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The role of mirror neurons in relational dysfunction in posttraumatic stress disorder

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Graduate School of Education and Psychology

THE ROLE OF MIRROR NEURONS IN RELATIONAL DYSFUNCTION IN POSTTRAUMATIC STRESS DISORDER

A clinical dissertation submitted in partial satisfaction

of the requirements for the degree of

Doctor of Psychology

by

Andrew Walker

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Lou Cozolino, Ph.D. – Dissertation Chairperson

This clinical dissertation, written by

Andrew Walker

under the guidance of a Faculty Committee and approved by its members, has been submitted to and accepted by the Graduate Faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF PSYCHOLOGY

Doctoral Committee:

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VITA

CLINICAL EXPERIENCE

Neuropsychology Residency *September 2018 - Present*

Neuropsychology Associates of Western Massachusetts, Springfield, MA

Primary Supervisor: Mitchell Clionsky, Ph.D.

- Residency meeting Houston Conference guidelines for specialized training in clinical neuropsychology.
- Completed comprehensive neuropsychological assessments for an outpatient population with a wide range of cognitive impairments, including Alzheimer's disease, vascular dementia, other dementias, traumatic brain injury, ADHD, and various psychiatric comorbidities.
- Completed comprehensive neuropsychological assessments for inmates at the Hampden County House of Correctional Center to help determine competency to stand trial.
- Conducted diagnostic background interviews with patients.
- Conducted collateral interviews with family members of patients.
- Completed brief neurobehavioral screeners to determine need for comprehensive neuropsychological evaluations.
- Conducted short-term outpatient psychotherapy with a focus on anxiety and other disorders secondary to traumatic brain injury.

APA Accredited Predoctoral Internship *July 2017 – July 2018*

Tewksbury Hospital (Massachusetts Department of Public Health), Tewksbury, MA

Primary Supervisors: Tanya Pospisil, Ph.D. and Brendan Lynch, Ph.D.

- Completed comprehensive neuropsychological assessments for a diverse inpatient public hospital population with a wide range of medical and psychiatric conditions, including traumatic brain injury, developmental disorders, neurodegenerative diseases, psychotic disorders, and mood disorders.
- Maintained an average of ten individual short and long-term psychotherapy cases per week with inpatient medical population, including individuals with traumatic brain injury, neurodegenerative diseases, developmental disorders, substance use disorders, and various psychiatric comorbidities.
- Co-facilitated three psychotherapy groups per week:
    - Medical Illness Support Group for patients with a diverse range of serious medical conditions, including traumatic brain injuries, neurodegenerative diseases, and developmental disorders.
    - Cognitive Behavioral Therapy Group for patients with medical conditions related to substance use disorders.
    - Stages of Change Group for patients with medical conditions related to substance use

disorders.

- Created and led Cognitive Rehabilitation Group for traumatic brain injury patients.
- Evaluated patient competency to make independent medical decisions.
- Participated in multidisciplinary hospital-wide behavioral health rounds with psychology and psychiatry to assess patient self-harm risk.
- Participated in multidisciplinary medical unit rounds with psychology, psychiatry, medicine, social work, nursing, physical therapy, occupational therapy, and speech therapy to formulate diagnoses, develop treatment plans, monitor patient progress, and discuss discharge planning.
- Presented Continuing Medical Education seminar to a multidisciplinary audience on neuropsychological differentiation of psychosis and traumatic brain injury.
- Presented Continuing Medical Education seminar to a multidisciplinary audience on the cognitive effects of cerebellar disorders.
- Participated in regular neuropsychology, psychotherapy, and psychological assessment supervision, didactic, professional development, case conference, and journal club meetings.

Advanced Neuropsychology Extern *September 2015 – June 2017*

Harbor-UCLA Medical Center, Torrance, CA & UCLA Brain Injury Research Center, Los Angeles, CA

Primary Supervisor: Matthew Wright, Ph.D.

- Completed an average of two to three comprehensive neuropsychological assessment batteries per month for a wide range of neurology, neurosurgery, and psychiatry referrals, often with multiple medical and psychiatric comorbidities.
- Conducted neuropsychological assessment batteries at UCLA's Brain Injury Research Center for traumatic brain injury patients as part of interdisciplinary team during patient six-month post-injury follow-up appointment with UCLA Neurosurgery.
- Modified assessment batteries when appropriate based on referral questions and presenting problems.
- Conducted comprehensive clinical intake interviews of assessment clients.
- Wrote detailed assessment reports based on neuropsychological testing and interview results.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.
- Trained new externs on neuropsychological tests and department procedures.
- Presented on topics in neuropsychological assessment during clinical case conferences.

Neuropsychology Extern *September 2014 – August 2015*

Harbor-UCLA Medical Center, Torrance, CA

Primary Supervisor: Matthew Wright, Ph.D.

- Completed an average of two comprehensive neuropsychological assessment batteries per month for a wide range of neurology, neurosurgery, and psychiatry referrals.
- Conducted comprehensive clinical intake interviews of assessment clients.
- Wrote detailed assessment reports based on neuropsychological testing and interview results.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.

Doctoral Trainee *July 2013 – June 2014*

Coastline Community College: Acquired Brain Injury Program, Newport Beach, CA

Primary Supervisors: James Pasino, Ph.D. and Kim Peterson, LMFT

- Provided individual psychotherapy for students with a wide range of brain injury types and psychiatric co-morbidities in intensive cognitive rehabilitation program at a local community college.
- Completed neuropsychological assessment batteries of applicants to program and presented results at interdisciplinary admissions committee meetings to assist with applicant placement in program.
- Wrote detailed assessment reports based on neuropsychological testing and interview results.
- Conducted comprehensive intake interviews of assessment and therapy clients.
- Conducted feedback sessions with students regarding their assessment results.
- Led psychoeducational group on diet and exercise after traumatic brain injury for students in program.
- Participated in interdisciplinary team meetings on treatment and transition plans for students in program.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.
- Maintained progress notes for therapy clients to ensure proper documentation of session content and interventions.

Doctoral Trainee

Pepperdine University Community Counseling Center, Irvine, CA *September 2012 – June 2017*

Supervisor: Joan Rosenberg, Ph.D.

- Provided individual psychotherapy and couples therapy for clients with a wide range of presenting problems at sliding scale community mental health center.
- Conducted intake interviews and completed intake assessments in order to inform treatment planning.
- Conducted peer supervision of psychotherapy cases seen by first year doctoral students.
- Maintained progress notes for therapy clients to ensure proper documentation of session content and interventions.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.

Practicum Student *September 2011 – August 2012*

Orange County Rescue Mission: The Village of Hope, Tustin, CA

Supervisors: Duncan Wigg, Ph.D. and John DePaola, LMFT

- Provided individual psychotherapy at transitional living facility for homeless men and women.
- Provided couples and family therapy for homeless families.
- Co-led weekly supportive psychotherapy group for homeless male residents.
- Coordinated with case managers on treatment and transition plans for homeless residents.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.
- Maintained progress notes for therapy clients to ensure proper documentation of session content and interventions.

Practicum Student *September 2011 – August 2012*

Pepperdine University Community Counseling Center, Irvine, CA

Supervisor: Duncan Wigg, Ph.D.

- Provided individual, couple, and family therapy at sliding scale community mental health center.
- Completed intake assessments in order to inform treatment planning.
- Maintained progress notes for clients to ensure proper documentation of session content and interventions.
- Participated in weekly didactic learning experiences, case conferences, and clinical supervision.

RESEARCH EXPERIENCE

Research Extern *September 2015 – July 2017*

Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center, Torrance, CA

Supervisor: Matthew Wright, Ph.D.

- Conducted neuropsychological assessments of traumatic brain injury (6-month and 12-month post-injury) and control subjects.
- Conducted real world activity simulations with traumatic brain injury subjects (12-month post-injury) treated with transcranial direct current stimulation and control subjects.
- Wrote feedback reports to study participants.
- Analyzed data from study participants.
- Presented findings as part of symposium at the 2016 annual meeting of the Western Psychological Association.
- Presented findings in poster presentations at the International Neuropsychological Society annual meetings in 2016, 2017, and 2018.
- Described findings in manuscript currently in preparation.

Co-Leader, Research and Course Design Team *September 2011 – August 2012*

Pepperdine University Graduate School of Education and Psychology (Irvine Graduate Campus), Irvine, CA

Supervisor: Shannon Wilson, Psy.D.

- Reviewed and conducted IRB information and application process for a study of the impact of laptop use in the classroom on graduate student academic performance and a statistical review of instructor archival data pertaining to the subject.
- Selected to assist faculty advisers in developing a new experiential research course for Pepperdine University M.A. Psychology students.
- Coordinated development of course syllabus and additional materials.
- Collaborated with four-member student team through weekly research meetings.
- Completed literature review on the subject of the impact of laptop/technology use in the

classroom on student performance.

Research Assistant *September 2010 – August 2011*

Pepperdine University Graduate School of Education and Psychology (Irvine Graduate Campus), Irvine, CA

Supervisor: Amy Tuttle, Ph.D., LMFT

- Transcribed interviews of participants in supervisor's study regarding the inter-generational transmission of psychological trauma in Japanese-American survivors of World War II-era U.S. federal government internment camps and their descendants.
- Analyzed interviews for qualitative commonalities.
- Participated in regular collaborative research meetings and didactics on culturally/politically rooted trauma in Japanese-Americans.

MANUSCRIPTS IN PROGRESS

Fatoorechi, S., **Walker, A.**, Rad, H., Romero, E., Yeh, T., Vespa, P., McArthur, D., Hovda, D., Plurad, D.,

Woo, E., Boone, K.B., Fuster, J.M., Wright, M.J. Perceived workload on performance validity tests in persons with and without traumatic brain injury. Manuscript in preparation.

Wright, M. J., **Walker, A.,** Fatoorechi, S., Hardy, D. J., Vespa, P., McArthur, D., Hovda, D. A., Plurad, D., Woo,

E., Fuster, J. M., & Boone, K. B. The Dunning–Kruger effect in traumatic brain injury. Manuscript in preparation.

PROFESSIONAL PRESENTATIONS

Walker, A., Waite, E., Lopez, W., Hardy, D.J., Boone, K.B., Plurad, D., Vespa, P., McArthur, D., Hovda, D.,

Woo, E., Fuster, J., Wright, M.J. (2018, February). *Use of performance validity tests in traumatic brain injury*. Poster accepted for presentation at the 46th annual meeting of the International Neuropsychological Society, Washington, DC.

Wright, M.J., Lopez, W., **Walker, A.**, Martinez, F., Hardy, D.J., Plurad, D., Vespa, P., McArthur, D., Woo, E.,

Fuster, J. (2018, February). *Semantic clustering partially mediates encoding deficits in traumatic brain* *injury*. Poster accepted for presentation at the 46th annual meeting of the International Neuropsychological Society, Washington, DC.

Martinez, F., Waite, E., **Walker, A.**, Hardy, D.J., Budding, D., Woo, E., Fuster, J., Wright, M.J. (2018, February). *A role for neuropsychology in preventive healthcare: Executive ability predicts physical injuries in healthy young adults.* Poster accepted for presentation at the 46th annual meeting of the International Neuropsychological Society, Washington, DC.

Walker, A., Fatoorechi, S., Amaya, S., Yeh, T., Martinez, F., Hardy, D.J., Vespa, P., McArthur, D., Hovda, D.A., Pulrad, D., Woo, E., Fuster, J.M., & Wright, M.J. (2017, February). *The Dunning-Kruger effect and traumatic brain injury*. Poster presented at the 45th annual meeting of the International Neuropsychological Society, New Orleans, LA.

Fatoorechi, S., **Walker, A.**, Rad, H., Romero, E., Yeh, T., Vespa, P., McArthur, D., Hovda, D.A., Plurad, D., Woo, E., Boone, K.B., Fuster, J.M., Wright, M.J. (2017, February). *Perceived workload on performance validity tests in persons with and without traumatic brain injury.* Poster presented at the 45th annual meeting of the International Neuropsychological Society, New Orleans, LA.

Rad, H., Lopez, W., Fatoorechi, S., **Walker, A.**, Lara-Ruiz, J., Hardy, D.J., Vespa, P., McArthur, D., Hovda, D.A., Plurad, D., Woo, E., Fuster, J.M., Wright, M.J. (2017, February). *The role of cognitive speed and control in encoding deficits following traumatic brain injury*. Poster presented at the 45th annual meeting of the International Neuropsychological Society, New Orleans, LA.

Fatoorechi, S., **Walker, A.**, Martinez, F., Soto, A., Kakavand, H., Lopez, W., Lara-Ruiz, J., Boone, K.B., Hardy, D.J., Vespa, P., McArthur, D., Hovda, D., Plurad, D. S., Fuster, J.M., & Wright, M.J. (2016, April). *Perceived workload on performance validity and standard neuropsychological tests.* In Hardy, D.J. & Wright, M.J. (Chairs), *The assessment of workload in neuropsychology*. Symposium conducted at the 96th annual convention of the Western Psychological Association, Long Beach, CA.

Lara-Ruiz, J., Lopez, W., Soto, A., Martinez, F., Kakavand, H., **Walker, A.**, Fatoorechi, F., Hardy, D.J., Real, C.,

Vespa, P., McArthur, D., Hovda, D., Plurad, D.S., Fuster, J. M., & Wright, M.J. (2016, April). *Neuropsychological performance and perceived workload following traumatic brain injury.* In Hardy, D.J. & Wright, M.J. (Chairs), *The assessment of workload in neuropsychology*. Symposium conducted at the 96th annual convention of the Western Psychological Association, Long Beach, CA.

Fatoorechi, S., Lopez, W.D., Lara-Ruiz, J., Kakavand, H., Mangassrian, S., Cervantes, Y., Stark, P.Z.,

Walker, A., Hong, B., Wong, D., Soto, A., Martinez, F., Boone, K.B., Hardy, D.J., Vespa, P., Hovda, D., McArthur, D., Glenn, T., Fuster, J., Plurad, D., Woo, E., Wright, M.J. (2016, February). *Relationship between performance validity and perceived workload in healthy adults and adults with traumatic brain injury.* Poster presented at the 44th annual meeting of the International Neuropsychological Society, Boston, MA.

Lara-Ruiz, J., Lopez, W.D., Kakavand, H., Cervantes, Y., Wong, D., Hong, B., Fatoorechi, S., Mangassrian, S.,

Walker, A., Soto, A., Stark, P.Z., Martinez, F., Budding, D., Hardy, D.J., Vespa, P., Hovda, D., McArthur, D., Glenn, T., Fuster, J., Plurad, D., Woo, E., Wright, M.J. (2016, February). *Differential association of activity memory components and memory process deficits following traumatic brain injury.* Poster presented at the 44th annual meeting of the International Neuropsychological Society, Boston, MA.

Ibarra, A., Armstrong, L., Dubs, W., Markowitz, S., Faith, A., **Walker, A.** (2013, August). *Call for a paradigm*

shift in clinical training: The personal transformation of novice clinicians. Poster presented at the 121st annual convention of the American Psychological Association, Honolulu, HI.

EDUCATION

PEPPERDINE UNIVERSITY, Los Angeles, CA

- Doctor of Psychology (Clinical Psychology): 2020
  - Dissertation: *The Role of Mirror Neurons in Relationship Dysfunction in Posttraumatic Stress Disorder*
- Master of Arts (Clinical Psychology: Emphasis in Marriage and Family Therapy), 2012

- Master of Arts (Psychology), 2011

COLLEGE OF WILLIAM AND MARY, Williamsburg, VA

- Bachelor of Arts (Political Science, History), 1998

ABSTRACT

American military involvement in Iraq and Afghanistan has created a new generation of veterans suffering from posttraumatic stress disorder (PTSD). It has repeatedly been noted that these returning veterans have a particularly difficult time reconnecting with family and friends. Because of these findings, the impact of multiple deployments and prolonged combat exposure is shifting from the individual veteran to its effects on their ability to reestablish intimate relationships after the completion of their service.

Over the last 20 years, numerous studies have directly observed the firing of the same neurons of non-human primates while seeing a member of their species engaging in the behavior themselves. Cortical activity consistent with these findings has been subsequently discovered in the human brain. Some researchers have hypothesized that these neurons, referred to as mirror neurons, form one of the physiological underpinnings of interpersonal attunement and empathy. The present study will explore the possibility that mirror neuron dysfunction secondary to trauma may play a role in the etiology of relationship dysfunction in PTSD.

This study will first review the current research on mirror neurons and the neural systems they support with a particular focus on those systems involved in attunement, empathy, and affect regulation. Next, the impact of traumatic experiences on these systems will be explored. Finally, we will examine the possibility that mirror neuron dysfunction is a mechanism of action in the social dysfunction found in PTSD.

Introduction and Initial Review of Relevant Literature

As a new generation of combat veterans returns home from Iraq and Afghanistan, effective treatment will be of the utmost importance to avoid a replication of the high rates of relationship problems found in Vietnam veterans with posttraumatic stress disorder (PTSD). Given the high prevalence of relational dysfunction in past veterans with PTSD and the possible severity of its nature, understanding the causation of relationship problems often found in PTSD will be vital for mental health professionals in the future. This study will present a review of diverse research to explore the possibility of a biological foundation of the relational dysfunction in PTSD. Specifically, this study will examine the possible connection between mirror neuron dysfunction and problems in interpersonal relationships found in PTSD.

Beginning in the 1990s, researchers found that specific neurons in non-human primates fire when the animals observe a particular action in their conspecifics, such as picking up a banana. These neurons turned out to be the same ones that fire when the primates engaged in the behavior themselves and were dubbed mirror neurons. Specifically, the F5 area of the monkey's premotor cortex contained neurons that fired when the macaque either picked up a food item or observed the object being picked up by another monkey or human (Rizzolatti et al., 1996).

