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# How does Eye Movement Desensitization and Reprocessing (EMDR) work? An examination of the potential mechanisms of action

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# HOW DOES EYE MOVEMENT DESENSITIZATION AND REPROCESSING (EMDR) WORK? AN EXAMINATION OF THE POTENTIAL MECHANISMS OF ACTION

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by

Sara Forster

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Louis Cozolino, Ph.D. – Dissertation Chairperson

This clinical dissertation, written by

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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

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**Education**

**Pepperdine University,** Los Angeles, California 2017 - present
Doctor of Psychology in Clinical Psychology (Psy.D.)

**Pepperdine University,** Irvine, California 2015 - 2017
Master of Arts in Clinical Psychology with Emphasis in Marriage and Family Therapy

**Boston University,** Boston, Massachusetts 2011 - 2014
Bachelor of Arts in Psychology

**Clinical Experience**

**VA Long Beach Healthcare System, Department of Psychology**
Long Beach, CA
**Neuropsychology Clerk, PsyD Trainee,** August 2019 - present

- Conducting clinical interviews and administering, scoring, and interpreting a wide range of neuropsychological, cognitive, and personality assessments for veterans in an integrative medical center setting, including mild and major neurocognitive disorder (i.e., MCI, Alzheimer's, vascular dementia), TBI, Parkinson's disease, epilepsy, HIV+, multiple sclerosis, cerebrovascular accident/stroke, pseudodementia, and emotional presentations
- Writing weekly reports for all patients; observing and providing feedback sessions to patients with supervisor
- Completing chart reviews including a patient's relevant medical and psychosocial history and findings from neuroimaging studies (i.e., MRI, CT, EEG); collaborating and discussing cases with supervisor (i.e., battery to be administered; relevant medical and psychological concerns; potential obstacles, findings, and diagnoses)
- Attending presentations and presenting on patient cases, articles, and topics related to the field of neuropsychology during weekly neuropsychology seminars and case conferences, including a weekly seminar on functional neuroanatomy

**Southern California Neuropsychology Group - Private Practice**
Woodland Hills, CA
**Neuropsychology Extern, PsyD Trainee,** August 2019 – June 2020

- Conducting clinical interviews and administering, scoring, interpreting, and writing reports on a wide range of neuropsychological, cognitive, and personality assessments for a broad range of adult and child populations (i.e., neurocognitive disorders, TBI, mood disorders, learning disorders, ASD, ADHD, etc.)
- Conducting forensic evaluations for Workers' Compensation and Qualified Medical Examiner (QME) cases, interpreting results with supervisor, and integrating findings into comprehensive forensic reports
- Completing records reviews that include relevant medical and psychosocial background information; collaborating and discussing cases with supervisor on a weekly basis
- Presenting on patient cases, articles, and topics related to neuropsychology, and attending presentations by neuropsychologists, interns, and other externs in weekly neuropsychology seminars and case conferences

**Pepperdine Community Counseling Center**
Irvine, CA; Los Angeles, CA
**Therapist, PsyD Trainee**, September 2017 – May 2020

- Developing clinical techniques and interviewing skills with a broad range of client populations (primarily depression, bipolar disorder, anxiety, substance use, and trauma-related symptomatology), via individual, couple, and family therapy sessions
- Discussing client progress and collaborating with supervisors and fellow therapists in order to explore therapeutic interventions, learn from experienced clinicians, facilitate case conceptualization, and ensure proper self-care (via weekly individual and/or group supervision)

- Maintaining client progress notes, attending relevant workshops and trainings, advocating for clients, providing resources and referrals, and communicating with other clinicians and contacts in order to best serve each client's therapeutic needs
- Placing calls to Child Protective Services (CPS) and Adult Protective Services (APS) when necessary, and following up with written reports, in order to promote safety of clients and involved parties

**Kaiser Los Angeles Medical Center, Department of Psychiatry**
Los Angeles, CA
**Neuropsychology Extern, PsyD Trainee,** August 2018 - July 2019

- Conducting clinical interviews and administering, scoring, and interpreting a wide range of neuropsychological, cognitive, and personality assessments for a broad range of populations in an integrative medical center setting, including mild and major neurocognitive disorder (primarily Alzheimer's, MCI, vascular dementia), TBI, Parkinson's disease, epilepsy, HIV+, multiple sclerosis, cerebrovascular accident/stroke, pseudodementia, and emotional presentations
- Writing integrated reports for all independent cases; routing test results and reports to referring providers, such as neurologists and other physicians; providing feedback sessions to patients
- Writing case reports/chart reviews including a patient's relevant medical and psychosocial background, and findings from neuroimaging studies (i.e., MRI, CT, EEG); collaboratively discussing cases with supervisor (i.e., proposed battery; relevant medical and psychological concerns; potential obstacles, findings, and diagnoses)
- Presenting on patient cases, articles, and topics related to the field of neuropsychology during weekly neuropsychology seminars; attending presentations by neuropsychologists, interns, and other externs
- Attending monthly case conferences in Neurology department for both Epilepsy Surgery and Movement Disorder meetings, during which patients who are surgery candidates for epilepsy (i.e., Wada testing, temporal excisions, etc.), tremors, and Parkinson's disease (i.e., DBS surgery) are discussed among neurologists, neurosurgeons, neuropsychologists, and MRI technicians; presenting relevant neuropsychological test results for surgery candidates
- Observing weekly Wada testing performed by supervising neuropsychologist, and discussing patient results

**Rich and Associates - Private Practice**
Los Angeles, CA
**Therapist, PsyD Trainee,** June 2018 - July 2019

- Developing clinical techniques in group and individual therapy settings with children and adolescents experiencing a broad range of presenting concerns (i.e., ADHD, ODD, ASD, emotional dysregulation in the form of DMDD, Intermittent Explosive Disorder, MDD, GAD, SAD, etc.)
- Co-facilitating various weekly therapy groups with postdoctoral and licensed psychologists
- Co-facilitating and serving as a lead counselor for an intensive outpatient three-week summer camp designed to improve each client's social skills and ability to process emotions, thoughts, and behaviors in a group setting
- Discussing client progress and consulting supervisors and co-therapists to explore therapeutic interventions, learn from experienced clinicians, and facilitate case conceptualization (via weekly in vivo supervision)
- Maintaining client progress notes and consulting other clinicians to best serve each client's therapeutic needs

**Boys Hope Girls Hope of Southern California**
Irvine, CA
**Assessment Examiner, PsyD Trainee,** March 2018 - August 2018

- Interviewing an 8th grade student applying to BHGH program and administering, scoring, and interpreting assessments (including WISC-V, WRAT5, VMI-6, MACI, Roberts-2, and Child Sentence Completion)
- Completing an integrated assessment report for the BHGH agency
- Receiving training and supervision over the course of several months, including training on the Roberts-2

**Laura's House**
Ladera Ranch, CA
**Marriage and Family Therapist Trainee, Associate Marriage and Family Therapist**, August 2016 - August 2017

- Developing clinical techniques and skills across diverse therapeutic modalities via sessions with clients, including Eye Movement Desensitization and Reprocessing (EMDR) therapy (trained in June 2017)

- Facilitating a weekly process group, the Personal Empowerment Program (PEP), for survivors of domestic violence; offers a safe space for clients to discuss and receive education about domestic violence and its effects
- Conducting intake sessions for women, children, and men looking to receive therapy for concerns related to domestic violence; providing individual, family, and group therapy sessions
- Facilitating other psychoeducational and process-oriented groups and workshops for clients that center around healthy relationship topics, such as Codependency and Self Esteem
- Discussing client progress and consulting with supervisors and fellow therapists in order to explore therapeutic interventions, learn from experienced clinicians, facilitate case conceptualization, and ensure proper self-care (via weekly individual and group supervision)
- Maintaining client progress notes, attending relevant workshops and trainings, advocating for clients, providing resources and referrals, and communicating with other clinicians and contacts in order to best serve each client's therapeutic needs
- Placing calls to Child Protective Services (CPS) and Adult Protective Services (APS) when necessary, and following up with written reports faxed to these agencies, to promote safety of client and involved parties

**Teaching Experience**

**Pepperdine University, Graduate School of Education and Psychology**
Los Angeles, CA
**Teaching Assistant for Online MFT Program,** April 2018 – June 2020
**Teaching Assistant and Peer Consultant for Cognitive, Personality, and Advanced Assessment Courses,** September 2018 – May 2020

- Reviewing, tracking, and providing feedback to instructors for student submissions and performance in the Interpersonal Skills and Group Therapy course of the online MFT program for the past three semesters
- Double scoring assessments, reviewing student performance, and providing feedback to students and instructors in the 1st-year and 2nd-year Cognitive, Personality, and Advanced Assessment courses
- Meeting individually with students as a peer consultant to teach administration, scoring, and interpretation of neuropsychological tests

**Boys Hope Girls Hope of Southern California**
Irvine, CA
**Graduate Assistant and Peer Consultant, PsyD Trainee,** March 2018 – May 2020

- Double scoring assessments, providing feedback, and serving as a peer consultant to students currently involved with this site

**Research Experience**

**Applied Scholarship Committee (ASC) under Louis Cozolino, Ph.D. (Dissertation Chairperson)**
Los Angeles, CA
**Research Lab Member,** January 2018 - present

- Investigating brain-behavior relationships and completing a dissertation on mechanism of action in EMDR therapy under Dr. Cozolino's guidance

**Boston University Cognitive Neurophysiology Lab**
Boston, Massachusetts
**Research Assistant and Professor's Assistant**, 2012 - 2014

- Four semesters of directed studies with Dr. Jacqueline Liederman, researching and developing college- and field-level projects in various areas of study, including Autism Spectrum Disorder (ASD) and dyslexia
- Directly administering psychometric tests and computer tasks to study participants (i.e., KBIT-2 clinical assessment, modified Embedded Figures Test, Silhouette Task, Navon Task); scoring assessment data for inclusion in recently published research papers on Autism Spectrum Disorder
- Editing professional manuscripts for research papers relevant to the field of psychology, including:
  Olu-Lafe, O., Liederman, J., & Tager-Flusberg, H. (2014). Is the ability to integrate parts into wholes affected in Autism Spectrum Disorder? *Journal of Autism and Developmental Disorders, 44*, 2652–2660. doi:10.1007/s10803-014-2120-z

- Analyzing statistical data in programs such as SPSS, and aiding a professor daily in various tasks that needed completion (i.e., tasks associated with her academic courses, and graduate students' research)

**Employment Experience**

**California Psychcare, Inc., a Division of 360 Behavioral Health**
Long Beach, CA
**Process Group Developer and Facilitator, Program Coordinator, Registered Behavior Technician (RBT), and Board Certified Autism Technician (BCAT),** October 2015 – July 2020

- Designing, developing, and facilitating a novel 10-week process group for parents and caregivers, the Parent Empowerment and Psychoeducational Process group (PEPP), that aims to bring individuals with shared experiences together in a safe space
- Working with a diverse population of children and adolescents with a diagnosis of Autism Spectrum Disorder via in-home and in-office services, through evidence-based Applied Behavior Analysis treatment programs
- Teaching age-appropriate skills and adaptive behaviors one-on-one in an empathic and methodical manner
- Leading and co-facilitating two weekly social skills groups with up to sixteen children each (ages 2 to 9); groups involve arts and crafts, games, and learning to socially interact in developmentally appropriate manner
- Developing and integrating programs that are catered personally to each client, while collaborating with other program coordinators and BCBAs/providers
- Tracking quantitative and qualitative data; writing semi-annual reports on each client's behavioral progress

**Positive Behavior Supports Corporation**
Los Angeles, CA
**Registered Behavior Technician (RBT)/Behavior Instructor (Independent Contractor)**, September 2017 – December 2018

- Working with a diverse population of children and adolescents with a diagnosis of Autism Spectrum Disorder via in-home and in-office services, through evidence-based Applied Behavior Analysis treatment programs
- Teaching age-appropriate skills and adaptive behaviors one-on-one in an empathic and methodical manner
- Collaborating with supervisors and providers to develop and integrate programs catered to each client
- Tracking quantitative and qualitative data related to client progress

***The Raising Voices Program*: A Support Group for Families**
Huntington Beach, CA
**Co-creator and Co-facilitator, Associate Marriage and Family Therapist,** October 2017 - March 2018

- Collaboratively developing a curriculum, brochure, and structure for a psychoeducational process-oriented support group for families of individuals with a diagnosis of ASD and related developmental disadvantages
- Conducting biweekly support groups and facilitating open discussions that revolve around topics such as self-care, resources and therapeutic services, diagnoses, family dynamics, parenting, and behavioral interventions

**Northern Virginia Ophthalmology Associates, P.C.**
Falls Church, VA
**Assistant to the Practice Manager**, 2011 - 2015

- Aiding in the creation of various data reports, such as billing summaries, for the physicians and office administrators; assisting the practice manager in various administrative tasks
- Helping to integrate and implement new medical database software systems and transition to a new office
- Organizing and preparing patients' medical charts
- Managing correspondence with businesses and professional clients such as software developers and moving companies

**Infant, Child, and Adolescent Mental Health Service (ICAMHS) and Perinatal and Infant Mental Health Service (PIMHS), South Western Sydney Local Health District**
Liverpool, Bankstown, and Campbelltown, NSW, Australia
**Psychology Intern**, Fall 2014

- Assisting an ICAMHS Clinical Coordinator in the development of various Excel data reports concerning quantitative and qualitative details surrounding mental health presentations at the emergency departments of multiple hospitals in South Western Sydney suburbs
- Participating in dozens of clinical assessments, school and home visits, and intake meetings with Psychologists, Psychiatrists, Social Workers, and Clinical Nurse Coordinators (CNCs) involved with ICAMHS and PIMHS, over the course of eight weeks
- Discussing client's relevant medical and family history with clinicians prior to or during each assessment/visit; posing questions to clients directly when appropriate
- Discussing clinical impressions with clinicians regarding client behavior, potential diagnosis, and plans for therapy and treatment, following assessment and/or clinical interview

## Volunteer Experience

**Community Service Center at Boston University**
Boston, Massachusetts
**Volunteer in Various Programs**, 2011 - 2014

- Participating in FYSOP (First-Year Student Outreach Project), working at various food banks and community garden projects
- Serving as a Peer Leader and actor for Children's Theatre (playful and creative performances geared towards children in Jumpstart and related programs)
- Participating in the Global Day of Service program at a local animal shelter

**Nova Scripts Central**
Falls Church, Virginia
**Volunteer at Pharmacy**, Summer 2010

- Aiding in day-to-day management and revision of patient prescriptions on the medical database, under the supervision of pharmacists and health professionals
- Learning firsthand about the barriers faced by Northern Virginia's uninsured, low-income working class families

## Relevant Trainings, Credentials, and Awards

- Trained in EMDR (Eye Movement Desensitization and Reprocessing) therapy as of June 2017, a therapy indicated for use with clients who have an extensive history of complex trauma/PTSD
- Certified Domestic Violence Advocate (via 40-Hour Domestic Violence Advocacy Training in June 2016)
- Maintaining credentials as both a Registered Behavior Technician (RBT) through the Behavior Analyst Certification Board (BACB) since 2015 and as a Board Certified Autism Technician (BCAT) through the Behavioral Intervention Certification Council (BICC) since 2019 to better inform and advance therapeutic work done with children on the Autism Spectrum
- Former Associate Marriage and Family Therapist (#101281) through the Board of Behavioral Sciences (BBS) (from August 2017 to August 2018)
- Recipient of Pepperdine's Graduate School of Education and Psychology Evelyn Blake Scholarship for the 2017-2018, 2018-2019, and 2019-2020 school years

## Professional Organizations and Memberships

- American Psychological Association of Graduate Students (APAGS)

ABSTRACT

A mounting body of evidence suggests that Eye Movement Desensitization and Reprocessing therapy (EMDR) is successful in reducing the impact of posttraumatic symptoms. Although the exact mechanisms of action remain unknown, theories from the psychological to the neuroscientific continue to emerge, expand, and evolve. This study will examine four of the most prominent theories to date and weigh the evidence for and against each one. It will also review, compare, and contrast the theories, evaluate the research supporting each one, and propose the most likely explanation for EMDR's success given the state of the research. Neurobiological mechanisms and correlates as well as the controversy over the use of eye movements will also be reviewed. Implications for future research will also be discussed.

