eye Movement and Desensitization and Reprocessing portion of treatment (EMDR). As Phase 1 falls under the beginning stages of this protocol. Subsequently, the patient begins Phase 2 of EMDR. In this stage internal coping skills (i.e., resources) are honed. During this stage, this protocol infuses EMDR internal resource techniques with hypnotherapy interventions; specifically, the creation of a safe place, internal resources (which may also be called "calling on the ancestors") and developing a totem animal (if needed). Creation of a safe place and "calling on the ancestors" are hypnotherapy interventions that are utilized as Phase 2 of EMDR.

Neurologically, the visual imagery (hypnotherapy) techniques are designed to increase stimulation in the anterior cingulate cortex and decrease activity in the amygdala (Gruener, Dockery, & Mtui, 2015). It also provides the patient a space to mentally retreat when internal stimulation regulation, containment, and support is needed. This first step in the internal coping skills portion of this protocol is the creation of a container, which is in-keeping with EMDR practices. Next, the patient is given the directive to create a safe space where no one can enter or exit without their permission (this statement is specifically used in the creation of the safe space to prevent the events in their traumatic reprocessing from psychically impinging upon the space and causing overstimulation). Resources or "Ancestors" are figures that represent specific aspects of self: wisdom, nurturing, and protection. The patient may use these figures if/when that virtue is needed in reprocessing their trauma. A "totem animal" that represents their inner strength may be developed as well for the same purposes. Subsequent to this, the remaining six phases of EMDR are followed: Phase 3- assessment, Phase 4- desensitization, Phase 5- installation, Phase 6- body scan, Phase 7- closure, and Phase 8- reevaluation (Shapiro, 2007).

Upon successful completion of EMDR the patient is ready to create a new self-narrative and value system independent of their trauma and pain centered identity. This is performed using the tenants of ACT (Hayes & Lillis, 2012). As, Lankster and Williams (2018) explain, "Patients diagnosed with PTSD and chronic pain often tend to recreate their life narrative to center around minimizing, avoiding symptoms, and traumatic experiences" (p. 230). ACT walks the patient through the process of (a) choosing values, (b) managing experiential avoidance, (c) diffusion, (d) detaching from conceptualized self/perspective taking, (e) increasing flexible attention, and (f) focusing on committed action (Hayes & Lillis, 2012). In addition to ACT, post-EMDR patients use art therapy to process and learn new ways to express emotions.

Finally, patients are reassessed with the same measures used at the outset of treatment to assess outcomes and the needs for additional treatment. It is hypothesized that this intervention will alleviate PTSD symptoms while decreasing pain flare-ups.

Conclusion

The diagnoses of both PTSD and chronic pain are ever increasing, and the co-morbidity of these disorders is also seeing an increase (Apkarian, 2010). These co-morbid disorders present a mounting challenge for health-care professionals to treat due to their cyclical nature and the way they exponentially exacerbate each other. As such, this study has the potential for global utility and provides a practical protocol for practitioners. Due to the previously mentioned dearth

of research of this population, this study has implications that have utility in both clinical and nonclinical settings. This research provides insights into the alterations in glucose metabolism and grey matter density which occurs in co-morbid PTSD and CLBP with a comprehensive treatment guide that addresses the behavioral, neurological, and psychological effects. The outcomes of this study demonstrate whole-brain neurological effects of trauma and chronic lower back pain that may be informative in a variety of treatment settings (e.g., milieu, clinic, and field services).

When working with individuals who are dually diagnosed, it is imperative that one be aware of not only the psychological, behavioral, neurological, physical, and cognitive impacts of each disorder but to understand their combined impact. As this study shows, treatment must address combined effects as opposed to treating these disorders separately. Moreover, having a thorough understanding of the co-morbid outcomes is essential for formulating effective interventions.

The integrative treatment protocol addresses these issues in a holistic manner with interventions that are directly linked to the functional impact of their neurological origin. In addition, it is flexible enough to allow the patient to proceed through the treatment at their own pace and permit the healthcare provider to continually re-assess the patient to adjust intervention as needed. This treatment will improve treatment outcomes while providing a guideline for therapeutic intervention.

Limitations/ Delimitations

Limited neurological data on functional impact of metabolic changes and increased/ decreased gray matter in some areas of the brain was a limitation of this study. Additionally, the proposed treatment has yet to be examined in a comparative study. Also, this study only includes studies with brain scans, and only included participants 18+ years of age, and researchers excluded studies with other co-morbid diagnoses (e.g., CLBP and bipolar). Future research should address those limitations.

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