Due to ethical limitations, the invasive procedures required for single neuron studies are not normally used with humans and great apes. However, areas in the human brain analogous to the regions of the monkey brain inhabited by mirror neurons have been examined through imaging studies (Iacoboni et al., 1999). These imaging studies appear to indicate a complicated network of mirror neurons in the human brain, including the premotor cortex equivalent to the areas observed in the initial macaque studies as well as regions of the prefrontal cortex, including the inferior frontal gyrus, and parts of the parietal lobe including the somatosensory cortex

(Rizzolatti & Craighero, 2004). More recently, in specific cases involving patients with intractable epilepsy where single neuron studies are performed for medical reasons, mirror neurons have been directly observed (Keysers & Gazzola, 2010). In these cases, human mirror neurons have been directly observed firing in the supplementary motor area and medial temporal lobe (Mukamel et al., 2010).

By the early 2000s, evidence began to emerge implicating mirror neurons in the understanding of communicative gestures. For example, in 2003 researchers working with macaque monkeys discovered mirror neurons that were triggered when the monkeys observed communicative mouth gestures in fellow macaques (Ferrari et al., 2003). These neurons fired in a region of the monkeys' ventral prefrontal cortex homologous to Broca's Area in the human brain. Broca's Area and the equivalent areas in the brains of other primates are crucial to communication, indicating a possible role for mirror neurons in facilitating social understanding among primates. However, not only do mirror neurons appear to have a role in communication, but they may also be a vital component of the deeper level of interpersonal understanding known as empathy.

Many contemporary researchers have hypothesized that mirror neurons could be at the root of the human ability to perceive the actions, emotions, and sensations of other individuals. A 2003 study found that through structures such as the insula, which connects the areas of prefrontal and premotor cortex inhabited by many mirror neurons to the emotional centers of the limbic system, mirror neurons play a crucial role in the networks that underlie interpersonal comprehension (Carr et al., 2003). As a bridge between cortical processing and emotional understanding, the insula could be the point where the mirror neuronal registration of another individual's experiences gains emotional resonance.

As this emotional resonance develops in the context of interpersonal relationships, mirror systems appear to play a critical role in the establishment of emotional intimacy between relationship partners. A 2004 study of intimate partners found a role for the insula in how an individual emotionally experiences another person's pain (Singer et al., 2004). In this study, researchers used computer alerts to inform one partner that the other was being shocked. Activity appeared in affective processing areas of the anterior insula, along with the anterior cingulate cortex, which mirrored the regions implicated in the emotional reaction of the person being shocked.

If mirror systems play a role in the development of empathy, emotional intimacy, and other forms of interpersonal understanding, what happens if something goes wrong? Recent studies have identified networks containing mirror neurons as having a likely role in several major disorders involving interpersonal relationships. Functional magnetic resonance imaging (fMRI) studies of children with Autism Spectrum Disorder (ASD) have shown limited mirror system activity in the area of social mirroring or an apparent disconnect between premotor mirror systems and processing areas (Iacoboni & Dapretto, 2006). For example, a 2006 study found no activity in mirror neuron-rich Broca's area in ASD children compared to children in a control group when presented with emotional expressions to observe and imitate (Dapretto et al., 2006). In addition, a 2002 study found that the right insula was activated when subjects were shown faces they deemed untrustworthy (Winston et al., 2002).

Given the insula's role as a link between cortical mirror systems and the limbic system, an inability to perceive social signals from others accurately due to mirror neuron dysfunction could cause erroneous evaluations of others as untrustworthy. As noted, the insula has also been found to activate in response to the perception of pain in others (Gu et al., 2010), once again demonstrating its important role in bridging the gap between what is perceived through mirror systems and an emotional experience connected to it.

If problems in mirror neuron systems or their connection to the limbic system could cause a breakdown in the ability of an individual to empathize and accurately interpret the behavior of others, as appears to be the case in autism, it may be the case that such problems are involved in relationship dysfunction. Specifically, if trauma affects sections of the brain inhabited by mirror neurons, is it possible that a decrease in the ability to understand others empathically takes place, leading to the breakdown of an individual's ability to be emotionally present in intimate relationships?

A growing body of research has begun to establish a link between PTSD and intimate relationship dysfunction. In a meta-analysis of 31 studies in this area published between 1984 and 2009, the analysts found that PTSD positively correlated with discord, physical aggression, and psychological aggression in intimate relationships (Taft et al., 2011). This has been particularly notable among combat veterans with PTSD, where intimate relationship dysfunction has been a focus of study since the Vietnam generation of veterans. For example, in a 1998 study of Vietnam veterans (Riggs et al., 1998), researchers found relationship distress reported by over 70% of the veterans with PTSD and their partners in the study's sample. This was significantly higher than the 30% of veterans without PTSD and their partners in the study's control group who reported relationship distress. The degree of distress among veterans with PTSD and their partners was positively correlated with the severity of veterans' PTSD symptoms.

Several studies have indicated that the avoidance and hyperarousal symptom clusters of the Diagnostic and Statistical Manual of Mental Disorders' (DSM-5) criteria for PTSD diagnosis could be implicated in relational dysfunction. Mistaken identification of individuals as threatening could be a part of the social avoidance seen in many individuals with PTSD. By perceiving innocuous actions as threatening, an individual with PTSD may decide to withdraw from social interactions to avoid the threat. This withdrawal can be detrimental to the establishment and maintenance of close relationships.

Recent studies suggest that trauma has an impact on regions of the brain inhabited by mirror neurons. A 2012 study of 16 PTSD patients who had survived urban violence and 16 controls who survived similar violence without PTSD found decreased grey matter volume in the premotor cortices of the PTSD group members (Rocha-Rego et al., 2012). Imaging studies of PTSD patients have also shown decreased activity in the ventromedial prefrontal cortex–a region thought to inhibit amygdala-based fear reactions (Koenigs & Grafman, 2009). This region, along with the anterior cingulate cortex and the presupplementary motor area, has been hypothesized to be a region of super mirror neurons that provide executive control of other mirror systems (Iacoboni, 2008; Iacoboni, 2009a).

If trauma affects regions of the brain inhabited by mirror neurons or the links between them and the limbic system, a possible hypothesis for relational dysfunction in PTSD emerges. Determining whether mirror neuron systems are impacted in PTSD will inform effective treatment of relationship dysfunction in PTSD by providing a more thorough understanding of its neurobiological underpinnings.

Hypotheses

The following hypotheses concerning the connection between mirror neurons and relationship dysfunction in PTSD will be tested via findings from the literature:

- *Hypothesis 1*: Aberrations in mirror neuron systems contribute to the neurobiological basis of PTSD.

Testing this hypothesis will entail an examination of whether overlaps exist between brain structures and networks inhabited by mirror neurons and those implicated in the neuropathology of PTSD. In addition, hypothesis testing will involve a comparison of mirror neuron functions with the forms of relationship dysfunction common in PTSD. Finally, it will involve an examination of interactions between mirror neuron systems and other large-scale neural networks involved in PTSD.

- *Hypothesis 2*: Properly functioning mirror neuron systems can help decrease relationship dysfunction in PTSD.

Testing Hypothesis 2 will involve analyzing the contribution of mirror neuron systems and related networks to the development of empathy and interpersonal understanding and whether this role may assist in improving relationships for people with PTSD. This hypothesis may be especially relevant for clinical practice.

Methodology

Purpose

This study aims to improve the current understanding of the neurobiology of relational dysfunction in posttraumatic stress disorder through a critical review and integration of existing literature. First, the review will provide an overview of research on mirror neurons in non-human primates as well as the corresponding cortical systems in humans. Following this overview, the study will examine literature concerning the impact of trauma on the systems where mirror neurons are found. These two areas of research will be synthesized into a comparison of the social dysfunction common to PTSD with the consequences of mirror neuron dysfunction.

The objective of this synthesis and analysis will be to evaluate the possibility that dysfunction in cortical systems containing mirror neurons may play a role in the social dysfunction found in PTSD. After the review of existing literature is completed, recommendations for future research will be provided and implications for clinical practice will be discussed. These recommendations will be based on an assessment of the limits of this review, any gaps in the literature that are discovered, and the theoretical implications of the review's findings.

Identification of Relevant Literature

The first element involved in identifying the appropriate literature for this analysis is determining where to search. The following search sources will be used: PsycINFO electronic database, the PsycARTICLES electronic database, Google Scholar, the PubMed electronic database, the ScienceDirect electronic database, and university library catalog holdings (e.g., Pepperdine University, UCLA, etc.). By utilizing all of these sources, the chances of collecting the highest amount of relevant literature as possible will be maximized.

After the search locations have been determined, the next step is to decide which key search terms will be most effective. Since the focus of this dissertation is on the potential role of mirror neurons on relational dysfunction in PTSD, the following keywords and terms, along with similar variations on them, will be utilized individually and in combinations to find as much literature on the topic as possible: *posttraumatic stress disorder, PTSD, trauma responses, mirror neurons, combat veterans, intimate relationships*, *domestic violence*, *neurobiology of trauma, combat related trauma, impact of combat*. Additional keywords may be included as the review progresses.

A variety of literature types will be explored in this dissertation, including qualitative studies and quantitative studies. For this dissertation, qualitative literature will include results such as case studies and theoretical pieces. These studies will examine things such as the views of participants (e.g., veterans and their significant others) and theoretical models for understanding their experiences. Quantitative studies are commonly defined as studies that examine the relationship between an independent and dependent variable in a particular population through experimental or descriptive methods, usually quantifying the resulting data. The literature reviewed in this dissertation will be restricted to sources written in English.

The time frame of the literature is another search parameter that will be used in this dissertation. Since mirror neurons were first isolated in non-human primates in the early 1990s, the review of research on mirror neurons and the cortical networks that they inhabit will examine studies since 1990. Contemporary literature on the interpersonal aspects of PTSD will be emphasized, with a focus on studies from 2000 and on. However, earlier literature may be cited if they are generally considered landmark pieces on their subject matter.

Organization of the Literature Table

To enhance ease of use for both author and reader, a series of topics will be covered within a literature table:

1. Mirror Neurons
2. The Neurobiology of PTSD
3. Relationship Dysfunction in PTSD

Within each topic, literature will be organized according to the following categories:

1. Author(s)
2. Title
3. Source Title and Source Type (e.g. journal, book, etc.)
4. Year of Publication
5. Summary of Main Findings
6. Comments Regarding Strengths and Weaknesses

Analysis Procedures

Basic Analysis Techniques

Each piece of relevant literature will be thoroughly reviewed several times. Following this initial review, the pieces of information summarized above will be placed in the literature table in order to organize the content. Next, the literature table will be used to organize literature further into sub-categories in order to aid the synthesis and critique of the literature in the following sections. If a piece of literature fits into more than one sub-category, it will appear in each relevant category in the literature table, but will be written about in the body of the dissertation only in the category in which it most strongly fits.

Review of Current Literature

These sections will contain an analysis of the strengths and weaknesses of the individual pieces of literature, along with those in the body of literature as a whole. For example, in the case of quantitative studies, issues concerning design and methodology will be examined, along with any concerns about the reliability and validity of the findings. Qualitative studies will be discussed in terms of issues such as practical clinical implications and soundness of theoretical arguments.

Synthesis of General Findings

This section will integrate the literature on mirror neurons with literature on relationship dysfunction in PTSD and examine the major themes that exist throughout the analyzed research. The goal of this critical analysis will be to develop hypotheses about the role mirror neurons may play in relationship dysfunction in individuals with PTSD. Limits of any potential hypothesis will also be examined. These limits may include methodological issues as well as limitations to the hypotheses developed by the study. The pros and cons of approaching the topic as a review of pre-existing research will be discussed. Other possible research designs and recommendations for areas of further investigation will be examined. Finally, implications for clinical work with clients with PTSD and their loved ones will be suggested.

Literature Review on Mirror Neurons

This chapter provides a review of research literature on mirror neurons. This review examines what mirror neurons are, their discovery in non-human primates, theories about their function, and current research regarding the role of mirror neuron systems in humans. The chapter concludes with a literature table providing an overview of the findings in the examined studies. The literature is derived from a search on the term mirror neurons in sources such as the PsycINFO electronic database, the PsycARTICLES electronic database, Google Scholar, the PubMed electronic database, the ScienceDirect electronic database, and university library catalog holdings. Based on the organization of the chapter, the search terms and restrictions were amended to include relevant research objectives; for example, by adding terms such as: history and functions. In the last part of the review, pertaining to a description of the current state of research on mirror neurons, literature is restricted to studies published in the post-2010 period in order to provide a more contemporary view.

What are Mirror Neurons? Overview and Theories about their Origins

Throughout the 1980s and 1990s, evidence for mirror neuron systems emerged as a result of research conducted with monkeys. In a comprehensive review of the history of mirror neuron research, Iacoboni (2009b) describes these neurons as having been first discovered in the premotor and posterior parietal cortices. Early studies found these neurons to be notable for their firing not only during an individual monkey's performance of a particular action but also when the monkey sees another monkey performing a similar action. Iacoboni's historical overview traces this early research undertaken in nonhuman primates, specifically macaques. As in other primates, the macaque brain's premotor cortex is crucial for the planning, preparation, coordination, and enaction of movement. As Iacoboni notes, the premotor cortex is not monolithic. Instead, it is comprised of various smaller regions with specialized properties. For example, the ventral premotor cortex in the macaque brain contains two primary areas, F4 and F5. Specifically relevant to mirror neurons, area F5's role includes control of hand and mouth movements, including grasping operations and using hands to bring a food item to the mouth. F5's neurons fire when a macaque performs grasping actions and other hand and mouth movements but also fire when the same macaque, when not performing such activities, observes a fellow macaque performing these hand and mouth actions. This neuronal action, being reminiscent of a monkey seeing its actions reflected in a mirror, resulted in early researchers using the term "mirror neurons" to describe the neurons involved in this scenario.

Gallese (2001) elaborates on early mirror neuron research in the late 1980s and early 1990s, describing the discovery of their role in action representation. In this overview, Gallese describes single neuron recordings undertaken in area F5 of the macaque brain's ventral premotor cortex. These neurons in area F5 activated during such movements as grasping, holding, and purposefully manipulating objects. They also activated when the macaque observed similar actions undertaken by another monkey of the same species. In experiments that controlled for other factors, early findings demonstrated that a mirror neuron response did not occur when a monkey saw another monkey by itself or a relevant object separate from another monkey. Moreover, mirror neuron activation was notably less significant when a monkey would perform mimicking actions without the relevant object. Overall, the relational aspect of the action between a monkey and an item appeared to be the most important in prompting mirror neuron activation. Rather than a solely visual representation of an observed behavior, embedded motor schema appear crucial to the activation of mirror neuron systems in F5.

Two significant viewpoints emerged regarding the origin of mirror neurons: an associative hypothesis and a genetic hypothesis. Heyes (2013) examines both perspectives and analyzes the evidence for each, describing the genetic hypothesis as the longstanding standard explanation of mirror neuron origin and function. According to this hypothesis, evolutionary factors resulted in the tendency of mirror neurons to fire when a monkey engages in an action or observes a similar action. In this hypothesis, their presence is evolutionarily advantageous in social primates due to the facilitation of action understanding. Not only can mirror neurons result in action understanding, but they developed specifically for that purpose. Another major hypothesis, the associative one, does not merge the evolutionary origin and function of mirror neurons. Instead, the associative hypothesis emphasizes sensorimotor associative learning as a process that provides particular neurons with a capacity for mirroring. According to Heyes, the evidence currently points to the associative hypothesis rather than the genetic one as the best explanation for the development of mirror neurons. Heyes also argues that the associative hypothesis appears to be stronger than hybrid models that claim mirror neurons develop through a combination of associative learning and evolutionary adaptation.

In an earlier study, Heyes (2010) examined this debate over the origin of mirror neurons, exploring the merits of the argument that mirror neurons are byproducts of associative learning versus the view that they are an evolutionary adaptation designed for action understanding. While both the associative learning and evolutionary adaptation hypotheses appear plausible on the surface, Heyes argued that the associative hypothesis has several strengths compared to the adaptation hypothesis. The first strength is the associative learning approach’s ability to provide a testable explanation for differences between monkeys and humans that have been cited as evidence against the existence of mirror neurons in humans. Secondly, this hypothesis is consistent with current research that indicates mirror neurons are not a dominant component in action understanding but still play an important role in social cognition. Finally, the associative learning hypothesis appears to be supported by research indicating that sensorimotor learning contributes to the ongoing development of mirror neuron systems throughout the lifespan. These findings seem to indicate that mirror neuron systems originate from sensorimotor experiences over the course of a primate's life, including and perhaps especially through interactions with other primates of the same species, rather than being genetically innate.

What do Mirror Neurons do?

In addition to forming hypotheses about the origin of mirror neurons, research since the 1980s has delved into their specific functions. In his review of mirror neuron research history, Iacoboni (2009a) also explores possibilities regarding the function of mirror neurons. He notes that the initial hypothesis about their function pertained to action recognition, where premotor neurons fire both when carrying out an action and observing another individual carrying out the same action. This creates a monkey see, monkey do neural mechanism that allows an individual to recognize an action carried out by someone else. However, in this historical review, Iacaboni notes that later research evolved beyond the initial monkey see, monkey do understanding of mirror neuron functionality towards the possibility that mirror neurons make up complex neural systems that encode information about the perceptual and motor aspects of actions carried out by individuals and those they observe. Here, Iacaboni makes a distinction between mirror neurons that are strictly congruent and those that are broadly congruent. One-third of mirror neurons fall into the strictly congruent category, firing only when the action observed in others is precisely the same as the observing individual's action. A two-thirds majority of mirror neurons, however, are broadly congruent. These broadly congruent mirror neurons fire for individual and observed actions that do not have to be the same but can simply reach the same goal or be related in a somewhat less direct way. Broadly congruent mirror neurons may allow for more nuanced encoding of action recognition, perhaps generating the flexibility that is often vital to social interactions.

Gallese and Goldman (1998) describe *mind reading* and learning via imitation as two possible primary functions of mirror neurons. In terms of learning through imitation, they note that learning a new motor skill often necessitates a training phase that involves the replication of an instructor's movements. Given the efficacy of this learning strategy, mirror neurons could be a mechanism for learning by imitation. Mind reading refers to a role for mirror neurons in developing theory of mind, wherein an individual understands that others experience their own cognitive and emotional states. This could prove advantageous since by being able to determine the intentions of another individual, a primate may be able to anticipate the resulting actions of that fellow member of their species. Accurately identifying whether another's actions or inner processes are prosocial, threatening, or even just neutral can help an individual formulate an effective response.