*Keywords:* EMDR mechanism of action, neurobiology of EMDR, psychophysiology of EMDR, how EMDR works, EMDR and PTSD, PTSD treatment

# Chapter 1. Introduction

## Origins and Background

Eye Movement Desensitization and Reprocessing therapy (EMDR), developed by Francine Shapiro in 1987, was originally designed to reduce the impact that traumatic memories have on a client. The therapy follows a protocol, as established by Shapiro and her colleagues, and includes eight phases that are carried out over the course of treatment (Shapiro, 2002). By the end of the eighth phase, the client's cognitive appraisal of the traumatic event would ideally have shifted in a way that increases the client's sense of mastery over the memory. Subsequently, the emotions associated with the memory of the event, including those brought on by negative thought attributions, would neutralize or perhaps even become positive. Finally, the cognitive and emotional shifts that had taken place within the client throughout the protocol would be mirrored in the client's physiological reactions; in other words, the memory and images associated with the event would no longer trigger a bodily sensation of anxiety, discomfort, or pain. In sum, Shapiro (2002) claims that by the end of successful treatment with EMDR, a client will no longer endure negative thinking patterns, unpleasant emotions, or bodily discomfort when faced with the memory and associated images of a past trauma.

The foundation of Shapiro's work with EMDR revolves around the Adaptive Information Processing (AIP) model. Shapiro and Maxfield (2002) assert that the interventions involved in EMDR therapy serve to hasten information processing, and this acceleration results in an adaptive resolution of traumatic memories. They further suggest that every individual has a physiological information processing system, where information is processed generally to an adaptive state (Shapiro & Maxfield, 2002). Information is processed to an adaptive state when it allows for non-distressing recall of memories, which promotes overall psychological wellbeing

(Solomon & Shapiro, 2008). Solomon and Shapiro (2008) concede that many theories exist around how EMDR works to facilitate adaptive information processing, stating that their AIP model is one of many current hypotheses surrounding the mechanism of action in EMDR. In the AIP model, they state that information processing allows for the assimilation of new experiences into pre-existing memory networks (Solomon & Shapiro, 2008). During the adaptive processing proposed by the AIP model, associations are forged with material that was stored previously, resulting in new learning and amelioration of emotional pain; additionally, any stored material is rendered accessible for use in the future (Shapiro & Maxfield, 2002). Shapiro and Maxfield (2002) go on to discuss the links that are present between associated memory networks, which contain related thoughts, images, emotions, and sensations; these memory networks center around the earliest related event, and memories of recent incidents can contain elements connected to earlier experiences. However, issues can arise when information around a distressing or traumatic experience is not fully processed. Specifically, Shapiro and Maxfield (2002) mention that distorted perceptions can end up being stored in the memory network as they were initially input; consequently, "dysfunctional reactions" in the present can result from leaving distressing memories unprocessed (i.e., PTSD intrusive symptoms are thought to result from the unprocessed sensory, affective, and cognitive elements of a traumatic memory).

The core hypothesis of how EMDR works, in the eyes of Shapiro and Maxfield (2002), involves several basic tenets. The authors' first conjecture is that dual-attention stimuli and eye movements enhance information processing via bilateral stimulation (BLS) and resource development and installation (RDI). This theory purports that an individual's innate information processing system allows for the integration of novel experiences by way of assimilating these experiences into pre-established memory networks (Solomon & Shapiro, 2008). In EMDR, they posit that information processing happens in sessions via bilateral stimulation, which allows for the rapid stimulation of intrapsychic connections between emotions, cognitions or insights, bodily sensations, and memories that are accessed and subsequently changed with each set of eye movements (Solomon & Shapiro, 2008). Solomon and Shapiro (2008) consider this linking of adaptive information from previously established memory networks with the network that holds the isolated distressing experience to be a likely mechanism of action in EMDR. Once an individual has completed treatment, they suggest that the previously disturbing memory is no longer isolated, as it has successfully achieved integration within the larger memory network; new learning occurs via this integration into a larger, healthy memory network, which is the crux of adaptive information processing (Solomon & Shapiro, 2008).

Shapiro and Maxfield (2002) further believe that eye movements in EMDR are thought to decrease the vividness of the associated image and related affect in one's memory, which may reduce distress and related avoidance, and therefore enhance processing through desensitization (Shapiro & Maxfield, 2002). As the image loses its salience, the individual's ability to access and attend to more adaptive information increases; as a result, the individual is then able to create new connections and associations within the memory network.

In their description of EMDR, Shapiro and Maxfield (2002) appear to be somewhat vague and metaphorical, as they tie together various psychological ideas about how the therapy works. In research and clinical communities, the combination of this conviction and apparent vagueness has naturally spurred many lines of inquiry into the true mechanism of action underlying EMDR. Thus, a variety of theories on how EMDR works have been put forth, with varying degrees of support from researchers and clinicians alike. The hypotheses that currently predominate the field will be discussed and reviewed in the subsequent sections of this manuscript.

**Mechanism of Action Theoretical Debate**

The mystery of how EMDR works has sparked a great amount of curiosity among researchers and clinicians alike, and the controversy around its use as a therapeutic modality naturally stems from the unanswered questions and conflicting results. Numerous researchers throughout the years have attempted to elucidate the mechanism of action behind EMDR and have generated a myriad of theories around the topic, which range from psychological to neuroscientific in nature. As these theories continue to evolve, they give rise to new questions regarding how the therapy works to bring about change in a client's experience of posttraumatic symptoms.

Elofsson et al. (2008) offered a list of the current competing theories as they see them, which include the following: a conditioning and distraction paradigm, which incorporates emotional interference with learning; an orienting response paradigm; and a theory concerning the induction of a neurobiological state (similar to Rapid Eye Movement or REM sleep) that may follow repeated orienting responses, which leads to increased cortical integration of traumatic memories (Armstrong & Vaughan, 1996; Dyck, 1993; Stickgold, 2002).

Gunter and Bodner (2009) have also commented upon their idea of four different theories that exist in the literature regarding the mechanism of action behind EMDR, including the following accounts: a taxation of working memory; psychological distancing; increased interhemispheric communication; and psychophysiological changes (subsumed in this account are the orienting response, induction of a REM-like state, and reciprocal inhibition).

Given the relatively new yet burgeoning field of research on how EMDR works, this manuscript will attempt to review the current state of the literature on the mechanism of action. Ideally, this investigation will shed light on whether there have been consistent findings in support of one or more theories, while delineating the areas of research that deserve further inquiry.

**Clinical Relevance and Importance of the Investigation**

This investigation appears quite pertinent to the field of clinical psychology at present, given the diverging opinions around not only the effectiveness of EMDR, but also around its mechanism of action. Ideally, a comprehensive analysis of how EMDR works will contribute to the existing research in the field of clinical psychology in the hopes of approaching greater levels of clarity and agreement among researchers and clinicians alike. The use of EMDR continues to grow rapidly and has been recommended by the American Psychiatric Association (2004) as an effective treatment for PTSD; the American Psychological Association (2020) also lists EMDR as a conditionally recommended treatment for PTSD. Clinicians utilize this modality in a wide range of settings, including hospitals, community mental health centers, and private practice, for both chronic traumatic stress and acute crises (i.e., as a form of rapid response intervention following natural disasters or acts of terrorism). Unfortunately, the rising rates of mass interpersonal violence in this country reveal the need for an increasing number of clinicians who are trained in brief trauma-focused interventions like EMDR. This investigation is therefore conducted with the hope of increasing awareness and understanding of how EMDR works in order to render this effective therapy more scientifically accessible, and therefore increase the number of clinicians trained in its delivery. The mechanisms involved in both PTSD and its effective treatments in general may also be elucidated via this investigation.

## Chapter 2. Literature Review

The following section contains a preliminary overview of the literature on experiences with EMDR as reported by clinicians and clients, treatment outcome studies, the controversy over eye movements, the neurobiology of EMDR, and mechanism of action theories. It will end with the statement of the problem and the research question for the current investigation. For reference, a discussion of the eight-phase protocol of EMDR can be found in Appendix A.

### Clinicians' Reports and Experiences

Success in EMDR is dependent on the therapist's ability to achieve the following: an exploration of preceding events that led to the client's present framework of cognition and affect, once the events are brought into the client's awareness; a discovery of which stimuli trigger the traumatic symptoms, followed by desensitization of such triggers; and the installation of a positive cognition, which would permit a more valid affective and cognitive appraisal of (and behavioral response to) the traumatic event, so as to bolster feelings of self-efficacy (Sprang, 2001). Clinicians who use EMDR come from a milieu of therapeutic backgrounds and operate under the guidance of various theoretical orientations. Research has indicated that EMDR as a therapeutic approach may be preferred by clinicians and clients alike, as it offers a less distressing experience for clients, and is a relatively short-term treatment when compared to other techniques, such as prolonged exposure (Sondergaard & Elofsson, 2008). In a similar vein, another research team discusses their finding that clients and clinicians might opt for EMDR over other exposure techniques, due to the emotionally taxing nature of direct therapeutic exposure for both client and clinician (Boudewyns & Hyer, 1996). Indeed, EMDR offers a unique treatment that has many similarities with the leading exposure therapies in the field, like prolonged exposure and cognitive processing therapy.

**Clients' Reports and Experiences**

The extent to which any therapeutic intervention is deemed successful depends on a multitude of factors. The idiosyncratic qualities of the therapist, for example, would likely play a significant role in the implementation of any therapy, especially one as nuanced as EMDR. The relationship between therapist and client has been singled out as one of the most important factors of all in determining outcome; in fact, research has consistently shown that the amount of change seen in a client stemming from the therapeutic alliance is roughly five to seven times greater than the amount that is attributable to a specific therapeutic model (Duncan et al., 2010). Marich (2012) conducted a study examining the therapeutic alliance, as well as several other therapist qualities that were highlighted as important by a group of clients who had received EMDR treatment. Chief among these was the client's impression of safety, which appears to be a crucial element of any form of therapy, especially when trauma presents as a primary cause for treatment (Marich, 2012).

The burden of first creating and subsequently maintaining a feeling of safety is one that lies solely with the therapist in the room with the client. The extent to which the therapist is able to generate and maintain safety factors greatly into the strength of the therapeutic alliance, and therefore has a significant impact on the entire course of therapy (Marich, 2012). Based on the disclosures of the clients included in the Marich (2012) study, it appears that deep EMDR work would benefit from beginning only after a client's feeling of safety with the therapist has been assured. The clients in this study stated that certain qualities of the therapist led to an increase in feelings of safety, and these included the following: personality; flexibility (as opposed to rigidity) in terms of adherence to EMDR protocol; calmness, ease, and comfortability when working with trauma; the extent to which a therapist instilled feelings of empowerment in the client; overall intuition; and a general sense of care for the client's wellbeing (Marich, 2012). The findings of Duncan et al. (2010) suggest the same importance of the therapeutic relationship when assessing overall outcome in therapy.

During sessions, clients disclosed how important it was to trust the therapist; they indicated that the care taken by the therapist in orienting and preparing the client before commencing the reprocessing in each session and willingness to move at the client's pace allowed trust to be built to a great extent (Marich, 2012). In general, the participants of the Marich (2012) study classified the preparation, orientation, and session closure as being chiefly important to their overall sense of safety in the room. By creating an atmosphere free of judgment and conducting sessions with a natural flow, a therapist using EMDR may enhance the quality of the therapeutic alliance, and the client will likely appraise such features positively (Marich, 2012). Indeed, the therapeutic alliance has the most robust evidence with respect to treatment outcome.

**Treatment Outcome Studies**

The effective and ethical use of EMDR has been demonstrated for certain populations, and the American Psychiatric Association (2004) recommends EMDR as an effective treatment for individuals with PTSD. While EMDR has its fair share of critics, as expected of any novel therapeutic modality, there are countless researchers who serve as proponents of the therapy and its effectiveness, and have demonstrated such effectiveness through various studies. A brief review of some studies that either support or refute the effectiveness of EMDR can be found in Appendix B.

Overall, the question of effectiveness when it comes to EMDR is a topic that continues to permeate the world of research, and compelling arguments have been made on both sides.

EMDR has been widely demonstrated across numerous research studies as an effective therapy for certain populations (i.e., individuals with PTSD). As might be expected of any novel treatment, there appears to be an ongoing discussion around the details and generalizability of such effectiveness. The work conducted by DeBell and Jones (1997) as well as Feske (1998) suggests that EMDR shows promise as a potentially effective treatment for certain populations, though further research is necessary (Davidson & Parker, 2001). Boudewyns and Hyer (1996) also state their belief that EMDR could function as an effective technique in psychotherapy due to its incorporation of dosed exposure, although further research around the addition of eye movements is necessary. It suffices to say that these researchers appear correct in their conviction: ongoing and focused research studies and analyses will only serve to further elucidate any questions around the therapy's effectiveness and should be encouraged. Continued investigations into the contextual factors that surround optimal treatment outcomes will only benefit the field and further the state of the research on the overall effectiveness of EMDR. Furthermore, research investigating how EMDR works will also serve to elucidate the mysteries behind this increasingly widespread treatment.

**Controversy over the Significance of Eye Movements**

There have been numerous studies regarding the role of eye movements in EMDR, particularly when assessing the impact that this component has on the therapeutic process. Some researchers argue that the eye movements are not integral to the overall process of bringing about change in a client's symptoms, thereby disputing the theories that render eye movements responsible for the mechanism of action in EMDR. Davidson and Parker (2001), for example, conducted a meta-analysis of EMDR and its effectiveness. Included in their findings were the results of another review, which categorized EMDR as an imaginal exposure technique, and alluded to the unessential nature of the eye movements in bringing about a change in symptoms (Acierno et al., 1994). Acierno et al. (1994) claimed that a therapeutic task that was equivalent to EMDR, but without the eye movement component, was just as effective as EMDR when results were compared between the two treatment groups (Davidson & Parker, 2001).

Further reviews have led to similar findings regarding the role of eye movements and their significance, or insignificance, in the overall process of symptom reduction (Davidson & Parker, 2001). Studies conducted by Lohr et al. (1995, 1998) suggest that any type of lateral stimulation, including eye movements, might not be necessary to the overall mechanism of action in the EMDR protocol (Davidson & Parker, 2001). Elofsson et al. (2008) reported psychophysiological findings that they determined to be inconsistent with an orienting response, and discussed similar contradictory evidence found by Renfrey and Spates (1994), who did not find any added effect of eye movements on overall effectiveness in therapy. Furthermore, the research findings of Boudewyns and Hyer (1996) suggest that the addition of any lateralizing stimuli does not appear necessary when assessing for positive outcome in EMDR.

A multitude of researchers, on the other hand, comment upon the benefits and necessity of incorporating dual attention stimuli into the process of EMDR and related protocols. One proposed theory is that the bilateral stimulation of the eyes in EMDR causes a de-arousal effect in the client following this orienting response (Barrowcliff et al., 2003; Barrowcliff et al., 2004; MacCulloch & Feldman, 1996). The orienting response will be discussed further in subsequent sections of this paper as one of the predominant mechanism of action hypotheses in the field at present. Jeffries and Davis (2013) discuss the significance of eye movements in relation to another theory of how EMDR works that has garnered support in the field: namely, the working memory taxation hypothesis, which will also be discussed later in this review. Jeffries and Davis

(2013) mention the work of Lilley et al. (2009) in their discussion as well; the latter team of researchers investigated exposure to traumatic images in individuals diagnosed with PTSD using three conditions: eye movements, a counting task, and a control group in which no distractor was present. Lilley et al. (2009) assert that their findings support the basic tenets of the specificity hypothesis of the working memory model; this hypothesis states that eye movements will reduce the vividness and accompanying distress associated with visual traumatic images, by taxing the part of an individual's working memory that holds visuospatial information (Jeffries & Davis, 2013). Lilley et al. (2009) further suggest that the counting task included in their paradigm, which taxes the phonetic loop of the working memory system, does not provide the same symptom relief (Jeffries & Davis, 2013). Ultimately, the eye movement condition led to greater decreases in ratings of vividness and distress when compared to the counting task and the exposure without a distractor task; however, this finding only held true at the treatment session, and no differences were seen at a one-week follow-up (Lilley et al., 2009; Jeffries & Davis, 2013). Thus, Lilley et al. (2009) concluded that eye movements are successful in effecting these reductions when they are performed simultaneously as a task that matches the modality of the traumatic imagery; however, pure distractor tasks are not successful in this regard, and the authors mention that eye movements therefore serve a purpose beyond that of a general distractor task (Jeffries & Davis, 2013).

Another study by Wilson et al. (1996) found that eye movements were more effective when compared with two control conditions. Leer et al. (2014) discuss similar findings around the benefits of eye movements for recall capability, stating that eye movements led to reductions in memory emotionality and vividness in their participants when comparing pre-treatment to follow-up; furthermore, this effect was not demonstrated by the control condition (recall without eye movements). Additionally, Elofsson et al. (2008) describe eye movements as they relate to the retrieval of memories, stating that eye movements are often accompanied by retrieval of formerly forgotten memories or information that has been ignored, and new information brought to light during the session can often serve to reframe the experience of trauma. Thus, as with many competing theories around the various facets of EMDR therapy, the question as to whether eye movements are essential to achieving success remains an ongoing discussion with variable answers in the field today.

**Neurobiology of EMDR: Neuroimaging Studies and Implicated Brain Regions**

Another body of research surrounding the mechanism of action in EMDR involves the results demonstrated by psychological testing and neuroimaging studies. These studies attempt to elucidate the how EMDR affects certain parts of the brain, if at all. Sripada et al. (2013) discuss how several intrinsic connectivity networks (ICN) of the brain have been implicated in PTSD, including structures like the insula, amygdala, ventromedial prefrontal cortex (vmPFC), and hippocampus. Hyperactivity can be seen in the insula and amygdala, which are both part of the salience network (SN); the SN is involved in the detection of and orienting to novel salient stimuli, which may be particularly pertinent to the discussion of the orienting response (OR) throughout this manuscript (Sripada et al., 2013). The default mode network (DMN) focuses on internal thought and autobiographical memory and operates independent of external stimuli; the vmPFC, hippocampus, and posterior cingulate cortex are involved in the DMN, and the former two structures are known to be hypoactive in PTSD (Sripada et al., 2013). The central executive network (CEN) includes the dorsolateral prefrontal cortex (dlPFC) and lateral parietal regions, and is involved in higher order executive functions (i.e., planning, working memory, decision-making) and goal-directed behavior. In their study on individuals with PTSD, Sripada et al.

(2013) found reduced connectivity in the DMN, increased connectivity in the SN, and increased connectivity between regions associated with both networks; these findings highlight the idea that PTSD may neurologically wire the brain to overly attend to external stimuli (suggesting a possible dysfunctional OR mechanism), which correlates with hypervigilance and hyperarousal.

Other researchers directly discuss EMDR and the regions thought to be associated with the therapy. Bergmann (2008) discuss the impact of certain brain areas on an individual's level of emotionality, including the relationships between the structure and function of the amygdala, thalamus, left dorsolateral prefrontal cortex, and hippocampus. Regarding the role of the thalamus in PTSD, Bergmann (2008) cites this structure's unique ability to synchronize and logically combine the signals from all the functional networks in the brain in real time, also known as thalamocortical temporal binding. This binding in turn permits the integration of information across perceptual, somatosensory, cognitive, and memory-related domains (Bergmann, 2008). The author cites previous research that investigated the relation of cortical and subcortical structures to EMDR, stating that bilateral stimulation (i.e., eye movements) activates the lateral cerebellum; this association area in turn projects to and activates the ventrolateral and central-lateral thalamic nuclei (Bergmann, 2000; Bergmann, 2008). Subsequently, the ventrolateral thalamic nucleus projects to and activates certain areas of the dorsolateral prefrontal cortex; this projection and activation process ultimately facilitates the integration of traumatic memories into general semantic networks as well as other neocortical networks (Bergmann, 2008).

Some studies have investigated the role of specific neural structures in the EMDR treatment of individuals diagnosed with PTSD. Nardo et al. (2010) found that subjects who had a high trauma load, a diagnosis of PTSD, and who did not respond to EMDR were also shown to have lower grey matter density in limbic and paralimbic cortices. Specifically, each of these participants appeared to have lower grey matter density in the bilateral posterior cingulate, as well as in the anterior insula, anterior parahippocampal gyrus, and amygdala in the right hemisphere (Nardo et al., 2010). According to a study done by Levin et al. (1999) on individuals diagnosed with PTSD, specific areas of the brain showed hyperactivity following treatment with EMDR: the anterior cingulate gyrus and the left frontal lobe. Based on these findings, the authors concluded that success in treating PTSD may lie in enhancing the brain's ability to differentiate real from imagined threat, as opposed to reducing arousal at a limbic level (Levin et al., 1999).

Some researchers assert that memory and new learning play a large role in reducing or eliminating the impact of a traumatic memory. Ecker and Bridges (2020) recently published a paper discussing this "erasure" and the mechanism by which it occurs: namely, through the neuroplastic effects of memory reconsolidation. In order to overcome a traumatic memory, the authors assert that an individual must undergo neural re-encoding of the target memory's contents; reactivating the stable, consolidated, long-term memory permits it to biochemically transition into an unstable memory that is deconsolidated and malleable (Ecker & Bridges, 2020). This vulnerable memory is then neutrally re-encoded through new learning processes and ultimately transitions back into a stable consolidated memory; subsequently, changes in associated behaviors, affects, and thoughts can be observed (Ecker & Bridges, 2020). The mechanism of memory reconsolidation may be at play during EMDR, given the similarity of these processes to the EMDR protocol.

Ultimately, an in-depth analysis of clinical studies investigating the role of neural structures and mechanisms in the context of EMDR treatment of PTSD is warranted. This analysis as well as the relationship between underlying neurobiological structures and the mechanism of action in EMDR will be further discussed and investigated in the subsequent sections of this manuscript.

**Mechanism of Action Theories**

Multiple theories, ranging from metaphorical to neurobiological, have been set forth for how EMDR works. Elofsson et al. (2008) listed the predominating theories as they see them, which include the following: a conditioning and distraction paradigm, which incorporates emotional interference with learning; an orienting response paradigm; and a theory concerning the induction of a neurobiological state (similar to Rapid Eye Movement or REM sleep) that may follow repeated orienting responses, which leads to increased cortical integration of traumatic memories (Armstrong & Vaughan, 1996; Dyck, 1993; Stickgold, 2002). In another study, Gunter and Bodner (2009) listed four potential accounts of how change occurs in EMDR: a disruption in/taxation of working memory; psychological distancing; increased hemispheric communication; and psychophysiological changes (subsumed in this account are the orienting response, induction of a REM-like state, and reciprocal inhibition).

Van den Hout and Engelhard (2012) first discuss their convictions about how the effectiveness of EMDR has been widely demonstrated and go on to mention their curiosity as to *how* the therapy works. Similar to the aforementioned researchers, Van den Hout and Engelhard (2012) also comment upon different theories that have been put forth by researchers in the field. They discuss the following three concepts in relation to how EMDR works in their review: a reduction in the vividness and emotionality of traumatic memories as a function of imaginal exposure (i.e., the eye movements are inessential); the promotion of interhemispheric communication; and the taxing of an individual's working memory (Van den Hout & Engelhard, 2012). These researchers argue that the effectiveness demonstrated by the addition of eye movements in EMDR has garnered enough support in empirical studies; thus, the first hypothesis, stating that EMDR works via an imaginal exposure mechanism without the need for eye movements, can be refuted (Van den Hout & Engelhard, 2012). They discuss but do not overtly refute the second hypothesis involving interhemipsheric communication; rather, they state that this theory is widely accepted in EMDR circles (Van den Hout & Engelhard, 2012). This account states that bilateral eye movements during the therapy help stimulate communication between the hemispheres of the brain, thereby permitting the retrieval of aversive memories without the addition of negative arousal (Van den Hout & Engelhard, 2012).

As for the final hypothesis involving the taxing of working memory, Van den Hout and Engelhard (2012) determine that this theory does in fact show promise as a likely mechanism of action. This theory states that the combination of two competing tasks that both draw upon working memory overburdens the capacity of an individual's working memory: in this case, the two competing tasks would be the bilateral stimulation via eye movements, and the recall of an aversive memory (Van den Hout & Engelhard, 2012). When the individual is asked to recall the memory under the simultaneous condition of attending to the eye movements, the memory is thought to become less vivid and emotional as a result; this less distressing version is then thought to be reconsolidated into the individual's memory (Van den Hout & Engelhard, 2012). Thus, the memory itself may be altered, while the individual's relationship or response to the memory changes. Van den Hout and Engelhard (2012) describe this theory and thus EMDR as a function of imagination deflation, a mechanism thought to counteract the imagination inflation process that strengthens the distress associated with traumatic images in memory.

In comparing the proposed theories discussed by Eloffson et al. (2008), Gunter and Bodner (2009), and Van den Hout and Engelhard (2012), it becomes evident that certain concepts have garnered speculation among researchers who have investigated how EMDR works. The orienting response, defined by Armstrong and Vaughan (1996) as a behavioral response triggered by a stimulus that aids in the extraction of environmental information deemed to be most important for the individual, has been researched heavily in studies pertaining to this matter. Elofsson et al. (2008) describe the orienting response as being elicited through the stimulation of dual attention, which leads to a reduction in avoidance and the incorporation of new trauma-related information into an individual's cognitive processing system. Furthermore, these authors purport that the orienting response is accompanied by physiological changes, as it generates a lower threshold for sensory stimuli while inhibiting somatic functions that might interrupt the perception of stimuli; it also causes a decrease in respiration, heart rate, and skin temperature, and an increase in skin conductance (Elofsson et al., 2008; Öhman et al., 2000).

Theories concerning the integration of neural networks, the creation of a biological state similar to that of REM sleep, and behavioral conditioning and inhibition have also gained the attention of researchers as potential mechanisms at play in EMDR. Additionally, it is clear that the working memory taxation hypothesis has accrued support among many researchers. The theories and accompanying descriptions set forth by these three research teams can be seen in Table 1 at the end of this manuscript; the third column in this table denotes which theories have been investigated and discussed across multiple research teams.

The following section contains an in-depth discussion of four of the competing theories, as organized by Gunter and Bodner (2009), and how they relate to the overall process of change in EMDR.

***Working Memory Taxation Hypothesis***

Gunter and Bodner (2009) describe the first theory as a function of straining the resources of an individual's working memory: by having the individual hold a memory in mind while performing a competing task (i.e., eye movements), working memory capabilities are depleted, thereby causing decreases in the vividness, emotionality, and completeness of an unpleasant traumatic memory. The authors state that eye movements may not be unique with regard to their role in this theory; that is, any distractor task strong enough to tax the resources of the working memory will suffice when the individual is simultaneously holding an unpleasant memory in mind (Gunter & Bodner, 2008). The speed of a distractor task may also impact the overall benefits gained by an individual, as seen in a study by Maxfield et al. (2008), wherein participants in the faster eye movement condition experienced greater benefits than those in the slower eye movement condition.

The work of Baddeley specifically has been at the forefront of research around working memory. His working memory model posits that working memory consists of a central executive (CE) system and three subsystems, namely the phonological loop (PL; involved in auditory information processing), the visuospatial sketchpad (VSSP; involved in visual and spatial information processing), and the episodic buffer, which integrates input from the VSSP and PL with a sense of time, sequencing events (Baddeley, 1986; Baddeley & Hitch, 1974). These research teams referenced the concept of simultaneous tasks competing for working memory resources and stated that even verbal memory may be impacted when a secondary visuospatial processing task is involved, if that verbal memory relies upon visuospatial imagery (Andrade et al., 1997).

Andrade and Baddeley expanded upon this model, stating that concurrent visuospatial tasks in general will likely impact an individual's ability to perform visual imagery and memory tasks, rendering such tasks more difficult. These researchers further suggest that the competing visuospatial task may even reduce the vividness of the recalled images for each individual (Andrade et al., 1997). Drawing upon the working memory model, the same team of researchers conducted a study with individuals diagnosed with PTSD and found evidence of a mechanism in line with the working memory account. They found that the visuospatial sketchpad of the working memory is specifically implicated in the mechanism of action behind the eye movements in EMDR, as opposed to the central executive or the phonological loop (Andrade et al., 1997). The researchers also found that eye movements specifically led to greater reductions in image vividness than did tapping, which was utilized as a competing task in another condition; this suggests that eye movements may indeed be unique as a competing task, as participants in this study described the images as being blurred due to the eye movements (Andrade et al., 1997).

Andrade et al. (1997) found less evidence for eye movements leading to a reduction in the emotional response elicited by associated images, though they suggest that the affect of such images may be directly related to the vividness of the recollected image. That is, the greater the vividness, the greater the emotionality of the image; in turn, the vividness of the images is dependent on the available resources of the working memory (Andrade et al., 1997). They also mention that greater reductions in the emotionality of the images were found in one experiment in particular, wherein participants chose a personal recollection for use in the protocol instead of photographs provided to them; the authors relay that this may have implications for PTSD, as the associated images are personally relevant stimuli (Andrade et al., 1997).

*Psychological Distancing Hypothesis*

Gunter and Bodner (2009) discuss this theory as a function of eye movements and how well they permit an individual to either detach or distance themselves from a traumatic memory or experience; furthermore, the authors state that there are few studies that actually analyze whether such a relationship exists. In the EMDR protocol, the patient is instructed to avoid passing judgment on whatever comes to mind while performing eye movements; instead, the individual is told to focus on the memory and simply remain present to any other experiences that arise in the moment. Gunter and Bodner (2009) comment upon the relatedness of such an instruction to the mechanisms seen in mindfulness and acceptance-based practices, approaches found to be therapeutically efficacious; furthermore, they describe the ability to process a trauma from a detached perspective as evidence of a distancing response.