Kohler et al. (2002) explore an auditory role for mirror neurons in understanding the actions of others, observing that many actions can be recognized by their distinct sounds. Their study found premotor cortex neurons in monkeys that fire when a monkey engages in a particular action as well as when the monkey hears a sound related to that action. Also, these neurons behaved like other mirror neurons by firing when the monkey observed the action. These mirror neurons could be considered audiovisual since they responded to actions regardless of whether the animal saw or heard them. Kohler et al. speculated that audiovisual mirror neurons could have played a role in the origin of language by relating meaningful actions to their auditory characteristics. Of note, the mirror neuron inhabited F5 region of the macaque brain is homologous to Broca's area in the human brain, a structure vital to language comprehension.

A study by Ferrari et al. (2003) further elaborated on the macaque brain premotor cortex's F5 area as homologous to the human brain's Broca's area, focusing on the role of its mirror neurons in communication. In this paper, the authors noted that most previous research on mirror neurons concentrated on hand movements by monkeys, while their own findings built a case for mirror neurons also having a role in understanding mouth movements. This study found that approximately one-third of these neurons fire when the monkey sees another monkey's mouth movements. A majority, however, specifically fired for ingestive behaviors involving food. Mouth motor neurons fired most often when the monkey observed another monkey making communicative mouth gestures such as lip-smacking. Some also fired when a monkey made its own communicative gestures. Overall, this study expanded the role of mirror neurons from understanding hand gestures to understanding mouth ones as well, suggesting that Area F5, homologous to Broca's area in humans, plays an important role in communication. Comparing their results to other literature, Ferrari et al. speculated that mouth mirror neurons might explain the origins of vocal communication.

Debate continues over the significance of these findings on the functions of mirror neurons. For example, Jacob (2008) replied to the Gallese and Goldman (1998) study's conclusion that mirror neurons represent a form of mind reading ultimately responsible for theory of mind. According to Jacob, the evidence for this level of cognitive sophistication in macaque monkeys is far from conclusive. Additionally, according to his critique, the motor resonance generated by mirror neuron systems do not allow an observer to comprehend another individual's prior intentions. Instead, Jacob posits that mirror neurons comprise a predictive system that combines observation of a present motor action with contextual cues to understand another party's future intentions. However, Jacob notes that this stricter interpretation of mirror neuron data does not necessarily negate a role for mirror neurons in the development of social cognition. If mirror neurons can influence an observer's ability to predict future motor acts by another party based on information about their present motor actions, they are still playing an important role in developing social cognition.

Uithol et al. (2011) provide yet another angle on the functions of mirror neuron systems. First, their paper argues that single neuron recordings in monkey brains have provided substantial evidence of a premotor cortex mirror system role in action understanding. Translating this evidence to humans, neuroimaging and behavioral experiments support the possibility of similar mirror neuron systems in human brains. Although the data from single neuron recordings in monkeys appears strong, interpretation of this data has been the subject of debate. Uithol et al. combine this data with a theoretical analysis of the mirroring process to determine whether the existence of a mirror system could logically explain cognitive functions. In their view, mirror neuron systems acting by themselves can only explain relatively low-level action recognition. The higher level of abstraction that occurs in humans necessitates the involvement of non-mirroring processes and therefore cannot be explained by mirror systems alone. However, their analysis does not discount the role of mirror neurons entirely and argues for an integration of mirror systems and non-mirroring processes to explain higher level abstraction.

Current Direction of Research: Mirror Neurons in Humans

As discussed in the previous section, while researchers have debated the precise role and function of mirror neurons, the overall consensus points to an essential contribution by mirror neurons to social cognition. Given that research into their role in monkeys may have significant implications for understanding social cognition, more recent research has attempted to demonstrate their existence in humans. The primary method of investigating mirror neuron existence and function in humans involves comparing neuroimaging results in humans to predictions about the possible location and activity of mirror neurons. For example, Kilner et al. (2010) investigated the presence of mirror neurons in the inferior frontal gyrus, the location of Broca's area and homolog to area F5 of the macaque brain. The study incorporated a repetition suppression paradigm involving two tasks, a precision grip and an index finger pull, with fMRI. In repetition suppression, neuronal activity decreases when a stimulus is repeated. The study participants were asked to either execute the precision grip or finger pulling activity or observe a video of another person engaging in the activity. fMRI data from the inferior frontal gyrus found repetition suppression in the inferior frontal gyrus when the action carried out by a participant was followed by observation of the same action rather than a different one. Response suppression also occurred when the observed action was followed by the execution of the same action rather than a different one. Kilner et al. found this pattern of responses to be consistent with their predictions based on a mirror neuron model, concluding that their results constituted evidence of the existence of mirror neurons in the human inferior frontal gyrus.

Similarly, Hamzei et al. (2016) also used fMRI data to collect evidence for the presence of mirror neurons in the human inferior frontal gyrus. In this study, they used fMRI data to examine action observation and imitation, involving a grasping task, in a sample group of 102 participants. The study analyzed connections between mirror neuron areas of the inferior frontal gyrus and other parts of the human brain, specifically the postcentral gyrus (called by its less common name, the post-Rolandic area, in the paper), a region that includes the primary somatosensory cortex. Using the two-stream/dual-loop model, the study's results found that action observation accompanied by imitation arose from the dorsal stream from Brodmann Area (BA) 44 in Broca's area. This also involved ventral and dorsal connections from BA45, also located in Broca's area, to the postcentral gyrus. Hamzei et al. (2016) concluded that these regions of Broca's area might be a crucial point where mirror neuron systems of the inferior frontal gyrus connect to the dual-loop system. Mirror neuron systems, in other words, appear to be intricately linked to other important sensory systems of the brain.

In a broad review of the literature on the evidence for mirror neurons in the human brain, Kilner and Lemon (2013) found evidence of mirror neurons throughout the premotor and primary motor cortices and in various parts of the parietal lobe. The research reviewed in this paper primarily employed neuroimaging of the human brain and found neuronal activity during action observation in areas of the human brain homologous to regions of the macaque monkey brain where mirror neurons were discovered. This overlap appears to indicate the presence of mirror neurons in humans. However, the review also points out a notable caveat to many studies pointing to the existence of mirror neuron systems in humans—the lack of single neuron recordings, due to ethical considerations, that can confirm mirror neuron existence in humans with the precision used on monkeys. Of note, one study (Mukamel et al. 2010) cited in the review involved single neuron recordings in neurosurgical patients who also consented to be research participants and demonstrated mirror neuron activity like what has been found in macaque single neuron recordings. These recordings found this activity in temporal lobe structures and the medial frontal cortex.

Specifically, this single neuron study by Mukamel et al. (2010) exposed 21 epilepsy neurosurgery patients to movies with facial expressions (frowns and smiles) and hand actions. The specific neurosurgical needs of each patient constrained where Mukamel et al. could place electrodes and search for mirror neuron activities. This limitation caused the study to focus on mirror neuron activity in areas of the human brain not previously hypothesized to be inhabited by mirror neurons. However, single neuron recordings in these areas demonstrated firing during observation and execution of the same actions, similar to mirror neuron activity in monkeys. These neurons were in the medial frontal lobe (supplementary motor area) and medial temporal lobe (hippocampus, parahippocampal gyrus, and entorhinal cortex). Not only was the existence of mirror neurons confirmed via single neuron recordings like those performed on monkeys, but the results indicated that mirror neuron systems are far more widely dispersed in the brain than previously thought. Mukamel et al. also reported finding anti-mirror neurons that fired when an individual performed an action but exhibited reduced activity when the individual observed someone else performing that action.

Binder et al. (2017) employed a different method, lesion evidence, to obtain support for the existence of mirror neurons in humans. The study compared the ability to imitate, recognize, and comprehend meaningful intransitive (social) gestures in participants from three groups: left hemisphere stroke patients with apraxia, left hemisphere stroke patients without apraxia, and healthy controls. Results indicated that apraxic patients performed worse in all three abilities compared to the other two groups. No significant difference emerged between the non-apraxic stroke survivor group and the healthy control group. Compared to stroke survivors without apraxia, the apraxic patients had a more significant presence of lesions affecting areas of the frontoparietal network. More specifically, results found that lesions in anterior regions of this system appeared to result in gesture comprehension deficits, while lesions in the posterior parts of the system appeared to result in gesture imitation deficits.

Summary

This literature review defines mirror neurons as ones that fire during the performance of an action as well as when an individual observes another individual performing a similar action. Research in the early 1990s on macaque monkeys resulted in the discovery of mirror neurons. In these early studies, researchers noted the existence of neurons that fired when a monkey performed an action and also fired when a fellow monkey performed the same action. Specifically, these actions were purposeful and goal-directed hand actions such as grasping, holding, or manipulating an object. Building on this initial discovery, researchers delved further into the possible functions of mirror neurons, most notably mind reading and imitation. In terms of imitation, mirror neurons appear to facilitate learning new motor actions by observing and then attempting to replicate another individual’s movements. Beyond motor learning, mirror neurons also may facilitate mind reading by enabling an individual to build a representation of another individual’s mental state and intentions. By enabling this understanding, mirror neuron mind reading could be at the root of theory of mind and social cognition. However, debate continues regarding the specific functions of motor neurons. Despite this ongoing debate, the notion that they play an essential role in social cognition appears to be an emerging consensus. Recent research has begun to establish the existence of mirror neurons in humans via inference from imaging and lesion studies as well as through direct single neuron recordings similar to those initially used with macaque monkeys. Additionally, current findings appear to indicate the presence of mirror neuron networks in a variety of regions of the human brain in addition to those initially discovered in monkeys.

Literature Review on the Neurobiology of PTSD

This section provides a review of the literature on various aspects of the neurobiology of PTSD, examining how the brain is impacted by PTSD and the implications of research in this area for clinical practice. As in the previous chapter, this chapter concludes with a literature table providing an overview of the findings in the examined studies. In the same fashion as the literature review on mirror neurons, the sources reviewed in this literature review of PTSD neurobiology are derived from various databases, sites, and catalogs, including the PsycINFO electronic database, the PsycARTICLES electronic database, Google Scholar, the PubMed electronic database, the ScienceDirect electronic database, and university library catalog holdings. The search terms used in identifying and selecting relevant research are *neurobiology of PTSD*, *posttraumatic stress disorder*, *PTSD*, *trauma responses*, *combat veterans*, and *neurobiology of trauma*. The sources employed are restricted to those published within the last decade, which helps ensure the works reviewed are up-to-date.

Neurobiological Aberrations and Alterations in PTSD

PTSD is defined in the DSM-5 as exposure to severe trauma (e.g., death, serious violence, sexual trauma) followed by intrusive symptoms, avoidance of stimuli reminiscent of the trauma, negative alterations of cognition and mood, alterations in arousal or reactivity, a duration of a month or more, significant distress, and not the result of a substance or medication. As Krystal and Neumeister (2009) note, the etiology of PTSD is unclear in many ways. To provide etiological clarity, Krystal and Neumeister analyzed two and a half decades of PTSD literature in an effort to bridge research in psychopathology and neurobiology with effective clinical treatment. Citing survey findings from the United States that indicate the probability of trauma exposure leading to PTSD is about 10%, the review examines research on the neurobiology of trauma resilience and PTSD vulnerability. Anatomically, interactions between the amygdala and other regions of the brain (most notably the ventromedial prefrontal cortex, hippocampus, and anterior cingulate cortex) appear to be important to understanding PTSD neurophysiology. Specifically, amygdala response to threat-related stimuli is heightened by a traumatic experience. This response combined with a reduction in function in the ventromedial prefrontal cortex, a region vital to emotional regulation, leads to the appearance of characteristic PTSD symptoms. In terms of neurochemistry, a disruption of this frontal control over limbic response is associated with increased mesolimbic dopamine transmission along with increased prefrontal norepinephrine and serotonin transmission. According to Krystal and Neumeister, a greater understanding of this pathophysiology will be vital to developing effective treatment of PTSD.

Garfinkel and Liberzon (2009) build on this conceptualization of PTSD as a heightened response to threat-related stimuli by arguing that this does not account for other common characteristics of PTSD such as avoidance, numbing, fear generalization, vulnerability, or resilience factors. Their review of PTSD research focuses on neuroimaging studies in an attempt to understand the functional neuroanatomy of PTSD. Overall, their findings align with Krystal and Neumeister (2009) by implicating activity in the amygdala, hippocampus, medial prefrontal cortex (mPFC), and nucleus accumbens in PTSD. Garfinkel and Liberzon attempt to correlate disruptions in these structures and their connections with common PTSD phenomena other than heightened threat response. For example, since the mPFC is vital to emotional regulation, they speculate that disruptions in the mPFC could underly the emotional numbing and avoidance often found in PTSD.

In a meta-analysis of functional neuroimaging studies, Patel et al. (2012) provide further analysis of the possible functional neuroanatomy of PTSD. They note that the past two decades of research in this area includes findings that are not always consistent with each other, leading to multiple models of PTSD neurocircuitry. This analysis raises the possibility that, given evidence pointing to the role of interacting neural networks in cognition and behavior, PTSD could be understood through dysfunction in large-scale and distributed networks rather than being pinpointed to individual brain structures in isolation. The meta-analysis utilized activation likelihood estimates to quantify results from functional neuroimaging studies that included trauma-exposed and non-trauma control groups in addition to participants with PTSD. Results found PTSD to be associated with hyperactivity in the amygdala and hippocampus, and hypoactivity in the mPFC. Additionally, Patel et al. found functional alterations in PTSD to be consistent with the triple network model, a theory of the role of large-scale brain networks in psychiatric disorders which consists of the default mode network, salience network, and central executive network.

Sripada et al. (2012) hypothesized that the default mode network and salience network might play a role in the heightened threat sensitivity and disrupted attention often seen in PTSD. In this study, they measured resting state brain activity in Iraq and Afghanistan veterans with PTSD as well as in two control groups, Iraq and Afghanistan combat veterans without PTSD and healthy civilian controls. Compared to both control groups, individuals in the PTSD group displayed reduced levels of functional connectivity in the default mode network, most significantly in the rostral anterior cingulate cortex (ACC)/ventromedial prefrontal cortex (vmPFC) and the hippocampus. In the salience network, most significantly the amygdala, participants from the PTSD group displayed heightened connectivity compared to individuals from the two control groups. The study also found higher cross-network connectivity between the default mode network and salience network in the PTSD group compared to the control groups. Sripada et al. concluded that threat-sensitive circuits are relatively dominant among individuals with PTSD, even in a resting state. Thus, the large-scale neural network pathophysiology of PTSD may hinge on disequilibrium between the salience network and the default mode network.

In addition to dysregulation of internal networks, another aspect of PTSD neurobiology, as noted in Medina (2008), could be the specific characteristics of the external precipitant. Since not every person who experiences a traumatic event develops symptoms of PTSD, perhaps the interactions between the nature and duration of external stressors and individual capacity to manage them determine their psychiatric impact. While each individual's level of stress or trauma tolerance may vary, an individual can recover from stress that is either acute and of brief duration (e.g., fight or flight provoked in early humans by a saber-toothed tiger) or moderate since stress hormones are produced for only brief periods or in moderate amounts. However, ongoing acute stress (e.g., lengthy combat experiences) releases stress hormones over longer periods of time, causing neurotoxic results.

Goodman et al. (2012) observe that stress does not affect all neural networks the same, noting that stress and anxiety can enhance habit (unconscious or instinctual) memory (which is dorsal striatal-dependent) at the expense of cognitive (declarative) memory (which is hippocampal-dependent). The paper analyzes this in rats, finding that anxiety produced in rats by intra-amygdala or peripheral infusions of anxiety-inducing drugs impairs cognitive memory but enhances habit memory. Specifically, when given a task that could be solved by either habit or cognitive memory, the anxious rats favored a solution rooted in habit memory. The amygdala appears to mediate the choice of memory processes. During intense emotional arousal, such as in situations of stress and anxiety, amygdala activation seems to favor habit memory and override solutions based on the deliberate learning that characterizes cognitive memory. Goodman et al. propose that this mechanism may explain PTSD symptoms such as the recurrence of vivid memories of trauma in the presence of relevant stimuli even when an individual cannot consciously recall details via cognitive memory. This suggests a role for the basal ganglia's striatum, which is implicated in habit memory, in the flashbacks sometimes experienced in PTSD.

Liberzon and Abelson (2016) examine contextual processing as an explanatory mechanism for some of the symptoms of PTSD. Contextual processing is a mechanism by which an organism can distinguish between multiple environmental cues and incorporate situation-specific understanding into its understanding of a situation. As the study notes, in terms of neurocircuitry, it is a process in which a hippocampal-prefrontal-thalamic circuit modulates environmental understanding. Liberzon and Abelson conclude that dysregulation of this contextual processing mechanism may be a notable factor in the pathophysiology of PTSD. Specifically, deficits in contextual processing may lead to false or exaggerated threat detection, abnormal increases in fear learning, and other emotional dysregulated symptoms of PTSD due to poorly modulated emotional responses to environmental cues.

In the DSM-5, “PTSD with Dissociative Symptoms” was added as a subtype of PTSD. Lanius et al. (2010) provide a summary of the symptoms and neurobiological features that distinguish dissociative type PTSD from PTSD's more common presentation. While 70% of individuals with PTSD have hyperarousal responses to trauma-related stimuli, 30% experience symptoms of dissociation instead. In contrast to the undermodulation of affect characteristic of most PTSD, in the dissociative type overmodulation takes place. As previously noted, the hyperarousal characteristic of most PTSD cases appears related to the disruption of frontal control of limbic response. The dissociative subtype, however, is associated with strong frontal inhibition of limbic response, leading to the extreme emotional disconnection experienced in dissociative states. This distinction highlights that the neurobiological underpinnings and subjective experience of PTSD can vary considerably between individuals and points to the need for clinical interventions that take the dissociative type into account.