Lee et al. (2006) found that individuals showed improvement in PTSD symptoms when they appeared to be processing trauma from a detached perspective, or when an aforementioned distancing response had occurred; the authors attributed this manner of processing to the EMDR procedure. Lee (2008) also found that the therapist's instructions during a session had less of an effect on the process of distancing than did eye movements themselves, suggesting that the eye movements were uniquely able to encourage a distancing response. Gunter and Bodner (2009) further state that an individual's level of metacognitive awareness and attentional flexibility may also play into the theory of psychological distancing, and mention that these processes are also seen in mindfulness and other forms of therapy. The authors encourage further studies around this theory in particular, as it appears to be less researched than other competing accounts, and emphasize the process of psychological distancing or detachment as a valuable theory of the mechanism of action in EMDR (Gunter & Bodner, 2009).

***Interhemispheric Interaction Hypothesis***

The theory listed by Gunter and Bodner (2009) concerning the principle of interhemispheric interaction is one that has been frequently explored in relation to EMDR. In line with this theory, Christman et al. (2003) found that bilateral eye movements enhance the retrieval of episodic memories, stating that this explicit retrieval is improved by increased interhemispheric communication. Propper and Christman (2008) also analyzed the effects of the bilateral saccadic eye movements utilized in EMDR, and found that they increase interaction between hemispheres and lead to improved episodic memory on memory tasks that follow the intervention. These researchers further commented upon their findings around the exclusive effectiveness of saccadic horizontal eye movements, as opposed to smooth pursuit eye movements and control conditions in which no eye movements took place (Propper & Christman, 2008). Propper and Christman (2008) state that these horizontal eye movements are responsible for both increases in accurate recognition and decreases in false recall on false memory tasks, citing increased activity in the frontal lobe regions of the brain as playing a key role in episodic memory retrieval.

There are also researchers who argue against the validity of the interhemispheric interaction theory. Researchers like Samara et al. (2011) have investigated increased interhemispheric coherence using EEG studies, and have found results that cast doubt on this theory. While eye movements appeared to enhance recall of emotional words in a healthy sample as compared to a control group, there was no evidence to suggest an alteration in interhemispheric coherence during the protocol; thus, they found no attestable correlation between recall ability and level of interhemispheric coherence (Samara et al., 2011).

*Psychophysiological Changes Hypothesis*

In addition to their description of three theories rooted in psychological concepts, Gunter and Bodner (2009) describe one final account in their analysis of potential mechanisms of action in EMDR. The psychophysiological changes hypothesis appears to stand out as a more objective and scientific theory, and will be discussed at length in the following section. Subsumed in this account are the following three phenomena, which all stem from a psychophysiological framework: Reciprocal Inhibition, REM-like State, and the Orienting Response.

**Reciprocal Inhibition.** Gunter and Bodner (2009) break the psychophysiological changes account into three subcategories, including the orienting response, induction of a REM-like state, and reciprocal inhibition. The work of Sack, Lempa, et al. (2008) appears to demonstrate findings consistent with this theory of psychophysiological change. They mention the effects that eye movements have on memory, as they discuss the findings of recent studies that have examined various neurophysiology measures, including heart rate, breathing rate, skin conductance, parasympathetic tone, and more (Sack, Lempa, et al., 2008). These studies have suggested that the eye movements present in EMDR serve to increase an individual's capacity to retrieve episodic memories, while simultaneously decreasing both the vividness and the affect associated with emotionally charged images (Sack, Lempa, et al., 2008).

The research conducted by Sack, Lempa, et al. (2008) also mentions the possibility of a certain mechanism taking place during EMDR: counter conditioning; this mechanism appears to fit into the final category of the psychophysiological changes account offered by Gunter and Bodner: reciprocal inhibition (Gunter & Bodner, 2009). The authors suggest that desensitization via a non-frightening stimulus is at the core of what transpires in EMDR therapy, and that this allows for reciprocal inhibition to occur due to the presence of eye movements (Sack, Lempa, et al., 2008). To support this theory, these researchers state that, as evidenced by a lowered heart rate, lowered breathing rate, and increased parasympathetic tone, their participants experienced both psychophysiological de-arousal and within-session habituation of such arousal (Sack, Lempa, et al., 2008).

The findings of Sack, Lempa, et al. (2008) have been demonstrated by previous studies that have also shown a clear within-session psychophysiological habituation effect. One such study by Wilson et al. (1996) suggested that the following physiological changes occurred in participants during EMDR treatment: respiration slowed to match the rhythm of the eye movements, following a shallow and regular pattern; heart rate decreased significantly overall; systolic blood pressure increased at the outset of eye movement sets, consistently declined during abreactions, and decreased overall; fingertip skin temperature reliably increased; and the galvanic skin response steadily decreased. The authors concluded that such changes were reflective of a clear relaxation response that occurred within EMDR sessions, as a result of desensitization via reciprocal inhibition; that is, any emotional distress experienced by an individual was paired with a previously unconditioned and forced relaxation response (Wilson et al., 1996). Notably, they specify that these changes represent single-session treatment effects; they did not comment on subsequent changes in arousal and activation in the outside world.

Montgomery and Ayllon (1994) reported a similar correlation between psychophysiological measures and the changes brought about by repetitive eye movements in the original EMD protocol (the precursor to EMDR). They found that participants exposed to the eye movement desensitization condition showed consistent decreases in both heart rate and systolic blood pressure from baseline to follow-up; no such trend was observed in the non-saccade condition (Montgomery & Ayllon, 1994). Although these decreases did not meet statistical significance, the authors describe these findings as clinically meaningful, as subjects in the eye movement desensitization condition consistently reported decreases in the situational anxiety provoked by the associated distressing images (Montgomery & Ayllon, 1994). Another study conducted by Armstrong and Vaughan (1996) provides further support for the reciprocal inhibition paradigm. These authors found that dual attention stimuli serve to prevent avoidance and invoke a new conditioned response: while the previously learned fear response is extinguished, a new learned response takes its place in the form of positive cognitive appraisal (Armstrong & Vaughan, 1996).

**REM-like State.** The second facet of the psychophysiological theory proposed by Gunter and Bodner (2009) concerns the idea that the eye movements in EMDR work to induce a REM-like state, a theory that Bergmann (2000) discusses and Stickgold (2002) has supported. While in REM sleep, the brain experiences a flow of information between the hippocampus and the neocortex, which involves the interplay of memories and their associated semantic meanings (Bergmann, 2000). According to Bergmann (2000) and previous research teams, the cortex gleans memories from the hippocampus, and consolidates them into dense and carefully formed cortical memories; these cortical memories contain highly useful information based upon one's past experiences, and semantic knowledge stems from the extraction of such memories. However, in individuals with PTSD, this neurological flow of information is interrupted, as the hippocampal episodic memories of the traumatic event are constantly replayed in the mind, along with their corresponding affective components, due to the role of the amygdala in memory consolidation (Bergmann, 2000). When this occurs, the neocortex is unable to provide input around the semantic meaning of the traumatic event, thus inhibiting the individual's ability to fully understand their experience (Bergmann, 2000).

Stickgold (1998) states that an individual's REM sleep system is activated via the anterior cingulate gyrus during EMDR treatment, as EMDR facilitates a re-opening of the processing system involved in the information flow between the neocortex and hippocampus (Bergmann, 2000). By re-engaging this system of communication, the hippocampus is given a chance to reprocess dysfunctional information via the newly acquired semantic input from the neocortex (Bergmann, 2000; Stickgold, 1998). Stickgold (2002) states that the neurobiological state produced in EMDR, which is akin to that experienced during REM sleep, therefore serves to enhance the brain's ability to integrate traumatic memories into general semantic networks in the cortex. It is this integration, the author argues, that then decreases the salience of the episodic memories of the traumatic event, as mediated by the hippocampus; furthermore, the unpleasant affects associated with the memories, which are largely dependent upon the amygdala, also show reductions in potency (Stickgold, 2002).

Nelson et al. (1983) also comment upon the REM-sleep hypothesis, as they state that alternating stimulation causes a repetitive reorientation of attention, which may lead to a lowered adrenergic drive and subsequent shift of the brain's memory processing into a mode akin to that experienced during REM-sleep (Sack, Lempa, et al., 2008). In this way, Nelson et al. (1983) describe a mechanism of action that bridges the two theories of REM-sleep and an orienting response.

It is worth noting that other theories of REM sleep and dreaming may relate to the current investigation. For example, some researchers argue that REM sleep is not required for dreaming to occur, asserting instead that dopaminergic forebrain mechanisms are distinct from the brain stem cholinergic mechanisms associated with REM sleep (Solms, 2000). Cerebral activation can induce dreaming when the dopaminergic circuitry of the ventromedial forebrain is engaged, according to Solms (2000); this would mean that not only REM sleep is capable of inducing a dream state, as dreaming and REM sleep constitute two dissociable states with distinct physiological components. Thus, looking into non-REM sleep states (such as slow wave sleep) as potential mechanisms in EMDR may be worthwhile, given the recent findings related to such states.

**The Orienting Response.** The orienting response is one of the predominating and frequently researched theories behind the mechanism of action in EMDR, and is a process first described by Pavlov in 1927 (Armstrong & Vaughan, 1996). According to Armstrong and Vaughan (1996), the orienting response is a behavioral response triggered by a stimulus that aids in the extraction of environmental information deemed to be most important for the individual. In individuals with PTSD, certain traumatic stimuli are already established in what Armstrong and Vaughan (1996) label a cortical set: when presented with the same or similar stimuli, these individuals will be triggered to respond in a certain way. In other words, they have a lower threshold for such stimuli, which ensures rapid recognition of stimuli related to the trauma (Armstrong & Vaughan, 1996).

Sack, Lempa, et al. (2008) describe the orienting response phenomenon as a reaction to an environmental change, during which an individual's attention aligns with a source of sensory signals. Sack, Lempa, et al. (2008) draw upon the findings of Posner and Rothbart (2007) when they further state that the orienting response draws upon the executive attention networks thought to play a role in an individual's ability to regulate both positive and negative affect, by causing these networks to investigate the information presented to them. Sokolov et al. (2002) also comment upon the orienting reflex, as they call it, stating that neurotransmission and parts of the hippocampus are involved when this reflex activates cholinergic pathways and early gene expression. Specifically, they assert that the primitive mechanism of the orienting reflex may be triggering gene expression and transforming synapses intracellularly as the starting point in the formation of a long-term memory trace (Sokolov et al., 2002). The authors state that the protein-coding Cathelicidin Antimicrobial Peptide (CAMP) gene activates the transcription factor CREB (the CAMP-response element-binding protein) and this subsequently attaches to a DNA molecule; such transcription induces a gene transcription cascade that causes synaptic structural changes, which forms the basis of long-term neuroplasticity (Sokolov et al., 2002).

Elofsson et al. (2008) also describe the orienting response in relation to its effect on cholinergic pathways, stating that the eye movements in EMDR activate the parasympathetic (cholinergic) nervous system while simultaneously preventing regulation via the sympathetic nervous system. Specifically, these authors found that eye movements lead to the following physiological changes during EMDR treatment sessions: the sympathetic drive decreases in the beginning of sessions, as evidenced by a drop in skin conductance and an increase in skin temperature, while the parasympathetic drive is increased, as indicated by a decelerating heart rate and by differences in balance between high frequency and low frequency heart rate variability (Elofsson et al., 2008). They report further within-session patterns during stimulation phases, including a trend showing an increase in an individual's rate of breathing, a decrease in heart rate, and an increase in fingertip temperature (Elofsson et al., 2008). However, Elofsson et al. (2008) were unable to conclusively attribute such physiological changes to the definite occurrence of an orienting response.

Sack et al. (2008) further discuss the psychophysiological impact of the orienting response, citing previous research that found that individuals have short-term, spontaneous reactions that involve a heightened parasympathetic tone, a lowered heart rate, and a decrease in sensory gate levels. Other research teams led by Barrowcliff also comment upon the lower levels of electrodermal arousal experienced by individuals receiving eye movements as compared to those in a control condition (Barrowcliff et al., 2003; Barrowcliff et al., 2004). Overall, physiological changes and the parasympathetic nervous system in particular appear to play a significant role in the orienting response theory, as evidenced by the above findings.

## Statement of the Problem and Research Question

### *Problems with Agreement in the Field*

Further investigation into the proposed mechanism of action behind EMDR appears to be mandated, given the wide range of theories present in the literature today. Given the theories listed above, there appear to be several concepts that continually rise to the surface of scrutiny when research studies are conducted on this topic. However, there also appears to be a lack of coherent agreement on what each proposed mechanism entails; that is, consistent terminology appears somewhat sparse. In order to review, compare, and contrast the theories around the mechanism of action in EMDR that have garnered the most support in the research, it is therefore necessary to first review the literature and assimilate concepts that may differ in terminology, but appear overall equivalent in nature. After drawing coherent distinctions between these ideas and generating a set of proposed hypotheses to be investigated, the process of evaluating the most likely mechanism of action in EMDR can ensue.

By reviewing the existing research in the field, this manuscript aims to answer the question of which prominent theory of the mechanism of action behind EMDR appears to have garnered the most empirical support in the literature. In doing so, a systematic review of the evidence for and against each theory will be conducted; this review will compare and contrast the theories and evaluate the amount of research in support of each one. Finally, this manuscript will propose the most likely explanation for the effectiveness and success of EMDR, given the state of the research.

This manuscript will investigate the empirical strength of various theories based upon Gunter and Bodner's (2009) four potential accounts of the mechanism of action in EMDR: a disruption in/taxation of working memory; psychological distancing; increased interhemispheric communication; and psychophysiological changes (subsumed in this account are the orienting response, induction of a REM-like state, and reciprocal inhibition). Research studies that discuss potential theories that either mirror or relate to these four accounts will be incorporated into the investigation.

***Research Question***

The primary research question of this study relates to which prominent theory regarding the mechanism of action in EMDR appears most compelling, based upon empirical literature in the field. Each theory will be reviewed, compared, and contrasted in terms of conjecture as well as amount of empirical support; finally, an argument will be made for the most likely explanation for the success of EMDR, based on this review.

The research question can therefore be divided into the following subparts, to further elucidate the aims of this investigation:

**RQ1)** Which theory, based upon the four potential accounts listed by Gunter and Bodner (2009), has garnered the most empirical research and support in the field?

**RQ2)** Based on the research, what is the most likely explanation for how EMDR has achieved success as an effective form of therapy?

By conducting a critical review of the literature, this manuscript will attempt to elucidate the answers to these questions. In addition to surveying the likely mechanism of action behind this therapy, two other aspects of EMDR will also be discussed in this review to provide a glimpse into the literature present in the field. These areas of research include controversies around the use of eye movements and the supposed neurobiological underpinnings of EMDR.

## Chapter 3. Review and Analysis Procedures

It is proposed that a thorough analysis of the literature be conducted to in order to review the current research on the mechanism of action in EMDR. A qualitative review of the literature is suggested. Research studies on the underlying changes seen in psychological, physiological, and neuroanatomical pathways during EMDR therapy have revealed various and occasionally conflicting findings over the past several decades. In their accounts of how EMDR brings about change, these investigations tend to converge upon distinct hypothetical constructs that are consistently mentioned in the literature. Following a preliminary literature review and consolidation of the varied terminologies seen in these hypothetical accounts, the critical analysis proposed by this manuscript will be able to ensue.

The purpose of this investigation is twofold: (a) To examine the assertions subsumed in the field's current leading theories regarding the mechanism of action in EMDR and the degree to which these hypotheses have received empirical support in the literature, and (b) To make an argument for the most likely explanation for the achieved success of EMDR as an effective form of therapy. To accomplish this, a critical analysis of the literature will be conducted for the purpose of reviewing literature that pertains to four distinctive and predominant theories regarding the mechanism of action in EMDR. These include the working memory taxation hypothesis, the psychological distancing hypotheses, the interhemispheric interaction hypothesis, and the psychophysiological changes hypothesis (which includes the subsumed accounts of reciprocal inhibition, REM-like state induction, and the orienting response). Supplemental examinations will also be performed on the role of eye movements in the therapy and the resultant controversies of their use, as well as the functional neurobiological correlates of EMDR, including neural structures and pathways that have been implicated in the therapy.

Detailed information regarding the proposed areas of research, databases to be used along with dates of publication, keywords to be searched, inclusion/exclusion criteria, and the primary methods of research to be used in the present manuscript are discussed below.

## Primary Methods of Research

When investigating the psychological constructs included in the mechanism of action theories, this manuscript will likely include both independent experimental investigations on human participants, as well as various meta-analyses and empirical literature reviews that aim to consolidate the findings of such independent experimental designs.

Regarding research on the neurobiology of EMDR, the studies included in this review will likely use multiple methods to examine the functional development of brain structures and neural pathways, including those seen in both the limbic system and cortical regions. These methods are expected to include electrophysiological stimulation techniques and imaging techniques. Structural and functional brain imaging techniques may aid in the localization and detection of neural circuitry and structures thought to be involved in EMDR by measuring the blood flow changes in the brain. These measurements often permit researchers to draw associations between observed neural activity and corresponding mental functions. To examine dysfunctional brain regions and neural circuitry pathways, some studies may also utilize mechanical and chemical techniques whereby intentional lesions are made to specific brain regions in animal subjects, with subsequent measurement of observed impairments on ability-specific tasks.

## Compilation of Literature Review

### *Inclusion and Exclusion Criteria*

Peer-reviewed articles from scholarly journals and textbook publications will be investigated depending on the amount of citations in other sources that they have accrued up until the point at which they are examined as part of this investigation between the years of 2019 and 2020. For all articles published prior to 2015, the cut-off for the publication's citation total will be fixed at five, to ensure that only pertinent research with an adequate amount of impact and impact in the field will be included in this review. This determination is subject to change based on the current state of the literature and the publication age of relevant studies that will be examined. However, given that more recent studies are apt to have fewer citations as a result of their nascence, articles and publications will not be excluded solely on the basis of citation amount if the content is deemed appropriate and pertinent to this investigation. Rather, all relevant articles published in or after 2015 will be examined and incorporated into the review. This stipulation is designed to optimize the comprehensive nature of this investigation while attempting to maintain its empirical validity, and as such it is subject to change as the review process continues to evolve.

Literature reviews and meta-analyses that include experimental studies on human subjects will be examined as they pertain to the role of eye movements and the existing theories on the potential mechanism of action in EMDR. In addition, research studies on rodent, primate, and human subjects may be included as they pertain to the neurobiological aspects of EMDR, including functional brain development and the neural structures and pathways implicated in the therapy. Subjects in the reviewed literature are expected to range in age from gestation to adulthood, depending on the methodology and purpose of each study, and will predominantly stem from human populations. It is expected that the studies examining human participants who are actively receiving EMDR therapy will include subjects ranging in age from late adolescence to late adulthood.

***Data Sources***

Most sources will be acquired from literature that is relevant to the present investigation on EMDR therapy and the proposed hypotheses regarding how it works. The dissertation will include peer-reviewed empirical articles on research findings that are relevant to the aforementioned mechanism of action theories, the role of eye movements, the neurobiology of EMDR, and other topics that inform the research questions. Notwithstanding, there are limitations to the availability of empirical studies exploring the mechanism of action behind EMDR, given its relative nascence in the field of clinical psychology and recent identification as an empirically supported treatment modality.

Textbooks and manuals will also be consulted as needed, in order to review topics such as the psychological constructs underlying theories on how EMDR works, bilateral stimulation and eye movements, neuropsychological foundations of behavior, functional brain development, as well as neural structures, circuitry, and dysfunction.

***Search Strategy Databases and Key Phrases***

An initial search will be conducted using the Google Scholar database, in order to permit a review of broad themes in the literature and gather a wide breadth of articles. Afterwards, the investigation will continue via the databases of EBSCOHost and PsycInfo, in order to facilitate a narrower and comprehensive collection of empirically reviewed psychological and neurobiological articles related to the stated areas of research. The details of this search strategy are further elaborated upon below.

First, publications will be searched for in the GoogleScholar database using the following key phrases: working memory disruption hypothesis of EMDR, psychological distancing hypothesis of EMDR, interhemispheric integration hypothesis of EMDR, psychophysiological changes hypothesis of EMDR, counter conditioning hypothesis of EMDR, reciprocal inhibition hypothesis of EMDR, REM-like state hypothesis of EMDR, orienting response hypothesis of EMDR, orienting reflex hypothesis of EMDR.

Second, the search will continue via the EBSCOHost Academic Search Complete database. In order to maximize the amount of articles garnered, the following Boolean search terms and combinations will be utilized for the EBSCOHost Academic Search Complete database: EMDR or eye movement desensitization and reprocessing + working memory; EMDR or eye movement desensitization reprocessing + distancing; EMDR or eye movement desensitization reprocessing + interhemispheric; EMDR or eye movement desensitization reprocessing + psychophysiological; EMDR or eye movement desensitization reprocessing + counter conditioning; EMDR or eye movement desensitization reprocessing + reciprocal inhibition; EMDR or eye movement desensitization reprocessing + REM or rapid eye movement; EMDR or eye movement desensitization reprocessing + orienting response; EMDR or eye movement desensitization reprocessing + orienting reflex.

Lastly, the search will continue via the PsycInfo database. In order to maximize the amount of articles garnered, the following Boolean search terms and combinations will be utilized for the PsycInfo database: EMDR or eye movement desensitization and reprocessing + working memory; EMDR or eye movement desensitization reprocessing + distancing; EMDR or eye movement desensitization reprocessing + interhemispheric; EMDR or eye movement desensitization reprocessing + psychophysiological; EMDR or eye movement desensitization reprocessing + counter conditioning; EMDR or eye movement desensitization reprocessing + reciprocal inhibition; EMDR or eye movement desensitization reprocessing + REM or rapid eye movement; EMDR or eye movement desensitization reprocessing + orienting response; EMDR or eye movement desensitization reprocessing + orienting reflex.

Additional databases may be consulted as needed. Naturally, the list of databases and publications included in this review is expected to evolve as the literature review progresses. Additional key words specifically related to the neurobiological correlates of EMDR that are pertinent to the aforementioned search terms may be utilized whenever needed, in order to increase comprehension and qualitative support for the primary topic areas. The listed key words and phrases are provisional, given that the literature review and critical analysis will be continuously evolving as this investigation proceeds. It is likely that this list will expand during the course of the literature review.

**Screening and Synthesis of Research**

Articles retrieved from the above databases will be screened based on their titles and abstracts in order to ensure relevance to the goals of this investigation: namely, to review and analyze commonalities between the aforementioned theories on the mechanism of action in EMDR. Studies that are determined to be irrelevant to this investigation will be removed from the selection. Additional subtopics that are deemed pertinent to the ongoing investigation will be researched in an effort to optimize comprehension of and support for the main topics included in this review (i.e., concepts related to neurobiological mechanisms). The studies will then be analyzed for eligibility requirements based on inclusion and exclusion criteria. The studies that meet inclusion criteria based upon eligibility will be qualitatively synthesized and categorized into their corresponding topic areas using Excel files. These comprehensive tables will be included in the final results section along with graphs that indicate the percentage of articles included per topic area.

## Reviewing the Literature

### *Categorization of Literature Findings*

An Excel spreadsheet will be utilized in order to categorize, organize, and finally analyze the publications retrieved for this investigation. Relevant notes and quotations from each source will be added into the Excel file, which will be organized based on each article's title, author, amount of citations, and publication date. The publications included in this investigation will be categorized according to subtopics, based on the content, objective, and findings of each data source. The following subtopics are proposed for use as classification categories when organizing and summarizing the included publications: Working memory taxation hypothesis support; Working memory taxation hypothesis rejection; Psychological distancing hypothesis support; Psychological distancing hypothesis rejection; Interhemispheric interaction hypothesis support; Interhemispheric interaction hypothesis rejection; Psychophysiological changes support; Psychophysiological changes rejection; Psychophysiological changes (reciprocal inhibition) hypothesis support; Psychophysiological changes (reciprocal inhibition) hypothesis rejection; Psychophysiological changes (REM-like sleep) hypothesis support; Psychophysiological changes (REM-like sleep) hypothesis rejection; Psychophysiological changes (orienting response) hypothesis support; Psychophysiological changes (orienting response) hypothesis rejection; Neurobiology of EMDR; Supporting evidence for eye movements in EMDR; Evidence against eye movements in EMDR; Integrative models that support a combination of working mechanisms. These categories are naturally subject to change as the investigation evolves.

A certain amount of crossover is expected to be seen when organizing articles, as many publications include investigative inquires that span multiple subtopics (i.e., a study wherein neurobiological findings are used in support of the orienting response hypothesis). Therefore, a data table will be developed that includes every article reviewed in this manuscript and an indication of the subtopic(s) that each article falls under. Each publication will have an "X" placed in the corresponding subtopic column(s) to indicate its investigative content. Thus, this categorization data table will subsequently inform how each article will contribute to the summarization of literature findings. Figures and graphs may also be developed to demonstrate the ratio or percentage of studies that inform each subtopic. A prototype of the proposed data table can be seen in Table 2 at the end of this manuscript.

**Analysis of Data and Organization of Findings**

The categories presented in Table 2 along with the information collected in the Excel spreadsheet will serve as an outline for the organization of this manuscript. Then, the dissertation will review the available literature and identify the information relevant to the mechanism of action in EMDR and the pertinent supplemental topics listed above. The literature will be synthesized in order to present the assertions, empirical support, and commonalities and differences between the four theoretical accounts under investigation. Associations between EMDR, the role of eye movements, and areas of the brain associated with these theories will also be summarized and presented. Based on the review of this literature, the research questions will be evaluated, clinical applications will be discussed, and recommendations will be made for future areas of study.

## Chapter 4. Results

The purpose of this investigation was to review the current state of the literature on how EMDR works, with the intention of discovering which theory (or theories) has garnered the most empirical research and support in the field. The details of these accounts were comprehensively examined in an effort to understand their assertions as well as the similarities and differences between them. Following the results of this review, a discussion on how EMDR has achieved success as an effective form of therapy will be able to ensue.

### Breakdown of Sample Characteristics

In following the search strategy, a total of 221 articles were accumulated that spanned the categories listed in the Excel table included in Appendix C. After accounting for duplicates across categories, the sample dropped to 132. Using this sample, a careful review of abstracts and article contents ensued, to ensure that only publications pertinent to this investigation were included. Articles that did not meet inclusion criteria (30 of the remaining sample) were excluded. Thus, the final sample consisted of 102 distinct articles that met criteria for inclusion in this study. Each of the 102 articles was thoroughly reviewed and categorized into subtopics according to those listed in Table 2; however, in order to ensure organization of additional article information and accommodate the size of the final Excel table, the table was formatted for inclusion in an Appendix. A separate Excel spreadsheet and Word document were also used to keep track of relevant notes, quotations, sample characteristics, methodologies, and findings for each article.

After completion of the sample review, the final table included in Appendix C was utilized to delineate how many articles and pieces of literature were categorized under each subtopic, the results of which can be found in the Excel table seen in Appendix D. It should be noted that multiple articles fell under more than one category. The categorical breakdown by subtopic is as follows: Working Memory Support (32 articles); Working Memory Rejection (3 articles); Psychological Distancing Support (6 articles); Psychological Distancing Rejection (none); Interhemispheric Interaction Support (6 articles); Interhemispheric Interaction Rejection (5 articles); Psychophysiological Changes Support (27 articles); Psychophysiological Changes Rejection (1 article); Psychophysiological Changes (Reciprocal Inhibition) Support (6 articles); Psychophysiological Changes (Reciprocal Inhibition) Rejection (1 article); Psychophysiological Changes (REM-like State) Support (10 articles); Psychophysiological Changes (REM-like State) Rejection (none); Psychophysiological Changes (Orienting Response) Support (17 articles); Psychophysiological Changes (Orienting Response) Rejection (3 articles); Neurobiological Mechanisms and Correlates (38 articles); Integrative Models (14 articles); Eye Movement Support (75 articles); Eye Movement Rejection (4 articles). A visual representation of the percentage of articles in support of each account can be seen in Figure 1 at the end of this document. Additionally, Figure 2 delineates the percentage of support for each theory subsumed under the psychophysiological changes account.

**General Trends**

In terms of the categories used for this investigation based on Gunter and Bodner (2009), it appears that the working memory taxation account has been investigated and supported the most often. However, studies examining the psychophysiological changes that accompany EMDR in general (irrespective of specific psychophysiological mechanisms) have also garnered a substantial amount of support, relative to the body of research reviewed in this investigation. Regarding the three subsumed psychophysiological theories, the orienting response model appears to have garnered the most empirical support, followed by the induction of a REM-like state, which in turn has received slightly more support than the reciprocal inhibition account. Distinct neurobiological mechanisms as well as the underlying neural structures and pathways that are thought to accompany certain theoretical accounts have also been discussed extensively in the literature. Furthermore, a substantial number of research teams have opted for an integrative model: that is, rather than supporting only one of the theories listed above, they have proposed an account that integrates multiple mechanisms.

The overwhelming majority of articles included in the review were in support of eye movements as an effective and necessary component of the overall EMDR procedure; however, other forms of bilateral stimulation and distractor tasks have been demonstrated to be effective in many of these studies. These results along with a breakdown of findings related to each subtopic and theory will be discussed in detail below. The categorical sections will be organized based on Table 2 and include the following headings: Working Memory Taxation Hypothesis, Psychological Distancing Hypothesis, Interhemispheric Interaction Hypothesis, Psychophysiological Changes Hypothesis (including the three subsumed accounts of Reciprocal Inhibition, REM-like State, and The Orienting Response), Neurobiological Mechanisms and Correlates, Integrative Models, and Controversy Over the Role of Eye Movements.

## Working Memory Taxation Hypothesis

Of the articles included in this investigation, 32 were in support of working memory taxation, while three rejected it. Some studies specified whether a slave system of working memory - the phonological loop (PL) or visuospatial sketchpad (VSSP) - was more impacted by dual tasks, or whether taxation of the broader central executive (CE) system was responsible for the effects seen. Others commented on the system as a whole or discussed a combination of effects depending on the sensory modality. These distinctions are discussed below.

### *General Working Memory Taxation*

Many studies do not specify which system of working memory was taxed but do suggest that taxation of working memory in general is responsible for the positive effects seen in their experimental design. De Jongh and colleagues (2013) asked 64 clinical participants, half with PTSD and half with another diagnosis, to bring up a traumatic memory while undergoing three consecutive tasks: performing eye movements, listening to bilateral auditory tones, and looking at a blank wall (recall only control condition) for six minutes each. Results showed that eye movements were better at reducing memory emotionality than recall only, while a trend showed that tones were less effective than eye movements, but more effective than recall only; findings for vividness were insignificant (De Jongh et al., 2013). Interestingly, the majority of subjects (64%) preferred using auditory tones to continue treatment, as opposed to eye movements or recall only (De Jongh et al., 2013). The authors also found that the observed effects did not differ between PTSD patients and those diagnosed with other conditions; thus, they assert that their findings provide further evidence of how valuable eye movements are in EMDR, and suggest a potential application to disorders other than PTSD (De Jongh et al., 2013).