Daniels et al. (2010) compared differences in resting state connectivity and working memory between people with PTSD and healthy controls. This study used fMRI to analyze functional connectivity while an individual switches between a working memory task and a resting state. fMRI results found that during the working memory task, the control group had significantly stronger connectivity than the PTSD group in the salience network and executive networks. The PTSD group, however, had stronger connectivity within the default mode network. These results indicated that healthy controls were able to shift from the default mode network into the networks necessary to perform a working memory task, whereas individuals with PTSD had significant difficulty doing so. This predominance of the default mode network and problems switching from it into other networks when appropriate appears to be a characteristic of how PTSD may affect an individual's interaction with the environment.

Other PTSD research has focused on the neurobiology of specific symptoms of the disorder. For example, Frewen et al. (2012) focus on emotional numbing in PTSD and its neural correlates. In this study, women with PTSD and a control group of women without trauma history underwent fMRI scans while performing emotional imagery tasks. Participants rated their level of emotional numbing on a 0 to 10 scale, with 10 being the highest level of emotional numbing. Among the study participants with PTSD, emotional numbing symptoms were associated with lower positive affect in response to emotionally positive audio vignettes than in the control group. In terms of fMRI data, lower activation occurred in the dorsomedial prefrontal cortex among women with PTSD during both positive and negative imagery in vignettes of social scenarios. In the control group, emotional numbing symptoms were associated with greater activation in the dorsomedial prefrontal cortex during both positive and negative vignettes. Frewen et al. concluded that these findings suggest the lower medial prefrontal cortex response in the PTSD group may indicate deficits in the conscious and reflective processing of emotions among individuals with PTSD.

Tursich et al. (2015) examined the symptoms of PTSD by focusing on PTSD’s symptom clusters: re-experiencing, hyperarousal, and avoidance/numbing, as well as the depersonalization/derealization found in the dissociative subtype. To determine whether disruptions to major large-scale brain networks (specifically the default mode network, salience network, and central/executive network) exist in individuals with PTSD, the study examined resting state fMRI data. Significant findings existed for hyperarousal and dissociative symptoms. Results indicated that hyperarousal symptoms were associated with decreased connectivity in the salience network, specifically in the posterior insula and superior temporal gyrus. The dissociative subtype’s depersonalization and derealization symptoms were associated with reduced connectivity in the default mode network, specifically between the ventromedial prefrontal cortex and the cingulate cortex, as well as between the default mode network and the central executive network.

Steuwe et al. (2014) examined a common interpersonal experience, direct eye contact, in survivors of prolonged child abuse with PTSD and in a healthy control group. In healthy individuals, direct eye contact activates subcortical pathways that modulate cortical areas associated with mentalization and other forms of social cognition. Researchers presented both groups with three-dimensional virtual characters on a computer screen that expressed happy, angry, or neutral facial expressions and either gave a direct or averted gaze. fMRI scans were used to analyze participant responses to the character expressions and eye contact. Irrespective of the character's emotion, direct gaze elicited heightened activation in subcortical structures of participants with PTSD. Specifically, increased activity occurred in the brainstem's locus coeruleus, a nucleus of the pons associated with stress and panic responses. Heightened activity also appeared in midbrain structures, the superior colliculus, and periaqueductal gray, also involved in anxiety response. The control group, however, demonstrated increased cortical activity, specifically in the dorsomedial prefrontal cortex, left temporoparietal junction, and right temporal pole. In addition to the dorsomedial prefrontal cortex's role in theory of mind and other aspects of social cognition, the right temporal pole is often associated with mentalization. The left temporoparietal junction contains Wernicke's Area, vital to language comprehension. Taken together, their activation demonstrates cortical involvement in social understanding among healthy individuals, while individuals in PTSD appear to react to eye contact based on deeper subcortical stress and anxiety responses. Steuwe et al. hypothesized that these midbrain and brainstem structures make up a neural alarm system. The activation of this alarm system in individuals with PTSD during a common social action like eye contact may shed light on larger social or relational problems.

Neurobiology and Other Contributing Factors to PTSD

The neurobiological factors mentioned in the preceding section appear to interact with other influences in PTSD. Noting that trauma does not always lead to the development of PTSD, Jovanovic and Ressler (2010) examine the mediating factors behind trauma resilience and PTSD risk. In this paper, the authors describe how genetic and neurobiological factors interact with environmental factors, such as childhood experiences, to determine an individual's trauma resilience and vulnerability to PTSD. Conceptualizing the inability to control fear as a critical aspect of PTSD development, the authors recap the neural circuits leading to fear regulation and dysregulation. The neurobiology of fear response interacts with childhood, social, and other environmental factors to determine whether trauma results in PTSD.

Skelton et al. (2012) also examine the interaction of neurobiological factors with environmental ones to heighten the risk of developing PTSD. In addition to identifying similar neural pathways relevant to PTSD as other studies, Skelton et al. discuss the potential for a genetic component for developing the disorder. They cite findings from multiple family and twin studies that find approximately 30% of the variance in PTSD vulnerability to be heritable. Although the specific gene interactions responsible for increased risk remain the subject of debate, studies have examined how genetic polymorphisms could be triggered under specific environmental conditions to produce either PTSD resilience or vulnerability. Epigenetic modification may also prove promising in shaping the interaction between environmental factors and gene expression. Ultimately, understanding PTSD on a genetic level and environmental expression of genetic factors may prove vital to future treatment.

At times, PTSD is comorbid with other psychiatric or medical conditions, complicating potential treatment options. Scioli-Salter et al. (2015), for example, examine the neurobiology of PTSD and chronic pain, noting that the comorbidity of the conditions involves greater pain, emotional distress, and disability than each of the disorders alone. According to the study, neural circuits implicated in threat detection and thus involved in PTSD overlap with those involving pain. Additionally, individuals with PTSD and chronic pain share reduced levels of neuropeptides (neuropeptide Y) and neuroactive steroids (ALLO) with anti-stress and pain-reducing properties.

PTSD’s neurobiology can inform clinical treatment, as Lanius et al. (2011) note in their application of social cognitive and affective neuroscience (SCAN) to PTSD treatment. Their literature review found applications to clinical practice, most notably interventions focused on emotional/self-awareness, emotion regulation, social-emotional processing, and self-referential processing. The study notes that the interconnections of the neural networks implicated in PTSD may explain how one problem common in PTSD, such as difficulty in emotional awareness, may relate to another deficit, such as in self-referential processing. Since these impairments manifest in multiple social and affective areas, the study notes, treatment of PTSD should focus on interpersonal and emotional challenges in addition to the traditional focus on processing the traumatic experience and memories of it.

Summary

Considerable attention has been devoted to the neurobiology of PTSD in recent years, as demonstrated in this chapter. While specific structures of the brain, such as the amygdala, ventromedial prefrontal cortex, hippocampus, and anterior cingulate cortex, appear to play a role in PTSD, recent research has often focused on the involvement of large-scale neural networks. Specific symptoms and subtypes of PTSD also appear to have a neurobiological component. However, even though many people experience trauma over the course of their lifetime, not all trauma survivors develop PTSD. Therefore, recent studies have also examined factors related to resilience and risk in PTSD, analyzing the intersection of childhood and present environmental factors and other influences with underlying neurobiology. The impact of neurobiological factors also appears to be a contributor to interpersonal deficits, pointing to the need for a greater understanding of relationship issues in PTSD, the subject of the next chapter.

Literature Review on Relationship Problems in People with PTSD

This chapter provides a review of the literature on relational dysfunction in people with PTSD. As in the previous chapters, this chapter concludes with a literature table providing an overview of the findings in the examined studies. The sources reviewed are obtained using similar databases and sites as the preceding chapters. The search terms employed in identifying relevant scholarly works primarily revolve around *posttraumatic stress disorder* accompanied by *relational dysfunction, relationship problems, social dysfunction, trauma responses, intimate relationships, domestic violence, combat related trauma*, and *impact of combat*. The sources employed are restricted to those published within the last decade, helping ensure the works reviewed are up to date.

The Nature of Interpersonal Challenges in PTSD

Beginning by noting the high prevalence of PTSD in Iraq and Afghanistan veterans, Tsai et al. (2012) investigated the factors that may mediate the relation between PTSD and various aspects of social functioning. Their study examined 164 patients at the Connecticut V.A. one year or less after the end of a deployment to Iraq or Afghanistan. These participants were screened for PTSD and filled out surveys about partner and family relationships, life satisfaction, coping, and social support. 52% of the participants screened positive for PTSD. Among those who screened positive for PTSD, the study found greater relationship difficulty with romantic partners, lower social support and family cohesion, worse social functioning in general, and lower overall life satisfaction compared to other Iraq and Afghanistan veterans. The association between PTSD and lower social functioning was mediated by such factors as lower community-based social support, few secure relationships, excessive worry, and reduced ability to accept changes in life. A combination of greater cognitive social avoidance and lower availability of secure relationships mediated the correlation between PTSD and greater relationship difficulty. Tsai et al. concluded that clinical interventions should target these mediating factors to improve social functioning in veterans with PTSD.

Erbes et al. (2011) examined the prevalence of interpersonal challenges in a study of 313 married or partnered Iraq War National Guard combat veterans. This assessment involved the administration of questionnaires (the Abbreviated Dyadic Adjustment Scale and the Navy Quality of Life Survey) and a PTSD screener at two points in time: two to three months after returning from deployment (Time 1) and one year after that (Time 2). At Time 1, 17% of participants screened positive for PTSD. Findings indicated that veterans who screened positive for PTSD reported lower relationship adjustment than those who screened negative for PTSD. After analyzing the data for Time 1, Erbes et al. identified dysphoria (generalized distress) as a latent variable and strongest independent contributor to predicting relationship adjustment. At Time 2, dysphoria indirectly predicted poor relationship adjustment. The study found notable gender differences among people with PTSD experiencing relationship problems, although the sample was majority male (89%). At Time 1, trauma-specific avoidance among female veterans was more highly related to relationship adjustment than among male veterans. Overall, the study found that emotional states categorized as dysphoria—anger, irritability, and emotional numbing—were contributors in both men and women with PTSD to relationship dysfunction.

Nietlisbach et al. (2010) hypothesized that, in addition to DSM symptoms of PTSD, trauma might also cause impairments in empathic ability and in sharing affective, emotional, or cognitive states. This study examined a PTSD group and a healthy control group, each including 16 participants, using a short testing battery. To assess empathic abilities, Nietlisbach et al. utilized a self-report measure of empathy as well as the Empathic Resonance Test, the Faux Pas

Test, and Reading the Mind in the Eyes Test. For nonsocial cognitive abilities, several common neuropsychological tests (Stroop, Verbal Fluency, and Five-Point tests) were utilized. Results indicated lower empathic resonance among participants in the PTSD group as well as a higher level of personal distress. The presence of any degree of PTSD appeared sufficient to result in lower empathic resonance, as the reported severity of PTSD symptoms did not correlate with impairments in empathic resonance.

Solomon et al. (2008) investigated the association between marital intimacy and PTSD symptoms along with the role of self-disclosure and verbal violence in mediating the effects of PTSD symptoms of hyperarousal and avoidance on marital intimacy. This study was part of a longitudinal study of Israeli veterans of the 1973 Arab-Israeli War, with the previous study conducted in 1994. These 219 veterans were divided into two groups: veterans of the 1973 war who were POWs during the war (125) and those who were not (94). The veterans completed several questionnaires: the PTSD Inventory, Conflict Tactics Scale, Capacity for Intimacy Questionnaire, and the Self-Disclosure Index. The study found that the ex-POWs experienced higher levels of PTSD symptomology than the non-POWs as well as higher levels of verbal violence and lower levels of self-disclosure than the non-POW veterans. Additionally, in the ex-POWs self-disclosure had a mediating effect on the association between PTSD avoidance and marital intimacy, while verbal aggression had an indirect effect on hyperarousal and marital intimacy. No significant correlation existed for non-POWs. The study concluded that verbal violence and self-disclosure are significant interpersonal factors in mediating PTSD symptoms and marital intimacy in former POWs.

Using questionnaires designed to measure satisfaction in various areas of marriage, Allen et al. (2010) investigated marital dysfunction in people with PTSD. The 434 couples who participated in the study consisted of active duty Army husbands and their civilian wives. The study examined the relationships between current PTSD symptoms, recent military deployment, and marital functioning. Results indicated that among the husbands deployed during the year prior to the study, current PTSD symptoms were higher than among those not as recently deployed. Current PTSD symptoms among husbands were also associated with several dimensions of marital problems. Specifically, for husbands as well as their wives, PTSD symptoms in the husbands were associated with lower marital satisfaction, confidence in the relationship, positive bonding between partners, parenting alliance, and even dedication to the marriage. Also, for both husbands and wives, increased negative communication was associated with current PTSD symptoms in the husbands. Higher PTSD symptoms in the husbands were also associated with husband experience of lower satisfaction with the level of sacrifice required in the marriage. Among the wives, when positive bonding, parenting alliance, and negative communication were controlled for, their marital satisfaction was no longer significantly associated with husband PTSD symptoms. However, when the same variables were controlled for among the husbands, marital satisfaction among the husbands was still significantly associated with their PTSD symptoms, albeit in a reduced fashion.

Wolf et al. (2009) examined emotional numbing and negative emotional response in PTSD. The sample included 49 male veterans with PTSD and 75 veterans without PTSD. Of note, the overall sample contained 36 Vietnam War combat veterans (29%), 18 of whom met criteria for PTSD. Participants were shown a series of photographs, some depicting combat scenes from the Vietnam War and others taken from the International Affective Picture System. Participants rated their emotional responses to the pictures, which varied in their affective nature and trauma focus. Results indicated that compared to veterans without PTSD, the Vietnam veterans with PTSD experienced greater negative emotional experience due to exposure to unpleasant imagery. The degree to which the photograph was related to trauma was a significant modifier of the image's emotional effect, with trauma-related photos eliciting stronger emotional responses than other pictures. However, pleasant photographs generated a similar emotional response in PTSD as well as non-PTSD participants. In contrast, both the PTSD and non-PTSD groups showed equivalent response patterns to exposure to pleasant images. The study's findings indicated that factors such as comorbid depression, the similarity of the combat images to a veteran's individual combat experiences, or a veteran with PTSD's level of combat exposure, suggesting that PTSD specifically was modulating emotional response in this study.

Beck et al. (2009) expanded the study of interpersonal deficits in PTSD to a broader set of relationships, examining the influence of trauma on relationships with friends and family in addition to romantic partners. A sample of 109 people seeking mental health treatment following a serious motor vehicle accident completed a clinical interview and a battery of self-report measures of emotional functioning and social support. The clinical interview was structured via the Chronic Stress Interview (CSI), producing clinician ratings for comparison with the self-report measures. The study utilized a hierarchical regression model to examine how PTSD symptoms (re-experiencing, avoidance, emotional numbing, and hyperarousal) affected relationship functioning. The effects of depression were also investigated. Clinical interview results from the CSI found that depression had a larger impact on interpersonal problems than PTSD. However, the self-report measures found a larger role for PTSD symptoms, specifically a significant impact of emotional numbing on emotional strain within relationships. Beck et al. concluded that comorbid PTSD and depression could have a powerful causal effect on interpersonal problems following a traumatic event such as a major motor vehicle accident.

Alderfer et al. (2009) broadened the demographics of relationship dynamics in PTSD to include adolescents. Specifically, they examined how family functioning relates to PTSD among adolescent survivors of childhood cancer. 144 families, consisting of adolescent cancer survivors one to twelve years post-treatment and their families, completed a multidimensional measure of family functioning (the Family Assessment Device). In addition, the adolescents underwent a structured diagnostic clinical interview. Within the families surveyed, 47% of adolescents, 30% of fathers, and 25% of mothers indicated poor family functioning via their Family Assessment Device results. In families where the adolescent met criteria for PTSD based on the diagnostic interview, poorer functioning was present than in other families. This manifested across multiple domains, including affective involvement, affective responsiveness, and problem solving. 75% of the adolescent cancer survivors with PTSD came from families with poor functioning–five times more likely than those without PTSD. Overall, the study concluded that family functioning appears to relate to PTSD symptoms among adolescent cancer survivors.

Monson et al. (2012) provided a treatment-based approach to investigating PTSD and relational dysfunction in 46 American veterans with PTSD. This study sought to determine whether cognitive processing therapy (CPT) can improve social adjustment, social and leisure participation, family relationships, and work life, as well as whether improvement in these areas was related to the remission of PTSD symptoms. The results indicated that CPT improved social adjustment and family relationships in veterans with PTSD compared to a control group of veterans who remained on a waitlist for CPT treatment. Hierarchical multiple regression analyses found that improvement in social adjustment and housework adjustment among the veterans with PTSD were associated with improvements in PTSD symptoms. Improvements in social adjustment, housework adjustment, and family relationships were associated with a reduction in the emotional numbing symptom of PTSD. The study concluded that these findings indicate that CPT may reduce PTSD symptoms by improving various social and family dimensions of life among veterans.

Gewirtz et al. (2010) examined how changes in PTSD symptoms among 468 National Guard fathers impacted their perception of two primary dimensions in their relationships: post-combat couple adjustment and parenting. This one-year longitudinal study utilized multiple clinical questionnaires to measure couple adjustment, parenting, social support, and alcohol use at intake and one year later. Results indicated that increased PTSD symptoms one year into the study were associated with lower post-combat couple adjustment and increased parenting challenges. PTSD symptoms were also associated with challenges in parenting even in the absence of an impact from the symptoms on couple adjustment. Gewirtz et al. concluded that the impact of PTSD on couple adjustment and parenting challenges will necessitate the development of clinical interventions specifically designed to target these areas.

Taft et al. (2011) undertook a meta-analysis of previous empirical studies of correlations between PTSD symptoms and challenges within intimate relationships. The meta-analysis covered 31 studies and found medium-sized associations between PTSD and relationship problems that were higher in studies with military samples than in civilian ones. Medium-sized associations also existed between PTSD and the perpetration of both physical and psychological aggression within intimate relationships. Of note, the severity of PTSD symptoms and perpetration of physical aggression appeared to be correlated, indicating that seeing PTSD as a spectrum rather than a monolithic disorder could be a key to understanding its association with intimate partner violence.