De Voogd et al. (2018) recently used 48 healthy participants across two experiments to test the hypotheses that eye movements could suppress amygdala activity as a working memory task, and that they could subsequently reduce fear recovery following memory reactivation. In their first experiment, they utilized functional MRI while participants performed one of two working memory tasks: a two-back task or eye movements; in addition to amygdala suppression, they assessed whether these tasks would modify the connection between the amygdala and dorsal lateral prefrontal cortex (De Voogd et al., 2018). Their second experiment implemented eye movements as part of a Pavlovian fear conditioning, extinction, and recall model to see if they would prevent fear recovery by way of amygdala deactivation (De Voogd et al., 2018). Their results showed that both working memory tasks deactivated the amygdala, while altering connectivity between the amygdala and dorsal frontoparietal network, and between the amygdala and ventromedial prefrontal cortex (De Voogd et al., 2018). Additionally, utilizing eye movements during extinction learning inhibited spontaneous recovery 24 hours later, and recovery after reinstatement of the fear response was attenuated if the amygdala was more strongly deactivated by eye movements (De Voogd et al., 2018). They concluded that eye movements are more than a standard extinction procedure, as they contribute to safety learning and tax the working memory system (De Voogd et al., 2018). They assert that these effects are likely due to concurrent amygdala deactivation and dorsofrontal parietal activation via pathways in ventromedial prefrontal regions, which are also seen in the cognitive process of emotion regulation (De Voogd et al., 2018).

Engelhard et al. (2010) asked 28 non-clinical participants to visualize two feared future events while participating in an eye movement condition or an exposure-only control condition (no eye movements) and tracked changes in ratings of vividness and emotionality. They found that eye movements led to decreases in vividness and emotionality for anxiety-provoking images of feared future events, consistent with research on past-oriented distressing memories (Engelhard et al., 2010). While their results suggested a dose-response relationship of working memory taxation (greater taxation leading to greater reductions in vividness), they conceded that an inverse U-curve relationship may also be possible, as presented by Gunter and Bodner (2008): there may exist an optimal level of taxation, with too little or too much taxation leading to less beneficial effects in reducing vividness (Engelhard et al., 2010).

Engelhard and colleagues (2011) conducted another study that investigated vividness and emotionality of distressing images of future events ("flashforwards") with 37 non-clinical participants who suffer from intrusive thoughts, via two conditions: recall with eye movements and recall only (control). While neither result was significant, they found trends for recall plus eye movements being superior to recall only in reducing vividness and emotionality (Engelhard et al., 2011). They discuss how it may be beneficial to adapt the degree of taxation (i.e., using eye movements or even more taxing tasks) to each individual's working memory span (Engelhard et al., 2011).

Although Littel and Van Schie (2019) did not use eye movements, they examined the likelihood of a linear versus a quadratic relationship of working memory taxation (i.e., based on the inverted U-curve suggestion), using 44 non-clinical undergraduates in four conditions: complex, intermediate, or simple subtraction, or no counting (control). Unlike Engelhard et al. (2011), they found strong evidence of a linear dose-response relationship, while the inverted U-curve was not supported, as greater taxation led to greater memory degradation in the form of reduced vividness and unpleasantness (Littel & Van Schie, 2019).

In their recent review of research on trauma memory, Engelhard et al. (2019) assert that there is a substantial amount of research backing the effectiveness of eye movements in EMDR. Consistent with the working memory taxation account, they discuss research that has found support for multiple dual tasks, including eye movements, backwards counting, attentional breathing, and playing Tetris on a computer (Engelhard et al., 2019). Specifically, they call for more research on modality-specific interference (i.e., auditory taxation for auditory memories, and visual taxation for visual memories), assert that faster eye movements are more effective than slower eye movements, and suggest that eye movements may weaken an aversive memory enough to encourage reappraisal (Engelhard et al., 2019).

In a unique within-subjects experiment with 53 healthy undergraduates, Hornsveld et al. (2011) investigated the impact of eye movements on positive memories (pride, self-confidence, and perseverance) akin to those used in the Resource Development and Installation (RDI) phase of EMDR. The three conditions included vertical eye movements, horizontal eye movements, and a recall-only control, and they tested the theories of working memory taxation (WM) and interhemispheric interaction (II); they predicted that decreases in vividness/strength/pleasantness would support the WM account, while increases would support the II account (Hornsveld et al., 2011). Results wholly supported the WM account, and vertical eye movements actually outperformed horizontal eye movements in decreasing all three outcome variables; given their findings, the authors call into question the ethical use of eye movements during RDI, as they appear to be detrimental to the overall goal of this phase (Hornsveld et al., 2011).

Leer et al. (2013) compared eye movements versus recall-only (control) in 63 healthy female undergraduates via a differential conditioning paradigm using aversive film fragments; they measured vividness, emotionality, and arousal via skin conductance. Although skin conductance was not correlated, they found that eye movements caused reductions in vividness, emotionality, and conditioned fear, which they argue could not be attributable to mere imaginal exposure; thus, they assert that their findings extend support for working memory taxation to include aversive film fragments (Leer et al., 2013).

Maxfield et al. (2008) investigated modality-specific interference via reductions in vividness, emotionality, and thought clarity in conditions of fast, slow, and no eye movements using a non-clinical undergraduate group. In the first experiment ($n = 24$), emotionality showed no significant reductions, but both fast and slow eye movements reduced vividness, with faster eye movements having a greater effect; the second experiment ($n = 36$) revealed that only fast eye movements led to significant reductions in both vividness and emotionality. Contrary to Kemps and Tiggeman (2007; mentioned below), they found no evidence of modality-specific interference, given that both slow and fast eye movements led to decreased thought clarity; rather, they argue in favor of consolidation via all four components of working memory (CE, PL, VSSP, and episodic buffer), as opposed to independent constructs of VSSP and PL (Maxfield et al., 2008). The authors also mention the likelihood of a distancing effect, which allows for more detached processing to occur (Maxfield et al., 2008).

Van Veen et al. (2015) replicated the findings of Maxfield et al. (2008) by studying how working memory load of an image interacts with that of eye movement speed by using non-clinical participants, five different speeds versus a control condition (no eye movements), non-distressing and negative autobiographical memories, and a reaction time task. Results of the first experiment ($n = 36$) supported taxation via eye movements, with the speed of 1.2 Hz reducing vividness and ease of image retrieval more so than 1.0 Hz and 0.8 Hz, which did not differ from each other; the second experiment ($n = 72$) also revealed that greater taxation outperformed lower taxation (1.2 Hz > 0.8 Hz) for reductions in vividness, emotionality, and ease of retrieval, which in turn outperformed recall only (Van Veen et al., 2015). Given that working memory load of the memory itself (i.e., vividness) did not interact with load of the dual task, they did not find support for the inverted U-curve theory proposed by Gunter and Bodner (2008) (Van Veen et al., 2015).

In 2016, Van Veen and colleagues again used 108 healthy undergraduates to investigate cognitive load via reaction time during eye movements versus only recall (control one) or only cognitive effort (control two), using relevant and irrelevant aversive autobiographical memories. They found that cognitive load of memory recall was similar to that of eye movements, given increased reaction times; furthermore, reductions in emotionality and vividness increased with longer durations of the dual task, and were not attributable to recall only or general cognitive effort (Van Veen et al., 2016).

Mertens, Krypotos, et al. (2019) used a non-clinical sample (*n* = 100) to investigate eye movements via four tasks: letters appearing on different sides of a screen, a moving dot, a combined condition, and a control task; outcome measures were auditory reaction time for the first experiment, and vividness and emotionality of a negative autobiographical memory for experiment two. Results of experiment one demonstrated that all three dual tasks led to significantly increased reaction time (greater taxation), with letter identification being most effective, followed by the combined dot tracking and letter identification task, and lastly dot tracking; in experiment two, all three tasks led to significant decreases in emotionality and vividness, with no distinctions between task (Mertens, Krypotos, et al., 2019). Given that there was no consistent relationship between greater taxation leading to greater memory degradation (i.e., letter identification task showing greater reductions), Mertens, Krypotos, et al. (2019) suggest that the working memory account may not be wholly responsible; rather, meta-cognitive beliefs or self-efficacy may also impact effects of eye movements, and should be tested.

Mertens, Bouwman, et al. (2019) conducted two experiments (*n* = 36; *n* = 60) with non-clinical students in which they installed novel visual and auditory unpleasant memories with pictures and sounds from databases, while assessing modality-specificity and cognitive load of dual tasks; conditions included an auditory task, an eye movement task with letters on a screen, and a control (blank screen). Both auditory and visual tasks led to reduced emotionality and vividness, but there was only evidence of modality-specificity for vividness in experiment one (auditory memories less vivid after auditory task, visual memories less vivid after visual task);

given that emotionality reductions were unrelated to modality-specific interference, the authors suggest that modality-matched dual tasks are not exclusively necessary for memory degradation (Mertens, Bouwman, et al., 2019). They conclude that the working memory account may be over-simplified and may operate in tandem with other factors, such as changes in memory appraisal and positive expectancies in the laboratory setting (Mertens, Bouwman, et al., 2019).

Pagani and Carletto (2017) speculate about the role of slow wave sleep (SWS) and other mechanisms in EMDR, stating that implicit highly emotional memories in subcortical regions may be transferred to cortical regions, thus allowing for proper processing to occur via semantic networks; specifically, they argue that SWS and working memory taxation (of VSSP and CE) are both permissible hypotheses and likely work in tandem during EMDR. They assert that slow wave sleep is involved in memory consolidation, transfer of hippocampal information to the neocortex, and reorganization of distant functional networks, which is further strengthened in REM sleep (Pagani & Carletto, 2017). Neurobiologically, they suggest that limbic neurons are depolarized at a slower rate via bilateral stimulation, such that emotional memories dysfunctionally stuck in the amygdala can move to and be fully processed by higher brain areas (Pagani & Carletto, 2017). In a similar vein, Pagani et al. (2017) conducted a review discussing the role of EMDR in depotentiation of AMPA receptors in the amygdala, which are over-potentiated during traumatic events, thus inhibiting normal potentiation in hippocampal regions for episodic memory encoding. They speculate that desensitization in EMDR occurs via depotentiation of fear memory synapses; if this is proven correct, they assert that such a mechanism could account for the effects explained by the orienting response, working memory taxation, and the hypothesis of Stickgold (2008) concerning REM sleep (Pagani et al., 2017).

Smeets et al. (2012) looked at the time course of reductions in vividness and emotionality in 61 healthy undergraduates and found that eye movements outperformed control (stationary dot) by reducing vividness after only two seconds of intervention and continuing until ten seconds before leveling off, supporting a non-linear relationship of vividness reduction. However, emotionality reductions were only significant over a gradual time period of 74 seconds and between sets, suggesting that changes in vividness precede changes in emotionality (Smeets et al., 2012). They suggest that eye movements impact the ability to keep a visual image active by mediating rate and frequency of memory refreshment, thus supporting working memory taxation (Smeets et al., 2012).

Using 72 healthy undergraduates across two experiments, Van den Hout et al. (2011) assessed attentional breathing (AB) of Mindfulness-Based Cognitive Therapy (MBCT), eye movements (EM) in EMDR, and a control task in their abilities to reduce vividness and emotionality of aversive memories, using a reaction time (RT) task as a measure of working memory taxation. In both experiments, both AB and EM led to increases in RT, suggesting that they both tax working memory comparably (Van den Hout et al., 2011). However, in experiment one, EM reduced both vividness and emotionality while AB only reduced emotionality; in experiment two, EM and AB both reduced vividness equally, but nether reduced emotionality (Van den Hout et al., 2011). Furthermore, the degree of WM taxation by EM during the RT task predicted subsequent decreases in memory vividness (Van den Hout et al., 2011).

In a review, Van den Hout et al. (2012) discuss and offer evidence to support and refute multiple theories of how EMDR works, including the finding that dual tasks are crucial as long as they tax working memory, but they do not have to be bilateral. They discuss how Lee and Cuijpers (2013) found eye movements to be additive and beneficial, suggesting that EMDR effects cannot stem solely from exposure alone; given that Gunter and Bodner (2008) found that vertical and horizontal eye movements were both effective, they also argue that the increased interhemispheric interaction account is likely incorrect (Van den Hout et al., 2012). They back findings of effectiveness for multiple dual tasks (i.e., mindful breathing) while binaural stimulation (i.e., beeps) has been shown to be largely ineffective; additionally, they assert that the use of eye movements during the RDI phase renders the installment of positive cognitions or recollections ineffective and possibly harmful (Van den Hout et al., 2012). Finally, they discuss the likelihood of an inverted U-curve of taxation, and how those with lower working memory capacity likely benefit more from taxation via eye movements (Van den Hout et al., 2012).

Van den Hout and colleagues (2014) conducted another investigation using 40 non-clinical undergraduates to test whether emotional memories show greater reductions in vividness than neutral memories, using recall plus eye movements or recall only (control). Although eye movements produced significant decreases in vividness for emotional memories, there were no significant effects on emotionality; additionally, eye movements had no effect on neutral memories, suggesting that emotional memories may be a prerequisite for memory degradation (Van den Hout et al., 2014). Van den Hout et al. (2014) speculate that this may be due to noradrenergic activation that leads to greater encoding and recall of emotional memories, or due to such memories requiring more working memory resources in general.

Van Schie et al. (2016) tested whether speed of eye movements should be adapted to an individual's working memory capacity in 66 healthy undergraduate participants, by using reading span and sentence evaluation tasks as measures of such capacity. Fast eye movements were more effective in reducing vividness and emotionality of memories than slow eye movements, with both outperforming recall-only (control); however, no support was found for adjusting the level of taxation to an individual's working memory capacity (Van Schie et al., 2016). Thus, their findings support the idea that increasing the speed of eye movements leads to greater effectiveness; however, they contradict the concepts of an inverted U-curve and titration of taxation based on working memory capacity (Van Schie et al., 2016).

Van Schie et al. (2019) again used healthy undergraduates to investigate vividness, unpleasantness, and intrusive thoughts of trauma film (analogue) memories, via three experiments ($n$ = 76, 74, and 100) with conditions of eye movements, counting, no task, and recall only (two controls). Eye movements and counting were significantly more taxing (based on reaction time) than control conditions, although neither led to consistent decreases in outcome variables (Van Schie et al., 2019). Given that counting was slightly more taxing, they suggest that modality-specific interference is possible, and discuss how working memory taxation may work alongside other mechanisms, such as memory reappraisal (Van Schie et al., 2019).

Yaggie et al. (2015) suggested that working memory taxation occurs in tandem with other mechanisms; they used EEG to examine interhemispheric coherence in 46 healthy female undergraduates via conditions of eye movements with a light bar, stationary dot, and stationary dot with background bilateral light movements, followed by free association periods. All three conditions decreased vividness and emotionality of memories (Yaggie et al., 2015). They found no evidence of interhemispheric coherence for any condition, but did find intrahemispheric coherence in the form of increased coherence between right frontal theta and beta EEG following eye movements; this suggests that a focus was placed on associations more relevant to the target event, in regions responsible for higher order processing, alertness, and attention (Yaggie et al., 2015). The increased theta coherence in right frontal regions also suggests increased self-referential processing of affective memory components, ultimately leading to a two-stage cortical coherence model: bilateral stimulation facilitates increased neural interconnectivity, allowing for the formation of more constructive associations between traumatic memories and positive reframes (Yaggie et al., 2015). As the authors discuss, their proposed model integrates conditioning as proposed by Dyck (1993) and Denny (1995) (the latter of which includes inhibition via an OR), and the accounts of imagination deflation/working memory taxation (CE and VSSP) and physiological connectivity that have been put forth by various research teams (Yaggie et al., 2015).