Secondary/Vicarious Traumatization

In addition to intimate partner violence as described above, vicarious trauma can also impact the partners of individuals with PTSD. In a review of recent research, Monson et al. (2009) studied problems in the intimate relationships of veterans with PTSD and how they influence trauma recovery. In addition to analyzing the causal chain that sometimes leads from PTSD to intimate relationship problems, the review noted instances of vicarious traumatization in the partners of veterans with PTSD. This heightened psychological stress in the partner can, in turn, exacerbate the symptoms of PTSD in the initially traumatized individual. In such situations, causation appears to flow both ways within the relationship's system. However, the study's findings also highlighted the importance of social support in improved functioning in both partners.

Ray and Vanstone (2009) studied ten Canadian veterans experiencing PTSD as a result of deployment on United Nations (UN) peacekeeping missions to determine how PTSD impacts families and how supportive relationships may influence recovery from trauma. Based on interviews with the subjects, the authors examined the subjective experience of PTSD through the eyes of those suffering from it. In terms of family relationships, two major themes emerged. The first dealt with the impact of a veteran's PTSD-induced emotional numbing or anger on family relationships. The second theme pertained to how emotional withdrawal from family support or the disruption of family relationships can make recovery from trauma more difficult. Given this potential dual directionality wherein PTSD can both cause relationship dysfunction and also be exacerbated by it, the study concludes by highlighting the need for clinical interventions that strengthen family support and interpersonal skills.

Dekel and Monson (2010) also highlighted the issue of vicarious traumatization through a review of previous research. The study notes that secondary traumatization in family, friends, and caregivers of individuals with PTSD can manifest through PTSD-like and other psychological symptoms such as intrusive imagery, emotional numbing, difficulty trusting others, and a heightened sense of vulnerability. Somatic symptoms, including headaches and breathing difficulty, are also common in people suffering from vicarious trauma. The authors attempt to explain this vicarious trauma by describing it as a process of traumatic countertransference that begins with attempts by loved ones to assist someone with PTSD. This can result in a form of empathic connection that leads to a significant other, friend, or family member taking on a traumatized person's feelings, memories, and experiences as their own, resulting in an experience of PTSD symptoms.

Charuvastra and Cloitre (2008) argue for a social ecology perspective on PTSD in which the social context of an individual drives symptomology. Reviewing a wide range of previous studies in fields ranging from attachment theory and social neuroscience to social support and family therapy, the authors note that PTSD resilience and vulnerability are highly related to social phenomena. Specifically, while relationship problems can develop following PTSD, the health of an individual's interpersonal relationships and social support also play a role in whether PTSD develops in the first place. Although this bidirectional interaction between PTSD and relationship health makes ascribing causality to one or the other more complicated, it calls for clinical work that targets the family system as a whole rather than the individual with PTSD in isolation.

Summary

The studies examined in this chapter provide strong support to the existence of relationship dysfunction as a common challenge faced by individuals with PTSD. This dysfunction can present in a variety of ways, from emotional numbing to domestic violence. Recent literature also points to the existence of vicarious trauma in partners of people with PTSD, creating a further possibility of relationship challenges. Other angles covered in the literature of PTSD and relationships involve the importance of social support in determining resilience or vulnerability to PTSD. These findings have implications for clinical treatment, wherein a focus on interpersonal understanding (such as in areas modulated by mirror neuron systems) and the patient’s social support system may help recovery from PTSD.

Synthesis: Mirror Neurons and Relationship Dysfunction in PTSD

The literature reviewed in this study has examined the existence and function of mirror neurons, the neurobiology of PTSD, and relationship dysfunction in PTSD. Specifically, the review sought to test the following hypotheses:

- *Hypothesis 1*: Aberrations in mirror neuron systems contribute to the neurobiological basis of PTSD.
- *Hypothesis 2*: Properly functioning mirror neuron systems can help decrease relationship dysfunction in PTSD.

Overall, the literature establishes that:

1. Based on research into non-human primates and more recent studies with humans, mirror neurons appear to be heavily involved in facilitating interpersonal understanding and empathy. Thus, they may play a key role in healthy relationships.
2. Mirror neurons may be present in many brain regions and neural networks, including the premotor cortex, inferior parietal lobe, hippocampus, medial prefrontal cortex, and other structures and pathways.
3. PTSD entails neurobiological aberrations affecting brain regions and circuitry in regions such as the amygdala, ventromedial prefrontal cortex, hippocampus, nucleus accumbens, anterior cingulate cortex, and major neural networks.
4. Relationship problems and social dysfunction often appear in PTSD, with complex etiology and symptoms.

The focus of this inquiry is in determining whether a connection may exist between aberrations in mirror neuron systems or their links to other areas of the brain and the interpersonal challenges often faced by people with PTSD. To do so, this chapter integrates findings from the literature on both topics in addition to further studies directly related to the connection of mirror neurons, related large-scale neural networks, and relationship problems. This approach will analyze relationship dysfunction in PTSD in a way that can inform future directions for research and clinical practice.

Mirror Neurons and the Neurobiology of PTSD

The role of mirror neurons in establishing interpersonal understanding may reveal a role for them in the neurobiology of PTSD. A strong consensus in the literature reviewed establishes the role mirror neurons play in learning behavior through observation, which may have led to the development of empathy and theory of mind in humans. These human attributes, arguably traceable to mirror neurons, are essential components in the establishment and continuation of healthy interpersonal relationships. For example, previous research points to the possibility that mirror neuron systems were evolutionarily advantageous in social primates through the development of intersubjectivity (Iacoboni, 2009b). By doing so, mirror neurons contribute to a theory of mind in humans wherein one individual can gain insight into the existence and properties of another's mind. Specifically, mirror neurons appear to play a role in understanding the intentions behind another's actions and anticipating whether those actions are cooperative, threatening, or neutral. This ability proves to be advantageous by enabling an observer to plan an appropriate response based on this information about another's intentions (Gallese & Goldman, 1998). The existence of these mirror neuron functions and their role in interpersonal understanding may indicate that mirror neurons play a crucial part in human relationships (Binder et al., 2017). Given that the relationship dysfunction common in PTSD often involves a breakdown in interpersonal understanding, a connection may exist between relationship challenges in PTSD and aberrations in mirror neuron systems. If problems occur in mirror neuron systems, the interpersonal understanding vital in successful relationships would likely be hindered.

Nietlisbach and Maercker (2009) examine the social neuroscience of PTSD, including the role of mirror neurons. In their paper, they note that mirror neurons may provide humans with the ability to share complex psychological states via emotional contagion. Through emotional contagion, humans can share the affective experience of another individual, often leading first to unconscious mimicry and then to synchronization of feelings between multiple people. These experiences appear to facilitate successful social interactions. Nietlisbach and Maercker continue by relating specific PTSD symptoms to particular social attributes. For example, their analysis associates emotional numbing and avoidance with empathy. In emotional numbing, detachment and feelings of alienation or indifference concerning others can lead to reduced empathy. The withdrawal from social interaction characteristic of avoidance can also damage the capacity for empathy due to isolation from interpersonal communication.

Similarly, hyperarousal and dissociation are associated with emotional resonance. Through the increased irritability and anger that characterize hyperarousal in PTSD or the decompensation that can result from dissociation, emotional resonance becomes difficult as affective states not conducive to shared experience occur. Given that mirror neuron systems play a foundational role in empathy and emotional resonance, disruptions in mirror neuron systems may contribute to difficulty in social interactions that involve empathy and emotional resonance.

In their previously cited study of empathic impairment in PTSD, Nietlisbach et al. (2010) expand on the definition of empathy, noting that it comprises several functions: empathic resonance, cognitive empathy, and emotional empathy. The authors note that empathic resonance is rooted in mirror neuron systems which, beginning from a foundation of mirroring motor movements, build to more complex experiences of empathic resonance. As Nietlisbach et al. found in their study, the shared emotional states made possible through empathic resonance can be disrupted in PTSD. Similarly, Ursano et al. (2009) note that the cognitive process of identification in humans may be a function of mirror neuron activity. Identification with others appears to contribute to emotional regulation, especially regarding interpersonal relationships. Problems in this process of identification, suggestive of disrupted mirror neuron activity, may lead to interpersonal challenges associated with PTSD and trauma-induced chronic stress.

The connection between mirror neuron functions and the relationship problems common in PTSD may also be found in the vicarious trauma experienced by loved ones of individuals with PTSD. As noted earlier, vicarious trauma appears to be rooted in a deep empathic connection with the traumatized person whereby symptoms similar to PTSD manifest in the loved ones of an individual with PTSD through emotional resonance. In addition to PTSD symptoms such as intrusive imagery, emotional numbing, difficulty trusting others, and a heightened sense of vulnerability, vicarious trauma can also result in headaches, breathing difficulty, and other somatic experiences (Dekel & Monson, 2010; Monson et al., 2009). This emotional resonance creating a shared experience of trauma appears suggestive of mirroring, indicating a possible role for mirror neuron systems in the creation of vicarious trauma.

Beyond such inferences, however, the structural overlap between mirror neuron systems and the brain regions implicated in PTSD helps establish the connection between mirror neurons and relationship problems in PTSD. The literature on mirror neurons previously reviewed in this study documented their presence in various regions of the brain. Some of these regions were also highlighted in the research reviewed on the neuroanatomy of PTSD and may be involved in the interpersonal challenges faced by individuals with PTSD. This neuroanatomical overlap suggests aberrant activity in mirror neuron systems may manifest in the form of relationship problems in people with PTSD.

Regions of the brain that appear to be inhabited by mirror neurons include structures of the temporal lobe (hippocampus, parahippocampal gyrus, entorhinal cortex), medial prefrontal cortex (including the supplementary motor area), premotor cortex, and inferior parietal lobe Hamzei et al., 2016; (Iacoboni, 2009b; Keysers & Gazzola, 2010; Kilner & Lemon, 2013; Mukamel et al., 2010). Multiple sources reviewed in this study suggest a significant neurobiological component to PTSD, implicating structures such as the ventromedial prefrontal cortex, hippocampus, anterior cingulate cortex, amygdala, nucleus accumbens, and large scale neural networks (Garfinkel & Liberzon, 2009; Krystal & Neumeister, 2009; Liberzon & Abelson, 2016; Medina, 2008; Patel et al., 2012). In comparing the literature on mirror neurons with literature on the neurobiology of PTSD, overlap emerges between regions of the brain inhabited by mirror neurons and those implicated in PTSD. For example, the hippocampus and medial prefrontal cortex contain mirror neurons and are also associated with PTSD. Impairment of the emotional regulation provided by the ventromedial prefrontal cortex may contribute to difficulty in emotionally complex interpersonal relationships. At the same time, hippocampal problems can result in lower reliance on declarative memory and greater reliance on subcortical instinctual memories, also leading to difficulties in accurately understanding interpersonal situations.

Current research directions, such as single neuron studies of the human brain undertaken when ethically possible, are establishing mirror neurons as more widely distributed in the brain than initially believed (Keysers & Gazzola, 2010; Mukamel et al., 2010). Additionally, recent research on the neurobiology of PTSD points to the role of large-scale neural networks having a significant role in addition to specific brain structures (Patel, et al., 2012; Sripada et al., 2012).

In addition to specific structures of the brain inhabited by mirror neurons, studies have also found that the large-scale neural networks in which these structures are embedded or connected play a role in PTSD. Specifically, disruption of the homeostatic balance and integration between the three executive networks can help explain the interpersonal challenges common in PTSD. These networks, a primitive executive network centered on the amygdala, the frontoparietal or central executive network, and the default mode network, are deeply interconnected with each other and with mirror neuron systems (Cozolino, 2017).

As noted in the studies cited in this review, during the hyperarousal state characteristic of PTSD, the amygdala is activated in response to a perceived threat in the environment. At the same time, the frontoparietal network and default mode network are inhibited (Patel et al., 2012; Sripada et al. 2012). As a result, impairments arise in the form of decreased abilities in reality testing and problem solving. Perhaps most notably for interpersonal relationships, these changes in neural networks lead to decreased ability to perceive the internal state of self and others accurately.

A properly functioning primitive executive network allows for correct identification of threats to an organism’s survival and appropriate responses to these threats. When the frontoparietal network is properly functioning, it allows an individual to turn their attention from these external survival concerns to their internal processes and, through the presence of mirror neurons within this network, the inner state of others. Finally, the default mode network (DMN) plays a crucial role in social cognition.

Research in the last ten years has emphasized the default mode network's (DMN) role in social cognition (Mars et al., 2012) in addition to its more widely recognized role in modulating cognitive rest. Recent research has posited that the DMN also activates during certain types of tasks. Specifically, studies have indicated that higher-order tasks of social cognition involve the DMN, with the precuneus becoming activated in the performance of tasks related to social interactions (Schilbach, et al., 2008). Researchers have also found that the left angular gyrus is activated when distinguishing between others and the self. Further, the anterior cingulate is associated with monitoring the actions of oneself and others, including attributing mental states to others.

The Default Mode Network, Social Cognition, and PTSD

Schilbach et al. (2008) refer to mental states in which subjects are not preoccupied with external stimuli as resting states or instances of unconstrained cognition. These states are associated with the DMN's role in social cognition and predominate when the brain is not interpreting external stimuli. The functional connectivity of the DMN was tested by researchers (Lynch et al., 2013) who focused on DMN function in these resting states. Twenty children with ASD were subjected to resting-state fMRI in order to investigate the link between DMN connectivity and impairment of social cognition. Study results suggest that children with ASD differ from typically developing children in the hyper-connectivity of their visual cortex, local posteromedial cortex, and basal ganglia. Social impairment characteristic of ASD is also associated in the same study (Lynch et al., 2013) with aberrant hyper-connectivity of the posterior cingulate cortex, an area that is likely a significant area of interaction between mirror neurons and the DMN (Molnar-Szakacs & Uddin, 2013). Hyper-connectivity of these areas is thus linked to defining social deficits of the child participants with ASD. While ASD and PTSD differ substantially, these proposed associations between the DMN and social cognition, especially in areas where mirror neurons and the DMN interact, may have implications for individuals with PTSD. Alterations to the default mode network resulting from childhood trauma have also been shown to play a critical role in the developmental genesis of PTSD in adults (Daniels et al. 2011).

The possible links between such DMN alterations and social cognition have also been explored through a clinical lens. Lanius et al. (2014) explore the social aspects of cognitive dysfunction in PTSD, including affect regulation, social cognition, self-referential processing, and emotional awareness. The researchers link such dysfunction in social-cognitive processing with traumatic experiences early in life. Like Daniels et al. (2011), Lanius et al. associate social cognition dysfunction in PTSD with the DMN.

The role of the DMN in threat response for individuals with PTSD is also evident in a study of military combat veterans (Grupe et al., 2016). Deactivation of the DMN, specifically the vmPFC, occurs in anticipation of a threat for those with more severe PTSD symptoms. The participants in this study showed a relative inability to alter DMN activation optimally in response to threat-dependent task conditions. Individuals with PTSD exhibit uniform vmPFC activation during both conditions of threat and safety, suggesting that those with the disorder overgeneralize threat responses due to impaired modulation of the primitive executive network (amygdala) and DMN in response to dynamic contexts (Garfinkel et al., 2014).

Interpersonal dysfunction and relationship issues characteristic of PTSD have been linked to dysfunction in theory-of-mind, a function that mirror neurons and the DMN play a key role in establishing. In one study, researchers tested a group of women with PTSD and childhood trauma against a control group for their ability to recognize familial relationships through images of facial expressions (Nazarov et al., 2014). Compared to the control group, the experimental group of women with PTSD showed decreased theory-of-mind ability and slower reaction time in their interpretation of family interactions. They also were deficient in reading non-verbal cues. This deficiency in interpreting family interactions is congruent with the difficulty of some male PTSD patients, demonstrated in previous research, to show normal theory of mind, particularly through eye contact and a propensity for averted gaze.

A study examining the ability of Bosnian War refugees to glean the emotive content of mental states as displayed in the eyes of another person (Schmidt & Zachariae, 2009) suggests that the refugee-participants with PTSD exhibit a reduced ability to recognize mental states through the medium of eye expression through the Reading of the Mind Eyes Test. Another study using this test along with other theory-of-mind tasks presented results suggests those with PTSD perform worse than normal control groups at accurately judging complex mental states through eye expression (Mazza et al., 2012).

Similarly, Steuwe et al. (2014) examine the reactions of healthy individuals and those with PTSD to direct eye contact, as well as their ability to accurately discern social and emotional information about others from the direct eye contact. The group of PTSD female participants in this study exhibited more activity than the normal group in the superior colliculus, periaqueductal gray supporting circuits, and locus coeruleus. These more primitive brain structures had greater activation than higher cortical regions associated with social cognition and theory-of-mind ability. The more primitive areas utilized by the PTSD group are associated with the emotional-defensive mechanism and withdrawal behavior rather than with social engagement. These results suggest that people with PTSD more frequently experience direct eye contact as a threat or threatening, giving rise to increased activity in the neural mechanisms for threat response. More broadly, this adds to evidence that social-cognitive networks in people with PTSD differ from the general population (Molnar-Szakacs & Uddin, 2014).

Link Between DMN and Mirror Neuron Systems

Over the past decade, research has begun to establish the existence of common networks and links between the default mode network (DMN) and mirror neuron system (MNS). One notable study consisted of fMRI data that was utilized to explore the hypothesized functional connectivity of mentalizing about the self and others (Lombardo et al., 2010). The study sought to uncover shared neural networks as well as explore the extent to which shared representations influence activities in the wider brain. This endeavor was based on the broader hypothesis that the same neural networks are responsible for referential cognition of both self and others.

The study by Lombardo et al. (2010) asked participants to make physical or mental judgments about the self or a well-known other (the Queen of England). For example, participants were asked how likely they were to sneeze if a cat was nearby and how likely the Queen is to do the same (physical judgment). They were also asked questions such as how likely they were to believe keeping a diary is important and how likely the Queen is to believe the same (mental judgment). Based on fMRI results of participants in this task, Lombardo et al. argue that mentalization about self and others involves activation of some of the same structures, such as the primary somatosensory cortex. They also note that higher level, inference-based neural processes interact with lower-level, embodied, sensory, and simulation-based neural processes.

Other research has sought to differentiate distinct regions of the DMN, exploring how they relate to self-referential processing and mirror neurons. For example, Broyd et al. (2009) examine how the medial prefrontal cortex and the posterior cingulate cortex activate during characteristic DMN tasks but deactivate during task-driven efforts that are also attention-driven

(Broyd et al., 2009). In a review of existing research, Molnar-Szakacs and Uddin (2013) pinpoint several likely functional connections between the DMN and MNS. Specifically, the DMN and MNS appear to directly interact at densely connected structures, including the anterior insula, posterior cingulate, and precuneus.

Attention has also emerged as a critical point of study for mentalization and social cognition in PTSD. Lapses of attention in children characteristic of attention-deficit hyperactivity disorder (ADHD) are associated with less deactivation of the DMN during the performance of tasks requiring heightened attention to external stimuli (Liddle et al., 2011). Such attentional deficits associated with dysfunction in DMN deactivation are also linked to schizophrenia.

Recent research has explicitly linked attentional deficits to PTSD and its characteristic social-cognitive dysfunction. In a newly published study, Tan et al. (2019) suggest that the social cognitive processes linked to both the DMN and mirror neuron system are also linked with attentional processes (Tan et al., 2019). This contention is significant because, as explored earlier in this review, PTSD is characterized by distinctive social impairments in addition to the impairments currently recognized by the DSM. Social inference is critical to accurate mentalization about the beliefs and intentions of others, which is, in turn, pivotal in successful social interaction. Research on the clinical treatment of PTSD has begun to recognize PTSD as fundamentally a disorder of social-cognitive functioning driven by the failure of mentalization (Palgi et al., 2014).

Mirror Neuron Overlap with Other Large-Scale Neural Networks

As noted in this review, while the imitative function of the mirror neuron system is comparatively well-understood, emerging research has begun to detail its role in reciprocal communication and wider social-cognitive functioning. In addition to their overlap with the

DMN, recent research has also detailed the interconnections between the mirror neuron system and other large-scale neural networks. This line of inquiry carries important implications for the social-cognitive issues characteristic of PTSD. Nagy et al. (2010) administered a study involving fifteen individuals and fMRI imaging data to test which neural networks may be involved in reciprocal imitative communication. Their results indicate the involvement of both the left infra-parietal lobule and the right inferno-frontal gyrus, as these regions showed activation during an interactive-imitative exercise. Nagy et al. suggest that these two regions worked in concert with a network that is involved in understanding the intentions of others with respect to the self. The authors further speculate that mirror neurons evolved for both purposes of imitation and interpersonal communication.

According to another review (Uddin et al., 2007), there is an emerging consensus that mentalization is tied to the activation of the cortical midline structures (CMS) and externally focused processes are embedded in the lateral frontoparietal networks. The right frontoparietal network is thought to be pivotal in representing the physical body of the self. At the same time, the cortical midline portion of the DMN is responsible for evaluative self-representation and thus includes mentalization functions, involving both self and others. Although it is not yet well-understood how the CMS and MNS act in concert during social interactions and social cognition, inhibition of these two networks may be linked to social-cognitive deficits, particularly for individuals with developmental disorders that emerge in childhood (Uddin et al., 2007). Turjman (2016) cited Udden et al. and other studies to contend that overlap between mirror neuron systems and the cortical midline structures of the DMN drive behaviors such as verbal mind-wandering and create a link between self-awareness and social cognition.

Another meta-study describes the structure of the mirror neuron system and the overlapping systems upon which many of its characteristic functions depend (Jeon & Lee, 2018). The meta-study notes that the mirror neuron system rests atop the visual dorsal stream, which allows for the processing of visual, somatosensory, and auditory data. Other regions linked to the mirror neuron system are involved in a wide variety of functions, including language production, phonological processing, contemplation and conceptualization of distance, and a range of functions related to embodiment and the perception of external stimuli (Jeon & Lee, 2018). In terms of embodiment and perception of external stimuli, one recent study identified the superior parietal lobe, a part of the broad mirror neuron system that also plays a role in the experience of pain, as key to self-other resonance. (Christov-Moore & Iacoboni, 2016).

A recent meta-analysis was undertaken by Molenberghs et al. (2012) in order to explore the existence of multiple systems overlapping the mirror neuron system. The meta-analysis of 125 distinct, motor and non-motor fMRI studies presents results that suggest the overlap of 14 separate clusters within nine distinct Brodmann areas. In addition to the regions more commonly associated with the mirror neuron system, the primary visual cortex, cerebellum, and elements of the limbic system also appear to have mirroring properties (Molenberghs et al., 2012), possibly extending the mirror neuron system into an overlapping array of distinct systems and regions working together in concert in order to observe and execute actions. While Molenberghs et al. emphasize close connections within nine Brodmann areas, they found that 34 separate Brodmann areas exhibit some form of mirror functioning.

Within this meta-analysis were traditional studies that involved the use of visual images depicting actions or otherwise asked participants to perform an action. These studies present results that indicate activation of the inferior frontal gyrus, inferior parietal lobule, and the ventral premotor cortex. A second subset of studies involved participants who were asked to listen to action sounds. This second subset presents evidence suggesting the involvement of both traditional mirror areas (prominent also in the first subset) in addition to activations in left posterior Brodmann Area 22 (part of Wernicke's Area) and the primary auditory cortex (Molenberghs et al., 2012).

A final subset of studies examined by Molenberghs et al. (2012) involving hand motions includes results exhibiting a range of vicarious activity in emotion-processing regions. These include the insula, which has a role in cross-activating regions tasked with action representation located in the limbic system. The insula may also play a role in mirroring the emotional response of disgust in others. As noted by Molnar-Szakacs and Uddin (2013), the anterior insula is also likely a significant location of interaction between the DMN and MNS.

According to the meta-analysis, in addition to well-established mirror neuron regions, structures related to auditory processing, emotional regulation, and somatosensory processing can support the established mirror neuron regions in performing various mirroring functions. The meta-analysis carried out in Molenberghs et al. (2012) has implications for the emerging social-cognitive element of PTSD and its role in interpersonal and relationship disruption, as mirror neuron systems may interact with a broader range of neural structures and networks than previously understood.

Hyperactive threat response, with its role in interrupting social cognition in individuals with PTSD, shows the practical effects of these overlapping connections within the brain. As noted, fMRI results from Grupe et al. (2016) suggest that over-compensated threat response relative to the actual threat posed is driven by a disrupted ventromedial prefrontal cortex (vmPFC). Specifically, results show that the vmPFC is deactivated in those with PTSD symptoms in response to a perceived threat that did not actually exist. The study's regression analysis shows that the differential response of participants to the perceived threat is due to corresponding differences in PTSD-linked hyperarousal symptoms (Grupe et al., 2016). The hyperarousal is, in turn, linked by the study authors to the tendency of those with severe PTSD symptoms to re-experience traumatic events in new contexts.

The study introduced stimuli that had to be interpreted a certain way in order to be perceived as a threat. The researchers noted that this is an element of threat uncertainty that contrasts with previous studies featuring threat certainty. The introduction by researchers of an uncertainty element was intended to increase the clinical relevance of the study. It also was used to help identify participants with PTSD who exhibited hypervigilance and hyperarousal, which is described by Grupe et al. (2016) as adaptive in combat environments but maladaptive in the context of normal civilian life entailing fewer threats.

Participants in the study with a higher measure of symptom severity experienced a higher level of tonic skin conductance from administered shocks than those with lower severity. In addition to deactivation of the vmPFC during threat anticipation, areas including the amygdala and hippocampus showed greater activation amongst the participants. Participants with higher symptom severity also exhibited increased anticipatory brain activation within regions associated with threat response (Grupe et al., 2016). Symptom severity was also associated with less deactivation of the vmPFC when the threat was unpredictable (uncertainty). The study authors speculate that the perigenual cingulate cortex may fail in its threat-assessment role amongst those with high symptom severity. This failure can result in a higher heart rate and other threat responses from the peripheral physiological response system.

Activation of these primitive brain structures and networks aligns with the proposed role of homeostatic balance in PTSD. Research has suggested that individuals with PTSD operate in a state of elevated arousal that impacts the three executive networks. Similarly to the PTSD group studied by Steuwe et al. (2014), the Patel et al. (2012) meta-review of fMRI studies involving individuals with PTSD found threat-response behavior to be triggered by the amygdala in response to higher than normal identification of perceived threats. Patel et al. (2012) associate this response with impairments in reality testing and problem solving. As in Steuwe et al. (2014), the abnormal response is also associated with problems in social cognition and theory of mind. This abnormal response stands in contrast to normal functioning in which the frontoparietal network and the presence of mirror neurons allow the individual to focus on internal processes and accurately determine the mental states of others.

PTSD may also modulate how the social brain comprising mirror neurons and the DMN activates in response to emotional stimuli. A separate, small study (Tan et al., 2019) examined how participants with PTSD reacted to a mix of emotional stimuli in comparison to a control group of military veterans exposed to trauma but without PTSD. Results suggest that the PTSD group experienced hyperactivation to emotional stimuli, with the severity of PTSD symptoms positively associated with this hyperactivation. Hyperactivation in the control and PTSD groups was not evident in response to non-emotional stimuli.

This hyperactivation in PTSD involves activation of the primitive executive system as well as inhibition of the frontoparietal network and DMN. In this state, the DMN exhibits reduced ability to perform the social-cognitive function of reality testing, in addition to reduced problem-solving ability. Mentalization abilities are also impaired, resulting in a less accurate understanding of the mental states and intentions of others.

Another emerging element of PTSD research is the role that dopamine and homeostatic balance play in the disorder. Researchers have emphasized the way disorders such as hypodopaminergia, a genetic condition, may also contribute to the incidence of PTSD in affected individuals. One meta-analysis and article review observes that dopamine regulation can play a pivotal role in determining the vulnerability of individuals to PTSD (Blum et al., 2019). The discovery of a possible link between dopaminergic genes and PTSD symptoms was recently proposed in a study involving Chinese female participants who had experienced significant trauma (Zhang et al., 2018). While this link has clear implications for those with this specific genetic mutation, it also suggests a significant link between PTSD and the brain's dopaminergic reward system. In a case study of two women with PTSD who experienced terrifying lucid dreams, a dopamine agonist was administered (McLaughlin et al., 2015). After administration of the dopamine agonist KB200Z, the two women reported improved dreams.

Overall, the overlap between mirror neuron functions and the relationship challenges often present in PTSD, as well as the overlap between specific structures inhabited by mirror neurons and those implicated in PTSD, suggests a connection may exist between mirror neurons and the neurobiology of relationship dysfunction in PTSD. Specifically, mirror neuron functions such as empathy and emotional resonance, crucial for interpersonal understanding, may go awry in PTSD. Additionally, the overlap between mirror neuron systems and other large-scale neural networks, such as the default mode network, suggests significant impairment of the social brain in PTSD. While recent literature points to initial confirmation of Hypothesis 1, further research into brain structures and neural networks inhabited by mirror neurons and also implicated in PTSD will be necessary for stronger confirmation.

Mirror Neurons and the Repair of Relationship Dysfunction in PTSD: Clinical Implications and Interventions

Given the evidence tentatively confirming Hypothesis 1, the possibility that mirror neuron processes could be used to treat relationship challenges in PTSD arises. Additionally, even if Hypothesis 1 ultimately fails under the scrutiny of further research and a direct link between mirror neurons and the neurobiology of PTSD does not exist, the possibility exists that the functions of mirror neurons could still be used for interventions aimed at repairing relationship dysfunction in PTSD. This section examines Hypothesis 2, that adequately functioning mirror neuron systems and related networks can help decrease relationship dysfunction in PTSD.

If mirror neuron systems play a direct role in the neurobiological underpinnings of relationship problems in PTSD, psychopharmacological or other means of targeting specific brain regions and neural networks could be developed. Additionally, literature examining the interrelation between neurobiological, genetic, and environmental factors (Jovanovic & Ressler, 2010; Skelton et al., 2012) could provide other avenues for direct intervention. Given the possible genetic component in the development of resilience or susceptibility to PTSD, advances in gene therapy could eventually target genetic precursors of PTSD vulnerability, including gene expression impacting mirror neuron systems. Ultimately, direct targeting of the neuroanatomical overlap between mirror neurons and PTSD may prove to be an area of future research.

At present, however, the functions of mirror neurons could be used through psychotherapy to address the interpersonal challenges present in PTSD. The literature reviewed in this study found mirroring to play a crucial role in adaptive social behavior. By allowing an observer to accurately understand the actions and intentions of others via the development of theory of mind, mirror neurons contribute to the ability to respond appropriately in an interpersonal situation (Iacoboni, 2009b; Gallese & Goldman, 1998). The interpersonal dysfunction and relationship challenges in people with PTSD often appear to result from the inaccurate reading of social situations, manifesting as heightened negative emotional responses in some individuals or social avoidance and emotional numbing in others (Frewen et al., 2012; Tursich et al., 2015). If mirroring could be used to facilitate an accurate understanding of other’s intentions, the negative interpersonal responses prevalent in PTSD might be ameliorated.

However, mirror neurons, especially in clients presenting with PTSD-derived relationship dysfunction, can play a role in the basics of psychotherapy. Given that psychotherapy is a relationship, the problems that mirror neuron dysfunction cause in other relationships can appear in the therapeutic relationship. As described in this review, PTSD’s characteristic hypervigilance develops in relationships through the primitive executive network (amygdala). As a result, in a therapeutic relationship, the client becomes potentially hypervigilant to the therapist. Because amygdala activation in PTSD corresponds to frontoparietal and default mode network hypoactivation, mirror neurons are impaired. In therapy, these impaired mirror neurons could cause a client significant difficulty in reading a therapist’s intentions, leading to the potential for significant misunderstandings.

Another example of mirror neuron dysfunction potentially affecting the therapeutic relationship similar to how it affects other relationships is impairment in emotional attunement. One possible signal of this in a therapeutic relationship could be if a therapist does not feel attuned to a client with PTSD. In this case, dysfunction in the client’s mirror neurons may be preventing the linkage between the client’s mind with the therapist’s mind that properly functioning mirror neurons can allow. This breakdown in emotional attunement can also make it more difficult for the client to sense the therapist's empathy for them due to the breakdown in their ability to accurately perceive another person's internal state. Mirror neuron dysfunction may also impede the development of transference, given that transference requires the mind-to-mind connection established by mirror neurons. Countertransference may also emerge as the result of the therapist feeling less connected to the client, resulting in a more technical treatment approach rather than one rooted in a relationship.

Given that, because of mirror neuron dysfunction, the therapeutic relationship is likely beginning with impaired emotional attunement, difficulty in accurately perceiving the therapist's intentions, and hypervigilance, working to establish a strong therapeutic relationship takes on even more importance than usual. Therefore, the foundational trans-theoretical skills that are key to psychotherapy outcomes in general become even more vital in PTSD cases. Building a secure therapeutic relationship might take longer, but when a client experiences a secure attachment to a therapist, amygdala hyperactivation decreases, allowing activation of the frontoparietal and default mode networks and, by extension, mirror neurons. Having a therapist bear witness to a client's experience in and of itself is something that can activate mirror neurons and the large scale networks that they are embedded in and connected to. Once activated through the therapeutic relationship, mirror neurons can then be taken back to help heal other relationships. From there, those newly activated mirror neurons can be taken back into their other relationships. While a therapist is using the foundational Rogerian stance to build a relationship that in and of itself has the potential to activate mirror neurons, it is possible to be simultaneously incorporating specific modalities that are also effective in activating mirror neurons in PTSD cases.

Specifically, empathy is a mirror neuron function that can be clinically targeted through psychotherapy. Clinical work focusing on empathic understanding appears to be a powerful mechanism for increasing the interpersonal abilities damaged in PTSD. Praszkier (2016) provides an overview of numerous studies of therapeutic interventions designed to build empathy. Noting a role for mirror neuron systems in the interpersonal and motor dysfunction characteristic of ASD, the review cites multiple clinical studies that successfully improved social intelligence in children with ASD, concluding that mirror neuron systems may have greater plasticity than previously assumed. Citing studies of unconscious behavior synchronization between therapist and client in the psychotherapeutic relationship, Praszkier (2016) also notes that the process of psychotherapy can increase empathic attunement through mirroring. Most notably, however, the review points to an earlier study (Farrow et al., 2005) of successful use of empathy and other forms of social cognition as curative factors in PTSD.

Farrow et al. (2005) studied 13 participants with PTSD who underwent cognitive behavioral therapy (CBT), focusing on mirroring-based social reasoning abilities of accurately understanding the intentions of others, empathy, and forgiveness. The participants underwent fMRI brain scans before and at the end of CBT treatment. Following the psychotherapeutic intervention, participant fMRIs showed increased activity in multiple brain regions involved in social cognition during tasks related to the targeted social reasoning abilities. These regions included the posterior cingulate gyrus/precuneus, which, as noted, is an area of significant interaction between the mirror neuron system and default mode network. Additionally, PTSD screening instruments found remission of PTSD symptoms to sub-diagnostic levels. As a result, clinical interventions targeting mirroring-based social cognition abilities appear to increase those abilities and decrease overall PTSD symptoms. These findings demonstrate that empathy-based interventions can play a useful role in helping address the aberrations in social cognition that occur in PTSD patients. By targeting forms of social cognition rooted in mirroring, CBT techniques could potentially be used to assist in improving relationship functioning in people with PTSD.

Since mirroring-based social cognition can be successfully improved through psychotherapy, the relationship challenges derived from it in PTSD can likely also be reduced as a result. Through a more accurate understanding of a partner's intentions and increased empathy, better communication within relationships and increased relationship satisfaction may result. However, further research will be needed to examine whether the increase in social cognitive abilities noted by these studies translates into the real-world context of actual intimate relationships.