***Visuospatial Sketchpad (VSSP) Taxation***

Andrade et al. (1997) used a controlled within-subjects design with 118 non-clinical participants to examine whether dual tasks (i.e., eye movements, spatial tapping, and counting) led to decreases in emotionality and vividness of distressing and neutral images. They found that eye movements and complex tapping both reduced ratings of vividness, with eye movements leading to the greatest reductions, while counting did not have any effect; however, results for emotionality were inconsistent (Andrade et al., 1997). The authors asserted that these findings were in support of the hypothesis that visual dual tasks (i.e., eye movements) tax the visuospatial sketchpad subsystem of working memory, as opposed to the phonological loop subsystem or the central executive system (Andrade et al., 1997).

Barrowcliff et al. (2004) also used a within-subjects design with 80 non-clinical participants to examine the effects of an eye movement versus eyes-stationary control on ratings of vividness and emotionality for positive and negative images; however, they added a measure of psychophysiological arousal in the form of skin conductance. They found that eye movements significantly reduced vividness and emotionality for both positive and negative autobiographical memories, as compared to the control condition; that is, less positive emotions were evoked with the positive memory, and less negative emotions were evoked with the negative memory

(Barrowcliff et al., 2004). However, an electrodermal de-arousal effect was observed in the eye movement condition, but only for negative memories; thus, they suggest that the degree of current symptoms does not factor into the strength of a de-arousal effect caused by eye movements (Barrowcliff et al., 2004). The authors conclude that the continued effects after the intervention were in line with an integrative model: concurrent reciprocal inhibition, working memory taxation of the visuospatial sketchpad, and an orienting response (Barrowcliff et al., 2004). Specifically, in discussing the likelihood of an orienting response, Barrowcliff et al. (2004) cite the "reassurance reflex" presented by MacCulloch and Feldman (1996) as a likely mechanism that acted in tandem with visuospatial sketchpad disruption.

Homer et al. (2016) asked 40 undergraduates with public speaking anxiety to perform an eye-movement task (taxing VSSP) and an auditory task (taxing PL) while visualizing a hypothetical public speaking scenario, and rated image representativeness, vividness, emotionality, confidence, anxiety, task difficulty, and scenario vividness. Their results showed that both tasks were effective in reducing vividness, suggesting that a sufficient amount of cognitive load regardless of modality should be beneficial; however, eye movement effects were larger and longer lasting, which adds support to the concept of modality-specific interference (Homer et al., 2016).

As with Homer et al. (2016), Kemps and Tiggemann (2007) found support for modality-specific interference when assessing auditory and visual taxation with healthy undergraduates across two experiments ($n$ = 30; $n$ = 68), who rated vividness, emotionality, imaging ability, and sensory components for both happy and distressing memories using three conditions (eye movements, articulatory suppression, and a control). They found that both dual tasks led to decreases in vividness and emotionality, with eye movements having a greater effect than articulatory suppression; thus, they argue that both the visuospatial sketchpad and the phonological loop can be taxed by visual and verbal concurrent tasks, respectively (Kemps & Tiggeman, 2007). Based on their results, the authors conclude that eye movements in EMDR are likely acting upon the VSSP slave system of working memory (Kemps & Tiggeman, 2007).

Landin-Romero et al. (2013) used fMRI, neuropsychological assessment, and self-report measures in a case study of a single patient with subsyndromal bipolar disorder who underwent 14 sessions of EMDR. They found a reduction in mood symptoms that was accompanied by a return to normalization on fMRI, with activations seen in frontal networks and other regions including the bilateral anterior insula, basal ganglia, thalamus (extending to the dorsolateral prefrontal cortex), supplementary motor cortex, and parietal cortex (Landin-Romero et al., 2013). A failure of deactivation, characteristic of abnormal default mode network (DMN) functioning, is common in psychiatric disorders; their results showed that EMDR is capable of modulating the DMN, as it led improved deactivation patterns and moved the patient closer to the mean activation value of the control group (Landin-Romero et al., 2013). Landin-Romero and colleagues (2013) also asserted that their findings were consistent with the VSSP theory of working memory taxation, as memory vividness was reduced by eye movements.

Lilley et al. (2009) examined the effects of visual and verbal interference (eye movements, counting, and control condition) on traumatic memories in 18 patients with PTSD; they found reductions in vividness and emotionality with eye movements, but not counting, in predominantly visual memories. They assert that their findings align with the modality-specific interference hypothesis via the VSSP; however, as effects did not persist at a one-week follow-up, they state that eye movement benefits may be limited to within-session (Lilley et al., 2009).

### *Phonological Loop (PL) Taxation*

As previously discussed, Homer et al. (2016) and Kemps and Tiggeman (2007) both found positive effects for eye movements as well as an auditory dual task, the latter of which they attributed to modality-specific interference of the phonological loop. However, Lilley et al. (2009) did not find any beneficial effects following a counting condition, relative to eye movements. Other research teams have not definitively implicated the PL despite use of counting paradigms, opting instead for support of broader working memory taxation.

### *Central Executive (CE) Taxation*

Gunter and Bodner (2008) investigated the likelihood of three accounts in separate experiments that employed an eyes-stationary control task: working memory taxation versus the investigatory reflex (orienting response), working memory taxation versus interhemispheric communication, and taxation degree of horizontal or vertical eye movements versus two different dual tasks: an auditory shadowing task and a Rey-O drawing task (Gunter & Bodner, 2008). They utilized non-clinical undergraduate students ($n$ = 37, 36, 72) who rated unpleasant autobiographical memories for vividness, emotionality, and completeness. They found support for working memory taxation and rejected the hypotheses of the orienting response and interhemispheric communication; given that vertical eye movements were as effective as horizontal eye movements, they suggest that increased interhemispheric communication is unlikely to account for the effects, but both tasks likely tax the visuospatial sketchpad (VSSP) of working memory (Gunter & Bodner, 2008). However, Gunter and Bodner (2008) also suggest that the central executive (CE) is likely to be more responsible than the VSSP alone, as all three dual tasks were effective in reducing vividness, emotionality, and completeness; thus, visual as well as auditory tasks were effective distractors. The authors also suggest that there may be an inverted U-curve relationship, with an optimal level of taxation to produce the greatest benefits, as well as the potential for too much or too little taxation (Gunter & Bodner, 2008).

Kristjánsdóttir and Lee (2011) investigated the likelihood of modality-specific interference via three conditions (variable smooth pursuit eye movements, counting, and control) with 36 non-clinical participants, who rated vividness, emotionality, and sensory modality of distressing memory images. They found that both conditions led to significant decreases in outcome variables, with eye movements resulting in greater reductions even when memories were not primarily visual; thus, they argue that modality-specific interference is not necessarily required for dual tasks to be effective, and the theory of central executive taxation best describes their results (Kristjánsdóttir & Lee, 2011).

Using non-clinical undergraduates, Patel and McDowall (2016) investigated the central executive hypothesis via testing the effects of fast, slow, and no eye movements on unpleasant memory ratings and related intrusive thoughts in two experiments ($n$ = 31, 33). They found that fast eye movements led to reductions in emotionality and intrusions, but not vividness in the first experiment; however, fast eye movements reduced vividness and intrusions (but not emotionality) in the second experiment, and slow eye movements had no effect on any outcome variables (Patel & McDowall, 2016). Findings suggested that greater CE taxation (measured via reading span scores) leads to greater suppression, and subjects with higher CE capacity had fewer intrusive thoughts after the fast eye movement condition than those with lower CE capacity (Patel & McDowall, 2016). Furthermore, Patel and McDowall (2016) assert that partial suppression via a dual task (recall plus eye movements) may lead to a distancing effect from traumatic memories.

Similar to previous researchers who opted for another dual task, Van den Hout et al.

(2010) studied a counting paradigm in 41 non-clinical undergraduates to investigate whether a dose-response relationship exists between working memory taxation and reductions in vividness and emotionality; they used a simple visual reaction time task during conditions of simple and complex counting and retrieval only (control), after which they recalled and rated autographical memories. They found evidence in support of a dose-response relationship: complex counting led to greater reaction times (greater taxation) than simple counting, and simple counting greater than no counting; both tasks led to reductions in vividness and emotionality (Van den Hout et al., 2010). Given that verbal counting interfered with a visual reaction time task, the authors assert that the CE rather than just the PL is taxed, although modality-specific interference may still be a factor (Van den Hout et al., 2010). Furthermore, given that simple counting was slightly more effective for emotionality than complex counting, the authors assert that an inverted U-shape curve of optimal taxation as suggested by Gunter and Bodner (2008) is also plausible (Van den Hout et al., 2010).

***Rejection of Working Memory Taxation***

Of the articles included in this investigation, three did not find support for the theory of working memory taxation. Matthijssen et al. (2017) analyzed the data of 30 clinical subjects with PTSD to investigate whether modality-specific interference (auditory via counting; visual via eye movements; control via stationary dot) leads to greater reductions in emotionality. Emotionality was reduced by all three conditions, and eye movements and counting did not produce any additive effects beyond the control group; thus, the authors conclude that the working memory hypothesis was not supported, nor was the concept of modality-specific interference (Matthijssen et al., 2017).

Novo Navarro et al. (2013) tested how eye movements impact information encoding in both VSSP and PL using 50 healthy undergraduates; specifically, they attempted to replicate the findings of Propper and Christman (2008), which found that eye movements prior to working memory tasks led to greater recall. Using horizontal eye movements versus a static eye condition prior to an encoding phase, they found no beneficial effects of eye movements on recall following the VSSP or the PL task (Novo Navarro et al., 2013). However, it should be noted that these researchers did not test working memory taxation in terms of reducing emotionality or vividness of autobiographical memories, unlike most aforementioned studies related to this account; thus, their findings do not necessarily take away from the results of other research teams regarding this specific mechanism.

In a group of eight patients with PTSD, Thomaes et al. (2016) used fMRI to examine whether eye movements increase activity in brain regions associated with working memory, decrease activity in emotional processing areas, and how they modulate functional connectivity between these areas. Thomaes et al. (2016) found that their script-driven imagery protocol activated regions of visual association cortex, emotion-processing (anterior insula, rostral anterior cingulate cortex/ACC, and dorsomedial prefrontal cortex/dmPFC), and working memory (dorsolateral prefrontal cortex/dlPFC). Although recall plus eye movements led to greater decreases in amygdala and rostral ACC activity and reduced connectivity between the right amygdala and rostral ACC, there were no significant differences in dlPFC activation between control and eye movement conditions (Thomaes et al., 2016). Given the latter region's role in working memory, the authors concluded that the working memory taxation theory was not supported by their results, despite the differences seen in emotion processing areas following eye movements (Thomaes et al., 2016).

Ultimately, the number of articles in support of working memory taxation is substantial, regardless of whether a specific system is implicated. These findings lend credence to this account as a likely mechanism of action in EMDR.

**Psychological Distancing Hypothesis**

Six articles included in this investigation were in support of a psychological distancing effect produced by eye movements in EMDR; no studies overtly rejected this hypothesis. Lee (2008) discusses how EMDR is distinct from both traditional and imaginal exposure, as traditional exposure focuses on reliving (i.e., re-experiencing the trauma in the present) as the vehicle of symptom alleviation, whereas EMDR focuses instead on distancing (i.e., experiencing the trauma as a past event in more of a detached or observational manner). Based on the results of Lee et al. (2006) and Lee and Drummond (2008), the author asserts that the greatest reduction in trauma symptoms is achieved when individuals engage in distancing or detached processing, which is triggered by eye movements as opposed to therapist instructions (Lee, 2008). Specifically, Lee et al. (2006) first rejected the idea that EMDR is akin to imaginal exposure via an experiment with 44 PTSD patients, which independently coded responses after eye movements as characteristic of either reliving, distancing, associated but not directly involved with the trauma, or a negative affective experience. They found that reliving responses did not lead to greater symptom improvement than distancing or associated responses, suggesting that imaginal exposure was not at play; rather, only distancing responses were significantly correlated with improvement (Lee et al., 2006). To expand upon this finding, Lee and Drummond (2008) used a non-clinical sample of 48 to decipher whether therapist instructions (encouraged either maximal reliving or distancing) or eye movements (versus eyes-stationary control) were responsible for the distancing effect achieved in EMDR, using vividness and emotionality as outcome variables. Eye movements reduced emotionality regardless of instruction; however, vividness was only reduced over time when eye movements were combined with a distancing instruction, rather than a reliving instruction (Lee & Drummond, 2008).

Three studies that supported psychological distancing were also in support of working memory taxation and/or other theories. Maxfield et al. (2008) supported a distancing effect that permits detached processing, which occurs in tandem with taxation of all four components of working memory (CE, PL, VSSP, and episodic buffer). Pagani et al. (2017) combined support for working memory taxation and the orienting response, which ultimately leads to detachment from the trauma; given the interrelated usage of "distancing" and "detachment" in the literature, their review also appears to support a distancing effect. Along with support for taxing the CE system of working memory, Patel and McDowall (2016) asserted that partial suppression via a dual task (recall plus eye movements) may lead to distancing.

Overall, this account has been far less researched in relation to how EMDR works. However, its relatively consistent integration with the working memory taxation theory appears plausible at first glance, and warrants further investigation.

**Interhemispheric Interaction Hypothesis**

Six articles found support for the interhemispheric interaction theory of EMDR, while five articles rejected this hypothesis. Christman et al. (2003) used two groups of non-clinical undergraduates ($n$ = 280; $n$ = 40) to examine whether bilateral eye movements would equalize interhemispheric interaction and thus improve retrieval of episodic memory; they used conditions of smooth pursuit versus saccadic, crossed with horizontal versus vertical eye movements, and a control of no eye movements. Recognition discrimination was improved in only the horizontal saccadic condition, while neither vertical condition had an effect; thus, Christman et al. (2003) assert that only horizontal eye movements lead to increased cortical activation of the opposite hemisphere, with saccadic stimulation outperforming smooth pursuit (increased interhemispheric interaction leads to improved episodic memory). They ruled out the possibility that arousal via oculomotor activity caused this improvement, given that only the horizontal saccadic condition had a significant effect (Christman et al., 2003). Christman et al. (2003) thus replicated the findings of Christman and Propper (2001) and encourage distinction between saccadic versus smooth pursuit eye movements in future research.

Christman and colleagues (2004) went on to replicate their findings of bilateral saccades increasing episodic memory via a false memory paradigm, again using two groups of healthy undergraduates ($n$ = 63; $n$ = 40) who were screened for handedness. Results indicated that strong right-handedness was associated with higher false memory rates than mixed-handedness, and bilateral saccadic eye movements led to significantly decreased false memories via increased interhemispheric interaction; specifically, they observed a decrease in false alarms rather than an increase in true hits in the eye movement condition relative to control (Christman et al., 2004).

Keller et al. (2014) used EEG to monitor inter- and intrahemispheric coherence after bilateral stimulation of EMDR for positive memories, using 30 healthy female right-handed undergraduates; they employed two control conditions (stationary black dot, and blinking green/red dot). While they found little support for a purely interhemispheric coherence model, trends indicated that bilateral eye movements tended to enhance coherence via delta and low alpha waves, which are generally not indicative of information processing. However, intrahemispheric coherence was enhanced by the eye movements via increased delta and low beta waves in right and left frontal regions, respectively; thus, they propose a cortical coherence model whereby cortical pathways increase activation based on the modality of stimulation, and subsequently become more easily activated upon processing of the trauma (Keller et al., 2014).