The intersection of social support and PTSD symptoms may point to a role for mirror neurons in repairing the relationship dysfunction often characteristic of the disorder. Research reviewed in this study highlighted the bidirectional causality between social support and PTSD, noting that while PTSD symptoms can lead to problems within relationships, social support or its absence can influence the development or reduction of PTSD symptoms. For example, premorbid challenges within an intimate relationship or broader family that are perceived as weak or absent social support may exacerbate PTSD symptoms (Monson et al., 2009; Ray & Vanstone, 2009). Additionally, the vicarious trauma noted above may also be an indication of how the effects of mirroring can impact multiple individuals in a relationship or family system in addition to the individual diagnosed with PTSD. Given the role of intimate relationships, family, and other sources of social support in PTSD resiliency and vulnerability, addressing the social context of an individual with PTSD may help treat the symptoms of the disorder. The role of mirror neuron based social cognitive abilities, such as empathic attunement and accurate understanding of someone's motivation, in the loved ones of an individual with PTSD arguably could play a role in the health of the individual's support system. In such a case, clinical interventions such as the ones described above could also target the members of the individual's support system in order to strengthen that support system, thus potentially reducing symptoms of PTSD and preventing vicarious trauma.

As noted, multiple studies indicate the importance of social support, including relationship strength, in resilience or vulnerability to PTSD. In terms of clinical interventions, the focus could be on mirroring in social support, by which a therapist could teach the loved ones of an individual with PTSD to utilize mirroring to stimulate positive relationship transformation. By intervening in the family system, a therapist could also potentially help to prevent secondary traumatization and its effects, such as the behavioral problems found in the children of Bosnian War veterans (Ćorić et al., 2016). By understanding the role of mirroring in transferring trauma symptoms from one individual to others, a therapist might focus on the mirroring of prosocial behavior, rather than psychopathology, within a family system.

In psychotherapy, researchers are examining potential methods for using the functions of mirror neurons to help heal interpersonal challenges faced by clients with PTSD. For example, Stupiggia (2012) explores the ability of the therapeutic relationship to treat the effects of trauma. The author observes that the trauma response of abuse victims often includes hypersensitivity to another's gestures as well as other sensory and motor information, leading to misinterpretation of others' actions and resultant relationship disruption. Stupiggia (2012) argues for the use of mirroring work during therapy, specifically repetition of key gestures between therapist and client connected to verbal communication during therapy. The synthesis of motor and verbal mirroring would stimulate the audiovisual mirror neurons described by Kohler et al. (2002). By directly incorporating mirroring into psychotherapy, the author hopes to promote the recovery of mirror system functioning in clients suffering from the effects of trauma and improve relationship functioning as a result.

Investigations into the efficacy of dance movement therapy in treating PTSD note the potential role of mirror neuron systems in explaining the therapeutic benefits of dance (Berrol, 2006; Levine & Land, 2015). By performing kinesthetic movements that mimic those of a dance partner, mirror neuron systems are activated in an individual experiencing the effects of trauma. Empathic reflection, a key goal of dance therapy, develops through this process of mirroring choreographed movement. Through dance movement therapy, intersubjective and empathic experience emerge in clients suffering from PTSD symptoms, leading to a foundation for improved social intelligence and the potential for healing interpersonal relationships.

As noted earlier in this review, mirror neuron systems may be key to the development of theory of mind and mentalization. Recent clinical research has suggested that targeting defective mentalization abilities may be an effective method for improving social cognition and interpersonal behavior in people with PTSD. In a recent DARPA-funded study, UCLA researchers (Tan et al., 2019) examined the interpersonal impairments common in PTSD. They proposed a clinical intervention that attempts to alter how individuals interpret social-cognitive information. Specifically, the study sought to use neuroimaging to investigate possible neural network contributions to deficits in mentalization and the accurate assessment of the emotional state of others. An experimental group consisting of 20 trauma-exposed veterans diagnosed with PTSD and a control group consisting of 20 veterans exposed to trauma but without PTSD or any other psychiatric condition underwent fMRI scans while performing the Why/How test, a social inference task.

In the Why/How test, participants were exposed to images of emotionally laden facial expressions or intentional hand movements. Each expression or movement appeared twice, once with a why question designed to prompt mentalization and once with a how question meant to identify actions. Participants viewed the images via virtual reality goggles while in an fMRI machine, clicking their responses on a hand-held button.

Results significantly differentiated PTSD participants, who showed significant hyperactivation to stimuli, from controls who did not. In PTSD patients, results showed hyperactivation to the emotionally laden stimuli but non-significant effects for the non-emotional hand movements. These effects were broadly distributed in the default mode network and in mirror neuron systems and were particularly strong in the frontoparietal network and attentional networks, pointing to a strong role and overlap between these large-scale neural networks in responses to stimuli with significant emotional content.

As a clinical treatment part of the study, the PTSD group underwent affect labeling training, an emotional regulation technique that has previously been found to downregulate amygdala response via activation of the right ventrolateral prefrontal cortex (vlPFC). In affect labeling training, individuals learn how to label the emotional content they observe accurately. In this study, participants with PTSD experienced a significant reduction in their PTSD symptoms after undergoing affect labeling training. fMRI results after affect labeling training found less reactivity to emotionally laden stimuli in the mirror neuron rich posterior inferior frontal gyrus. Of note, individuals with most hyperactivation to emotional stimuli during the initial part of the study also experienced the best outcomes in the affect labeling training. This may indicate that affect labeling is an effective therapeutic technique, specifically targeting mirror neuron systems and the three executive networks, for treating emotional dysregulation in individuals with PTSD.

Another intervention targeting theory of mind deficits is developed and chronicled by Palgi et al. (2014). The researchers propose an intervention to address the pivotal role of the collapse of mentalization in the decline of social functioning regularly experienced by those with PTSD (Palgi et al., 2014). Their traumatic mentalization change intervention attempts to train clients with PTSD to recognize how their current, erroneous mentalizations of the feelings and intentions of others are embedded in memories of past traumatic events. The success of interventions focusing on mentalization and related therapies could be a promising approach to PTSD clinical intervention. Mentalization has been linked to autobiographical memories in recent studies, making this connection even more promising for therapeutic purposes (Buckner & Carroll, 2007).

Autobiographic memory plays a particularly important role in people with PTSD because it includes memories of traumatic episodes. Some individuals with PTSD show dysfunctional coping effects with respect to autobiographic memory. Such coping strategies can include erasure or distortion of memories pertaining to a traumatic episode, a phenomenon chronicled in one meta-analysis study of how traumatic memories are treated differently than other types of autobiographical memories in clinical populations (Brewin, 2007). Episodic autobiographical memory has been associated with Brodmann Area 10 and the hippocampus. Traumatically altered autobiographical memories are thought to have a negative impact on mentalization ability by damaging the coherence and continuity of perception of self.

The intervention in Palgi et al. (2014) is designed to strengthen the ability of individuals with PTSD to create a more positive self-image through a mechanism referred to as the projective self. After reporting a traumatic story, the subject is first asked to construct a more positive self-image, and then to insert this altered self-image into the current narrative, to be integrated into autobiographical memory. This intervention, centered on rehabilitating projections of the self, is hypothesized by Palgi et al. (2014) to cause greater activation of the medial prefrontal cortex, in addition to the hippocampus. These activations may reduce characteristic PTSD symptoms, particularly those relating to mentalization of the self and others. The researchers report that individuals who were exposed to the intervention exhibit an improved level of cognitive empathy. This higher cognitive empathy is thought to be the result of improved mentalization ability, catalyzed by the intervention. Subjects were able to make more accurate distinctions between their inner and outer realities, rather than erroneously projecting a trauma-distorted inner reality onto the outer world. In turn, this reduced the subject's avoidance behavior, a significant interpersonal symptom of PTSD caused by mentalization dysfunction (Palgi et al., 2014). Such interventions ultimately may function through the recovery of normal mentalization functioning and restored homeostatic balance.

These insights and interventions suggest important implications for PTSD in the clinical environment and further underline the connection between mentalization, autobiographical memory, and interpersonal and relationship problems affecting individuals with PTSD. The importance of mentalization in the context of PTSD is suggested in a study examining attitudes of expecting parents who experienced childhood trauma (Berthelot et al., 2019). The study results suggest that PTSD is associated both with hyper-mentalization and hypo-mentalization. Hyper-mentalization in people with PTSD has been associated with the tendency to interpret social cues that others experience as ambiguous, as threatening. As a result, future interventions may include therapies intended to lower vigilance for threatening social cues and slowly acclimate patients to the assimilation of ambiguous cues. This process is vital because hyper-mentalization by individuals with PTSD can be linked with the re-experiencing of traumatic events (Berthelot et al., 2019). Trauma may be re-experienced when ambiguous interactions trigger affective dysregulation. In the context of parenthood, this can place a child in danger. However, with well-designed interventions, mentalization can once again play its necessary protective role by allowing the individual to interpret ambiguous social signals accurately.

Other studies highlight the role of dopamine in achieving functional homeostasis in patients with PTSD (McLaughlin et al., 2015). Some researchers have labeled PTSD as a reward deficiency disorder (Blum et al., 2019) characterized by dopamine deficiency. Clinical implications of such findings include the possibility that dopamine homeostasis could emerge as a potent area of focus for future therapies targeted at individuals suffering from severe symptoms of PTSD, including interpersonal problems. Blum et al. (2019) note the efficacy of exercise, mindfulness, biosensor tracking, nutritional supplementation, and meditation for improving dopamine deficiency. The role that dopamine deficiency plays in PTSD symptoms, such as the hyperactivation of various regions within the primitive executive system, is an important direction for further clinical research.

Overall, as with Hypothesis 1, current research appears to provide initial support for Hypothesis 2. The efficacy of clinical treatment targeting mirroring-based functions such as empathy and mentalization in PTSD shows promise, but further clinical trials will be necessary for a stronger confirmation of Hypothesis 2.

Discussion: Limitations and Future Directions

As a review of existing literature and a synthesis of prior research findings, this study has the inherent limitation of being theoretical in nature. Therefore, it draws inferences about the role played by mirror neurons in the relationship dysfunction often found in PTSD and how they might be utilized in psychotherapy. While these are strong inferences, they are likely not as strong as recruiting participants for a new study would have been.

There are several possible future research directions that could help solidify the inferences discussed in this study. Some of the approaches discussed in the section on clinical interventions are well-established treatments for PTSD. As noted, some of them already have promising imaging studies demonstrating their impact on mirror neurons and related networks. However, further pre- and post-treatment imaging of the networks and structures discussed in this study could help solidify the case for the role of mirror neurons in relationship dysfunction in PTSD.

One specific possible imaging study could be one designed to determine whether mirror neurons activate as interpersonal interactions occur within a relationship. For example, this study could be conducted during a psychotherapy session to analyze the neuroscientific processes occurring within the therapeutic relationship. Because conducting a therapy session while the therapist and client are inside fMRI machines would be difficult, this experiment could involve using EEG instead. Researchers could apply electrodes to the client and therapist, and monitor EEG readings during the session. If, over the course of the session, therapist and client feel a sense of attunement, researchers could use EEG readings to determine if there has been frontoparietal activation during that sense of attunement. If so, that would be evidence of mirror neuron activity occurring in the context of a relationship.

Another future direction that may involve mirror neurons is MDMA-assisted psychotherapy for PTSD, which has been labeled a breakthrough treatment by the FDA and is now in Phase 3 clinical trials. Imaging results from the Phase 2 trial showed downregulation in the amygdala as a result of MDMA-assisted therapy. As previously noted in this study, amygdala downregulation allows for activation of the frontoparietal and default mode networks, and thus mirror neurons. MDMA is well-known for generating a heightened feeling of empathy and the Phase 2 clinical trials showed that MDMA-assisted psychotherapy can increase empathy and compassion, important components of well-functioning relationships that derive from mirror neurons, as well as enhance communication and introspection. Perhaps as MDMA-assisted psychotherapy moves towards being a legal, accepted treatment for PTSD, further imaging studies could determine whether this treatment is activating mirror neurons and the networks they inhabit.

Conclusion

This study sought to explore possible connections between mirror neurons and relationship dysfunction in PTSD by examining existing literature on mirror neurons, the neurobiology of PTSD, and relationship challenges in PTSD. The review examined the history of mirror neuron studies in monkeys and provided evidence for their existence in humans. Further, this study demonstrated their foundational role in human social cognition and relationships. The review tracks the discovery of mirror neurons in monkeys, before demonstrating their existence in humans and their role in social interactions and relationships. PTSD was shown to relate to alterations in the activity of specific brain structures and large-scale neural networks as well as their interaction with genetic and environmental factors. Considerable research indicates that significant relationship challenges are common in people with PTSD.

Parallels between the literature on mirror neurons and PTSD demonstrate a plausible connection between the two topics given the possibility that mirror neuron systems are the neurobiological root of intersubjectivity, empathy, and other higher forms of social cognition. If these abilities are disrupted, the formation and maintenance of healthy relationships can become difficult. Additionally, the overlap between some of the brain structures inhabited by mirror neurons and those implicated in the neurobiology of PTSD provides further evidence for a connection. The interactions between mirror neurons and other large-scale neural networks, especially the three executive networks, also provide support for this connection.

This connection has implications for the use of mirror neuron functions to improve relationship functioning in people with PTSD. The incorporation of mirroring into psychotherapy has the potential to promote the development of empathic resonance, thus assisting in restoring the capacity for healthy relationships. Given the role of social support and vicarious trauma in

PTSD, clinical interventions could also focus on mirroring within the broader family system and social context of the individual with PTSD. Mentalization-based treatments, affect labeling, and targeting dopamine deficiency all show promise in addressing the role of mirror neuron systems and other large-scale networks in PTSD.

However, considering the theoretical nature of this study, additional empirical research is recommended to solidify the connection between mirror neurons and relationship dysfunction in PTSD further as well as to advance evidence-based clinical treatment.

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APPENDIX A

Literature Tables

Literature Table: Mirror Neurons

Author	Title	Source	Date	Findings	Comment
Iacoboni, M	Imitation, empathy, and mirror neurons	*Annual Review of Psychology*	2009	Neurons in the F5 area of the macaque monkey brain do not only discharge when the monkey performs actions but also when the monkey observes another monkey performing the same actions.	The author is one of the pioneers in the study of mirror neurons. The study's strength involves its convergent analysis of literature on cognitive models, social psychology, and empirical findings from neurosciences, enabling a comprehensive background review of mirror neurons.
Gallese, V.	The 'shared manifold' hypothesis: From mirror neurons to empathy	*Journal of Consciousness Studies*	2001	Some neurons are not only activated during action execution but also when observing similar actions.	The author is one of the original discoverers of mirror neurons, with the study's strength being its insights into his seminal work on the topic.
Heyes, C.	A new approach to mirror neurons: Developmental history, system-level theory and intervention experiments	*Cortex*	2013	The balance of evidence favors the associative account over the genetic account in the origin of mirror neurons.	Heyes offers a recent and up-to-date look into mirror neurons through the convergence of developmental history, intervention experiments, and system-level theory. However, the study is conceptual rather than empirical.
Heyes, C.	Where do mirror neurons come from?	*Neuroscience & Biobehavioral Reviews*	2010	The associative account (mirror neuron system is both a product and a process of social interaction) is a stronger origin account than the genetic account.	This study is also relatively recent, summarizing theoretical models on the origins of mirror neurons.

Gallese, V., & Goldman, A.	Mirror neurons and the simulation theory of mind-reading	*Trends in Cognitive Sciences*	1998	Social cognition role: Mirror neurons enable mental state representation, contributing to inclusive fitness.	The study offers a conceptual discussion based on proposed theories and experimental evidence, shedding light on the function of mirror neurons.
Kohler, E., Keysers, C., Umilta, M. A., Fogassi, L., Gallese, V., & Rizzolatti, G.	Hearing sounds, understanding actions: Action representation in mirror neurons	*Science*	2002	Audiovisual mirror neurons play a role in coding abstract contents, which is important in explaining the origin of language.	This empirical study provides strong evidence for a mirror neuron role in hearing and understanding actions, expanding the discussion on the functions of mirror neurons.
Ferrari, P. F., Gallese, V., Rizzolatti, G., & Fogassi, L.	Mirror neurons responding to the observation of ingestive and communicative mouth actions in the monkey ventral premotor cortex	*European Journal of Neuroscience*	2003	Mirror neurons play a role in the origins of vocal communication.	Using an empirical design, the study furthers the understanding of the role of mirror neurons through demonstrating their importance in communicative functions.
Jacob, P.	What do mirror neurons contribute to human social cognition?	*Mind & Language*	2008	In social cognition role, motor resonance generates a representation of actor’s motor intention, rather than his or her prior intention.	This study offers a critical view of the role of mirror neurons, using a conceptual approach that focuses on mirror neurons’ role in humans, whereas the previous studies are based on observations from monkeys.
Uithol, S., van Rooij, I., Bekkering, H., & Haselager, P.	What do mirror neurons mirror?	*Philosophical Psychology*	2011	Processes beyond mirroring are important for cognitive functions at higher abstraction levels.	This study provides a more recent observation on the role of mirror neurons. By combining findings from single neurons

					studies in monkeys, neuroimaging in humans, and behavioral studies in humans, it offers an important expansion of the study of mirror neurons to include their links to other neural networks.
Kilner, J. M., Neal, A., Weiskopf, N., Friston, K. J., & Frith, C. D.	Evidence of mirror neurons in human inferior frontal gyrus	*Journal of Neuroscience*	2010	Presence in humans: fMRI shows human brain activity significantly consistent with the model predicted by mirror neuron activity.	The study employs an experimental approach to demonstrate mirror neurons in humans using fMRI. However, the small sample size (10 subjects) may limit the generalizability of the findings.
Hamzei, F., Vry, M. S., Saur, D., Glauche, V., Hoeren, M., Mader, I., ... & Rijntjes, M.	The dual-loop model and the human mirror neuron system: An exploratory combined fMRI and DTI study of the inferior frontal gyrus	*Cerebral Cortex*	2016	Mirror neurons are present in humans, acting in conjunction with other systems that regulate action observation.	This study uses a large sample size to demonstrate the presence of mirror neurons in the human inferior frontal gyrus. The use of a large sample size makes the findings representative and crucial in offering evidence for mirror neurons in humans.
Kilner, J. M., & Lemon, R. N.	What we know currently about mirror neurons	*Current Biology*	2013	Mirror neurons are found in temporal lobe structures and the medial frontal cortex, revealing an extensive mirror neuron system in humans.	The study offers a review of evidence on mirror neurons to provide an up-to-date account of what is known or remains unknown about mirror neurons and their

					functions in humans.
Mukamel, R., Ekstrom, A. D., Kaplan, J., Iacoboni, M., & Fried, I.	Single-neuron responses in humans during execution and observation of actions	*Current Biology*	2010	Mirror neurons and anti-mirror neurons exist in humans, with the latter explaining why humans do not always imitate others' actions.	This study offers single cell recording evidence on the existence and function of mirror neurons in humans, demonstrating neuron activity in human brain regions during both execution and observation. This study also expands the neural geography of mirror neurons beyond locations initially observed in monkeys.
Binder, E., Dovern, A., Hesse, M. D., Ebke, M., Karbe, H., Saliger, J., ... & Weiss, P. H.	Lesion evidence for a human mirror neuron system	*Cortex*	2017	Mirror neurons exist in humans, playing a role in imitating, recognizing, and comprehending meaningful actions.	The study employs lesion-symptom mapping, using an empirical design that produces clinical data supportive of mirror neuron hypothesis in humans. The study's strength lies in its empirical design and being up-to-date, despite the relatively small sample size (63).

Literature Table: Neurobiology of PTSD

Author	**Title**	**Source**	**Date**	**Findings**	**Comment**
Krystal, J. H., & Neumeister, A.	Noradrenergic and serotonergic mechanisms in the neurobiology of posttraumatic stress disorder and resilience	*Brain Research*	2009	The amygdala, ventral/medial prefrontal cortex (vmPFC), hippocampus, and anterior cingulate cortex are the primary brain regions involved in PTSD.	The study involves a review of the noradrenergic and serotonergic mechanisms that underlie

					PTSD, using sources published over the past two and half decades to provide an overview of what is known about the disorder's neurobiological underpinnings. The wide range of sources makes the study a strong overview of the topic.
Garfinkel, S. N., & Liberzon, I.	Neurobiology of PTSD: A review of neuroimaging findings	*Psychiatric Annals*	2009	Structural abnormalities in amygdala, nucleus accumbens (ACC), hippocampus, and medial prefrontal cortex (mPFC) are associated with PTSD.	The strength of this study lies in its examination of a large number of neuroimaging findings pointing to the presence of abnormalities in specific brain structures in people with PTSD.
Patel, R., Spreng, R. N., Shin, L. M., & Girard, T. A.	Neurocircuitry models of posttraumatic stress disorder and beyond: A meta-analysis of functional neuroimaging studies	*Neuroscience & Biobehavioral Reviews*	2012	Hyperactive amygdala, hypoactive medial prefrontal regions, and hyperactive hippocampi, alongside functional alterations in salience network, default network, and central executive network, are implicated in PTSD.	This paper's strength lies in its use of a meta-analysis of fMRI data from multiple studies. Through this technique, it is able to pinpoint the most important structures and networks in PTSD.
Sripada, R. K., King, A. P., Welsh, R. C., Garfink	Neural dysregulation in posttraumatic stress disorder: Evidence for disrupted equilibrium	*Psychosomatic Medicine*	2012	The occurrence of disequilibrium between the large-scale neural networks pertaining to salience detection versus the individual's internally focused thought may	Although it has a relatively low sample size (45), this study's empirical design is a

el, S. N., Wang, X., Sripada, C. S., & Liberzon, I.	between salience and default mode brain networks			link to the pathophysiology of PTSD.	strength that complements the theoretical and meta-analytical findings of other studies cited in this chapter.
Medina, J.	Neurobiology of PTSD	*Psychiatric Times*	2008	The duration of the stress and somatic substrates (which may be genetic) helps determines PTSD resilience or susceptibility.	The study offers a conceptual discussion of the state of knowledge concerning PTSD neurobiology. However, it is older than other studies cited in this chapter, leading to the possibility that new research may supersede its conclusions in the years ahead.
Goodman, J., Leong, K. C., & Packard, M. G.	Emotional modulation of multiple memory systems: Implications for the neurobiology of post-traumatic stress disorder	*Reviews in the Neurosciences*	2012	Traumatic memories among PTSD patients can be deficient in hippocampus-dependent autobiographical or contextual aspects while being enhanced in subcortical memory systems in a response to trauma-related cues.	The study primarily employs rat models, which despite providing crucial observations about the neurobiology of PTSD still raise questions in terms of extending the observations to humans.
Liberzon, I., & Abelson, J. L.	Context processing and the neurobiology of post-traumatic stress disorder	*Neuron*	2016	Deficient context processing rooted in neural networks constitutes a parsimonious explanatory model behind the PTSD symptoms.	The paper's examination of contextual processing points to deficits in environmental/social understanding that may influence

					interpersonal problems in PTSD, making it particularly relevant to the present study.
Lanius, R. A., Vermetten, E., Loewenstein, R. J., Brand, B., Schmahl, C., Bremner, J. D., & Spiegel, D.	Emotion modulation in PTSD: Clinical and neurobiological evidence for a dissociative subtype	*American Journal of Psychiatry*	2010	Emotional overmodulation and undermodulation are associated with dysfunction of prefrontal inhibition of the limbic regions of the brain.	Given the notable distinctions between the dissociative subtype of PTSD and the more common presentation of PTSD, this study provides an important analysis of the neurobiological differences between the two.
Daniels, J. K., McFarlane, A. C., Bluhm, R. L., Moores, K. A., Clark, C. R., Shaw, M. E., ... & Lanius, R. A.	Switching between executive and default mode networks in posttraumatic stress disorder: Alterations in functional connectivity	*Journal of Psychiatry & Neuroscience*	2010	PTSD entails difficulty in switching from default mode network to salience and/or central executive networks.	The use of 12 treatment subjects and 12 controls could be a small sample size. However, the findings represent a convincing explanation for some of the features of PTSD.
Frewen, P. A., Dozois, D. J., Neufeld, R. W., Lane, R. D., Densmore, M., Stevens, T. K., & Lanius, R. A.	Emotional numbing in posttraumatic stress disorder: A functional magnetic resonance imaging study	*The Journal of Clinical Psychiatry*	2012	Emotional numbing and emotional awareness in PTSD entails less medial prefrontal cortex response when exposed to emotional imagery, indicating deficient conscious and reflective processing of emotions.	The empirical nature of the study and use of non-PTSD controls maximize the strength of the findings. However, the relatively small sample size (30) may minimize representativeness and generalizability.

Tursich, M., Ros, T., Frewen, P. A., Kluetsch, R. C., Calhoun, V. D., & Lanius, R. A.	Distinct intrinsic network connectivity patterns of post-traumatic stress disorder symptom clusters	*Acta Psychiatrica Scandinavica*	2015	Hyperarousal symptoms are associated with alterations in neurobiology in reduced connectivity of posterior insula/superior temporal gyrus within salience network. The severity of depersonalization/derealization is associated with a decline in connectivity of anterior cingulate/ventromedial prefrontal cortex in the default mode network.	The study's multivariate analysis approach strengthens the value of the findings. However, the small sample size (21) and lack of controls in the study could be weaknesses.
Steuwe, C., Daniels, J. K., Frewen, P. A., Densmore, M., Pannasch, S., Beblo, T., ... & Lanius, R. A.	Effect of direct eye contact in PTSD related to interpersonal trauma: An fMRI study of activation of an innate alarm system	*Social Cognitive and Affective Neuroscience*	2012	An innate alarm system that involves subcortical structures (the superior colliculus alongside the periaqueductal gray) can be triggered by direct eye contact in people with PTSD.	The study provides an interesting examination of a possible neurobiological explanation for interpersonal challenges faced by people with PTSD. However, the sample size of 32 could be too small to generalize the findings.
Jovanovic, T., & Ressler, K. J.	How the neurocircuitry and genetics of fear inhibition may inform our understanding of PTSD	*American Journal of Psychiatry*	2010	Vulnerability or resilience to PTSD is a function of neurobiological, genetic, and environmental interactions.	Although the study is conceptual rather than empirical, it introduces important insights into how other factors interplay with neurobiology to determine vulnerability or resilience to PTSD.
Skelton, K., Ressler, K. J., Norrholm, S. D., Jovanovic, T.,	PTSD and gene variants: New pathways and new thinking	*Neuropharmacology*	2012	Genetic and environmental factors act alongside neurobiology in explaining vulnerability or resilience to PTSD.	The study provides a strong overview of literature pertaining to the interplay of genetic and environmental

& Bradley - Davino, B.					factors in PTSD.
Lanius, R. A., Bluhm, R. L., & Frewen, P. A.	How understanding the neurobiology of complex post-traumatic stress disorder can inform clinical practice: A social cognitive and affective neuroscience approach	*Acta Psychiatrica Scandinavica*	2011	PTSD entails impairments in multiple social cognitive and affective functions. In turn, assessment and treatment should also involve SCAN (social cognitive and affective neuroscience)-based assessments and interventions responding to the variety of areas and functions affected.	The literature review approach helps demonstrate ways in which the current understanding of PTSD neurobiology can inform clinical practice.
Scioli-Salter, E. R., Forman, D. E., Otis, J. D., Gregor, K., Valovski, I., & Rasmusson, A. M.	The shared neuroanatomy and neurobiology of comorbid chronic pain and PTSD: Therapeutic implications	*The Clinical Journal of Pain*	2015	PTSD and chronic pain share similar neural circuits and individuals who suffer both conditions have elevated symptoms compared to individuals with only one of the disorders.	The study employs a conceptual rather than empirical design, which is appropriate for early deliberations on the practical implications of PTSD comorbidity with another disorder. Ultimately, however, other empirical studies will be needed to provide clinical implications for people suffering from both PTSD and chronic pain.

Literature Table: Relationship Problems in People with PTSD

Author	Title	Source	Date	Findings	Comment
Tsai, J., Harpaz-Rotem, I., Pietrzak, R. H., &	The role of coping, resilience, and social support in mediating the relation between	*Psychiatry: Interpersonal & Biological Processes*	2012	PTSD is associated with relationship difficulties with romantic partners, less family cohesion, lower social support, and	The large sample size of 164 veterans makes the

Southwick, S. M.	PTSD and social functioning in veterans returning from Iraq and Afghanistan			poorer social functioning, as well as lower life satisfaction.	study especially representative of war veterans, although the reliability of the findings could have been improved by introducing a control group.
Erbes, C. R., Meis, L. A., Polusny, M. A., & Compton, J. S.	Couple adjustment and posttraumatic stress disorder symptoms in National Guard veterans of the Iraq war	*Journal of Family Psychology*	2011	Trauma specific avoidance and dysphoria are associated with relationship dysfunction in PTSD.	The 313 participants constitute a sufficient sample size, which strengthens this study. However, the absence of a control group is a potential concern.
Nietlisbach, G., Maercker, A., Rösler, W., & Haker, H.	Are empathic abilities impaired in posttraumatic stress disorder?	*Psychological Reports*	2010	Lower empathic resonance exists in PTSD.	The use of controls is helpful in hypothesis testing in this study, although the small sample size of 16 for the treatment group and 16 for the control group may constitute a weakness.
Solomon, Z., Dekel, R., & Zerach, G.	The relationships between posttraumatic stress symptom clusters and marital intimacy among war veterans	*Journal of Family Psychology*	2008	Ex-prisoners of war have higher levels of PTSD symptoms alongside high levels of verbal violence and lower levels of self-disclosure.	The key sources of strength in this study pertain to its empirical design and use of a large sample size (125 primary subjects and 94 controls).

Allen, E. S., Rhoades, G. K., Stanley, S. M., & Markman, H. J.	Hitting home: Relationships between recent deployment, posttraumatic stress symptoms, and marital functioning for Army couples	*Journal of Family Psychology*	2010	PTSD symptoms are associated with reduced marital satisfaction, confidence in the relationship, positive bonding between spouses, parenting alliance, dedication to the relationship, and satisfaction with relationship sacrifice, alongside heightened negative communication.	The empirical nature and large sample size (464) in this study constitute key strengths, making the findings possibly generalizable to the wider population of active duty Army husbands and their wives.
Wolf, E. J., Miller, M. W., & McKinney, A. E.	Emotional processing in PTSD: Heightened negative emotionality to unpleasant photographic stimuli	*The Journal of Nervous and Mental Disease*	2009	PTSD is associated with greater negative emotionality, as embodied by heightened arousal and lower valence ratings.	The large sample size (124) constitutes a strength of this study that increases its potential value in understanding the emotional outcomes of PTSD.
Beck, J. G., Grant, D. M., Clapp, J. D., & Palyo, S. A.	Understanding the interpersonal impact of trauma: Contributions of PTSD and depression	*Journal of Anxiety Disorders*	2009	PTSD symptoms surrounding emotional numbing and the accompanying weaker associations may contribute to interpersonal strain that hampers the development and maintenance of desirable social relationships.	Besides the sizable sample (109 community) and use of a quantitative survey that allows for generalization, the value of this study also derives from its examination of the comorbidity of other mental health issues with PTSD.
Alderfer, M. A., Navsaria, N., & Kazak, A. E.	Family functioning and posttraumatic stress disorder in adolescent	*Journal of Family Psychology*	2009	Family functioning has a relationship with cancer-related PTSD reactions in adolescent survivors.	This empirical study is valuable due to its examination

	survivors of childhood cancer				of the impact of family context on PTSD.
Monson, C. M., Macdonald, A., Vorstenbosch, V., Shnaider, P., Goldstein, E. S., Ferrier-Auerbach, A. G., & Mocciola, K. E.	Changes in social adjustment with cognitive processing therapy: Effects of treatment and association with PTSD symptom change	*Journal of Traumatic Stress*	2012	Social adjustment, social and leisure, family, and work life improved after participation in cognitive processing therapy (CPT).	This study's examination of a model of psychotherapy in treating PTSD is notable, although the lack of controls and relatively small sample size (42) could be a concern in terms of the generalizability of its results.
Gewirtz, A. H., Polusny, M. A., DeGarmo, D. S., Khaylis, A., & Erbes, C. R.	Posttraumatic stress symptoms among National Guard soldiers deployed to Iraq: Associations with parenting behaviors and couple adjustment	*Journal of Consulting and Clinical Psychology*	2010	Heightened PTSD symptoms are associated with poorer couple adjustment and greater perceived parenting challenges.	The study's large sample size (468) makes its findings generalizable to the broader population of combat veterans, especially those from the National Guard. The multiple measurements used help untangle the various factors involved in PTSD and relationship dysfunction.
Taft, C. T., Watkins, L. E., Stafford, J., Street, A. E., & Monson, C. M.	Posttraumatic stress disorder and intimate relationship problems: A meta-analysis	*Journal of Consulting and Clinical Psychology*	2011	A greater association between PTSD and relationship discord exists in in military samples than in civilian ones.	The meta-analytic design used in the study represents an excellent way of synthesizing information

					from previous research, thus potentially improving clinical practice and providing direction for future research.
Monson, C. M., Taft, C. T., & Fredman, S. J.	Military-related PTSD and intimate relationships: From description to theory-driven research and intervention development	*Clinical Psychology Review*	2009	Secondary/vicarious traumatization: PTSD symptoms in a traumatized individual may result in similar symptoms in family members and intimate partners.	The extensive literature review used as the study's method allows it to find common themes in previous findings about relationship problems in people with PTSD.
Ray, S. L., & Vanstone, M.	The impact of PTSD on veterans' family relationships: An interpretative phenomenological inquiry	*International Journal of Nursing Studies*	2009	Emotional numbing and anger have a negative impact on familial relationships. Emotional withdrawal has negative effects on family support, which then exacerbates the struggle with healing from trauma.	The study entails an interpretive approach with 10 participants, with the phenomenological method allowing for collection and analysis of data in a way that uncovers the subjective meanings of the individual experience of PTSD.
Dekel, R., & Monson, C. M.	Military-related post-traumatic stress disorder and family relations: Current knowledge and future directions	*Aggression and Violent Behavior*	2010	The impact of traumatic events is not restricted only to the person exposed to the event. Consequences may often affect significant others in the context of those with PTSD, including family, friends, and caregivers.	The review provides a valuable expansion of current understanding of the role of PTSD in relationships by introducing the possibility

					of vicarious trauma in the loved ones of people with PTSD.
Charuvastra, A., & Cloitre, M.	Social bonds and posttraumatic stress disorder	*Annual Review of Psychology*	2008	Social ecology of PTSD: risk and recovery outcomes in PTSD are highly dependent on social phenomena.	This conceptual study provides crucial insights into the relationship between PTSD symptoms and social context.

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APPENDIX B

Pepperdine University IRB Non-Human Subjects Determination Notice

PEPPERDINE UNIVERSITY IRB NON-HUMAN SUBJECTS NOTIFICATION FORM FOR RESEARCH THAT DOES NOT INVOLVE HUMAN SUBJECTS

Investigator Name: Andrew Walker
Status: Faculty:____________________ Student: Psy.D. Dissertation
Faculty Chair (*if applicable*): Lou Cozolino, Ph.D.
Proposal Research Title: The Role of Mirror Neurons in Relationship Dysfunction in Posttraumatic Stress Disorder

Per Pepperdine University Institutional Review Board (IRB) guidelines all proposed research that does not involve direct contact with human subjects requires a notification form be submitted for review.

Research that requires IRB review must meet the definition of human subject's research. The code of federal regulations provides the following definitions:

- **For the purposes of the IRB, research is defined as a systematic investigation designed to develop or contribute to generalizable knowledge.**

- **Human subject meansa living individual about whom an investigator (whether professional or student) conducting research obtains**

  (1) Data through intervention or interaction with the individual, or
  (2) Identifiable private information.

If your research does *not* involve the participation of human subjects **and** you are *not* using/collecting any data that has identifiable private information, your research is not subject to IRB review and approval but *does* require the submission and filing of a non-human subjects notification form to the IRB office.

When submitting this notification form please include the following as separate documents:

- Signatures by ALL Principal Investigator(s) (student and/or faculty) and Faculty Chair (*ifapplicable*).

- Abstract (no more than 1-page) outlining the study's research design and methodology.

I verify that this proposed research does not involve the use of human subjects, either directly or indirectly.

____________________ 9/14/20
Principal Investigator(s)/Student Signature Date

Andrew Walker
Print Name (s)

Lou Cozolino
Faculty Chairperson Signature *(if applicable)* 9/14/20
Date

Lou Cozolino, Ph.D.
Print Name