They assert that such recruitment may involve interhemispheric network activation, or intrahemispheric coherence in localized regions (Keller et al., 2014).

In their review, Propper and Christman (2008) discuss evidence in support of bilateral saccadic eye movements for increased episodic memory retrieval and reduced emotionality through interhemispheric interaction via the corpus callosum; however, they assert that the majority of studies are testing smooth pursuit, rather than saccadic eye movements. Additionally, the authors state that research has shown that eye movements lead to improved recall/recognition for list words, spatial memory, color memory, paired associates recall, recent autobiographical as well as childhood memories, and decreased false recall (Propper & Christman, 2008).

Propper et al. (2007) also used EEG to examine interhemispheric interaction and coherence during bilateral eye movements using 18 right-handed healthy undergraduates. They found decreased gamma frequency coherence and interhemispheric EEG coherence in anterior prefrontal cortex following eye movements, which opposes interhemispheric coherence hypotheses (Propper et al., 2007). However, they assert that changes in coherence do not necessarily reflect decreased interaction between hemispheres; rather, they propose that eye movements may be facilitating consolidation of traumatic memories during EMDR via changing interhemispheric interaction (Propper et al., 2007).

In their speculative review on how EMDR works, Welch and Beere (2002) assert that REM-state induction, the orienting response, Shapiro's original assertions, and Dyck's conditioning model are very difficult to support or refute, due to a lack of scientific characteristics. Thus, they present their own integrative hypothesis: EMDR both enhances and reduces emotional arousal via increased interhemispheric interaction and normalization of brain activation patterns (through bilateral eye movements), while disrupting avoidance or constricted attention (Welch & Beere, 2002). Based on this theory, they argue that patients with PTSD begin with increased right hemisphere (emotional) activation, and EMDR should help to increase left hemispheric activity while reducing PTSD symptoms following successful treatment (Welch & Beere, 2002).

***Rejection of Increased Interhemispheric Interaction***

Five studies included in this investigation opposed the theory of increased interhemispheric interaction. Fleck et al. (2018) used EEG to study neural changes in response to eye movements in 91 healthy undergraduates, in an attempt to examine the interhemispheric interaction and attentional control theories. Their results did not overtly support either theory, although eye movements did lead to significant changes in EEG coherence, thus impacting brain activity at rest (Fleck et al., 2018). Furthermore, the reduction in frontoparietal alpha coherence over the midline suggests that bilateral eye movements may engage the frontoparietal attention network while disengaging the default mode network, leading to increased cognitive readiness (Fleck et al., 2018).

As aforementioned, Gunter and Bodner (2008) investigated the likelihood of three distinct accounts: working memory taxation versus the investigatory reflex (orienting response), working memory taxation versus interhemispheric communication, and taxation degree of horizontal or vertical eye movements versus an auditory shadowing task and a Rey-O drawing task. Their results supported working memory taxation and rejected the hypotheses of the orienting response and interhemispheric communication; given that vertical eye movements were as effective as horizontal eye movements, they suggest that increased interhemispheric communication is unlikely, although both tasks likely tax the VSSP (Gunter & Bodner, 2008). In a similar experiment that was also mentioned previously, Hornsveld et al. (2011) investigated how eye movements impact positive memories (pride, self-confidence, and perseverance) using vertical and horizontal eye movements and a recall-only control; thus, they tested the theories of working memory taxation and interhemispheric interaction. Results supported working memory taxation and rejected interhemispheric interaction: decreases were seen in vividness, strength, and pleasantness, and vertical eye movements actually outperformed horizontal eye movements for all three variables (Hornsveld et al., 2011).

Samara et al. (2011) used EEG to study whether increased interhemispheric coherence was correlated with memory enhancement (emotional and neutral word recall) after horizontal eye movements (or control) in a group of 14 healthy female right-handed undergraduates. Results indicated that only eye movements improved episodic recall of non-traumatic emotional words, with no effects found for neutral words in either condition; unlike Propper et al. (2007), they found no correlation with increased interhemispheric coherence in homologous cortical regions (Samara et al., 2011). As previously mentioned, Yaggie et al. (2015) found no evidence of increased interhemispheric coherence following eye movements; however, they did find increases in intrahemispheric coherence, specifically in right frontal theta and beta waves as measured by EEG, and ultimately argued for a two-stage cortical coherence model.

Ultimately, there does not seem to be enough consistent support for the theory of increased interhemispheric interaction. Rather, increased intrahemispheric coherence or alterations to the communication between hemispheres may be a more likely mechanism. Further research and the amending of this hypothesis are required before it can achieve credibility as a possible mechanism of action in EMDR.

**Psychophysiological Changes Hypothesis**

Studies that came out in support of psychophysiological changes (PC) occurring during

EMDR fell into one of four categories: General Psychophysiological Changes, Reciprocal Inhibition (RI), REM-like State (REM), and the Orienting Response (OR).

***General Psychophysiological Changes***

Twenty-seven articles found support for general psychophysiological changes, whether they specified a specific subsumed theory or not (i.e., RI, REM, or OR); one article rejected the existence of any such changes during EMDR. Aubert-Khalfa et al. (2008) tested psychophysiological responses in the form of skin conductance and heart rate both in a relaxed state and during trauma visualization before and after EMDR in six patients with PTSD. They found significant decreases in physiological responses to the traumatic event following a single session of EMDR, accompanied by reductions in PTSD symptoms. They assert that their findings, while limited by a small sample, underline the effects of EMDR on sympathetic arousal of the autonomic nervous system; given that the amygdala is believed to amplify electrodermal activity (while the hippocampus inhibits it), EMDR may be altering how the amygdala functions (Aubert-Khalfa et al., 2008).

In another study, Barrowcliff et al. (2004), as mentioned in the VSSP working memory section, measured working memory taxation as well as skin conductance and found a de-arousal effect produced by eye movements for negative memories. Barrowcliff et al. (2004) ultimately supported an integrative model: concurrent reciprocal inhibition, working memory taxation of the VSSP, and an OR akin to the "reassurance reflex" proposed by MacCulloch and Feldman (1996).

Carlson et al. (1998) examined the effects of EMDR, biofeedback-assisted relaxation, or a control condition in 35 male Veterans with PTSD on psychophysiological measures, including modules of electromyography (EMG), heart rate, temperature, and skin conductance. All three conditions led to lowered physiological arousal, and the authors concluded that these changes may have reflected a habituation of arousal response, regardless of the treatment used (Carlson et al., 1998).

Elofsson et al. (2008) investigated the physiological correlates of eye movements in EMDR based on distinct theories: distraction, conditioning, the OR, and REM-like mechanisms; they used 13 male refugees with PTSD and measured physiological arousal via fingertip skin temperature, heart rate, skin conductance, expiratory carbon dioxide levels, and blood pulse oximeter oxygen saturation, while autonomic balance was measured through the ratio between low and high frequencies of the heart rate power spectrum (LF/HF). Results indicated that the autonomic balance was shifted during eye movements, as evidenced by increased fingertip temperature, breathing frequency, and carbon dioxide, and decreased heart rate, skin conductance, LF/HF ratio, and oxygen saturation (Elofsson et al., 2008). The authors concluded that eye movements in EMDR do not appear to induce an OR based on their results; however, they do seem to activate cholinergic systems while inhibiting sympathetic systems, which is akin to the patterns seen during REM sleep (Elofsson et al., 2008).

As mentioned in a previous section, Fleck et al. (2018) used EEG to examine the interhemispheric interaction and attentional control theories. Their results did not overtly support either theory, but eye movements significantly changed EEG coherence, thus impacting brain activity at rest; this study therefore supports the occurrence of psychophysiological changes in EMDR (Fleck et al., 2018). Frustaci et al. (2010) used a group of four outpatients with small-t trauma experiences to study EMDR using a measure of heart rate variability. They found that decreases in symptom scores were maintained at the end of treatment and at 1- and 3-month follow-ups, while heart rate variability improvement (which occurred after cognitive memory reprocessing) suggested an increase in parasympathetic tone and overall de-arousal (Frustaci et al., 2010).

Kapoula et al. (2010) used five healthy participants to study the frequency and increase in smooth components of "catch-up saccades" (CUS) during EMDR, which they describe as a specific kind of smooth pursuit eye movement, via video-oculography. They found that when distress was completely eliminated (SUDS = 0), frequency of CUS decreased while smooth components increased, which they attribute to better use of visual attention resources following EMDR; by reducing distress, they suggest that EMDR may be activating a cholinergic effect that subsequently improves eye movements (Kapoula et al., 2010).

Pagani et al. (2011) used EEG during four EMDR sessions in a single patient case study (anxiety and posttraumatic symptoms) in order to identify brain regions activated during autobiographical trauma script listening and desensitization via bilateral stimulation. Before EMDR, the patient showed dominant activation in bilateral PFC and regions of the left parietooccipital cortex during trauma reliving; after treatment, left occipital and right temporal cortices were activated (Pagani et al., 2011). Thus, the authors assert that dominant electrical activity of lateral prefrontal cortex as well as decreased activation in the prefrontal limbic system occurred after trauma processing (Pagani et al., 2011). Pagani et al. (2011) discuss how their findings support Bremner's cortical inhibitory model, Shapiro's memory reconsolidation model, the Davidson model of emotional plasticity, and the emotional asymmetry model; they assert that a hallmark of successful EMDR may be a shift from emotional reliving to cognitive reliving, which is accompanied by increased beta and gamma (fast bands) activity in the left hemisphere.

In a pilot study, Pagani et al. (2018) treated two patients with PTSD with eight sessions of EMDR while using PET, EEG, and neuropsychological testing (verbal/semantic fluency, executive functioning, visuospatial ability, attention and working memory); they used a control group for PET comparison. Although there were no substantial changes in neuropsychological abilities, PET and EEG showed hypermetabolic and activity increases in prefrontal cortex and the ACC, which suggests better top-down inhibitory control of subcortical hyperarousal, as well as in temporoparietal regions (Pagani et al., 2018).

As mentioned above, Propper et al. (2007) used EEG to examine interhemispheric coherence during bilateral eye movements and found decreased gamma frequency coherence and interhemispheric EEG coherence in anterior prefrontal cortex following eye movements, which opposes interhemispheric coherence hypotheses. However, they argue that changes in coherence do not necessarily reflect decreased interhemispheric interaction; rather, eye movements may be facilitating consolidation of traumatic memories during EMDR by altering interhemispheric interaction (Propper et al., 2007).

In 2007, Sack and colleagues used trauma scripts to measure respiratory sinus arrhythmia (RSA), heart rate (HR), and heart rate variability (HRV) via electrocardiogram (ECG) during EMDR in 16 single trauma PTSD outpatients, without using a control group. Post-treatment reductions in trauma symptoms following EMDR held at a 6-month follow-up, as did reductions in psychophysiological arousal; the authors conclude that an increase in parasympathetic tone (increased RSA, decreased HR) may be a correlate of successfully resolved trauma memories following EMDR. They assert that their findings align with the suggestion that re-integrating traumatic memories may permit regulation of limbic arousal via the reactivation of inhibitory circuits (Sack et al., 2007). Additional work by Sack and colleagues is detailed further in the OR section.

Santarnecchi et al. (2019) used fMRI to explore the impact of TF-CBT and EMDR on the functional connectivity (FC) of 31 patients with single trauma PTSD due to an earthquake in Italy in 2002; they did not include a control group or condition. Both therapies were successful in reducing symptoms, with similar and contrasting FC patterns: in the left hemisphere, connectivity between visual cortex and temporal areas decreased, while connectivity between right temporal pole and bilateral superior frontal gyrus increased (Santarnecchi et al., 2019). Both treatments led to a likely modification of the ventral-dorsal stream balance; furthermore, increased connectivity between prefrontal cortex regions and the right temporal pole aligns with the general neurocognitive hypothesis that psychotherapy leads to increased top-down cognitive control of limbic regions (Santarnecchi et al., 2019).

**Rejection of General Psychophysiological Changes.** Only one study rejected the idea that eye movements in EMDR lead to general psychophysiological changes. Littel et al. (2017) attempted to discover whether noradrenergic mechanisms mediate the effects of eye movements on memory; they placed 56 healthy subjects into three conditions (eye movements, eyes still, and no recall) and asked them to recall three negative autobiographical memories. Before recall, participants were given a placebo or propranolol (to interfere with memory reconsolidation); the researchers expected to see decreases in psychophysiological measures of heart rate and skin conductance following eye movements, while degrading effects on vividness and emotionality would be attenuated by propranolol (Littel et al., 2017). Emotionality and psychophysiological measures were not reduced by eye movements any more than the control condition, although vividness was; however, the propranolol group did not experience vividness decreases (Littel et al., 2017). The authors assert that propranolol, by interfering with memory reconsolidation, successfully blocked noradrenergic activation and therefore negated the degrading effects of eye movements; this suggests that noradrenergic neurotransmission is required before desensitization via eye movements can occur, and noradrenaline may enhance reconsolidation of the degraded memory (Littel et al., 2017).

***Reciprocal Inhibition***

Six articles supported the theory of reciprocal inhibition, while only one rejected it. As aforementioned, Barrowcliff et al. (2004) measured skin conductance to show that eye movements degraded aversive memories and caused an electrodermal de-arousal effect; thus, they proposed an integrative model of reciprocal inhibition, working memory taxation of the VSSP, and an OR (the "reassurance reflex"). In a speculative review, Denny (1995) discusses the orienting reflex (OR) and proposes a model that appears to support reciprocal inhibition (i.e., a conditioning model): via external inhibition, the OR blocks the maintenance of conditioned responses. The author states that repeatedly eliciting the aversive memory (conditioned stimulus) and simultaneously inducing an OR reduces or halts the conditioned fear response; this allows new learning to occur via new meanings being attributed to the traumatic memory (Denny, 1995).

In a similar speculation, Dyck (1993) also discusses conditioning models as they relate to EMDR: a traumatic learning model is proposed, which incorporates respondent conditioning, emotional interference with learning, and operant conditioning. The author asserts that although eye movements are not essential, they are useful as a distracting stimulus; furthermore, the greater the complexity of the competing task, the greater the speed of extinction for a traumatic memory will be (Dyck, 1993).

Schubert et al. (2011) used 62 healthy participants to study the OR using psychophysiological measures during fixed and varied rates of eye movements; they measured heart rate (HR), heart rate variability (HRV), respiration rate (RR), and skin conductance (SC).

Both fixed and varied eye movements were beneficial over the control (no EM), and were accompanied by a significant within-session de-arousal: HR decreased at EM onset; SC decreased during EM sets, while HRV and RR increased (Schubert et al., 2011). Findings were consistent with ORs and a relaxation response, which were more common in EM conditions at exposure outset; specifically, they found small increases in SC that habituated rapidly, accompanied by reduced sympathetic activity (decreased HR) and increased parasympathetic tone (improved HRV) (Schubert et al., 2011). Thus, Schubert et al. (2011) argue for an integrated OR and reciprocal inhibition model: repeated ORs caused by eye movements cause short-term de-arousal, while the coupling of relaxation with distressing memory exposure leads to the weakening of negative appraisals, thus decreasing avoidance of trauma processing.

In a review of past research, Söndergaard and Elofsson (2008) discuss whether or not eye movements are accompanied by psychophysiological effects; firstly, they refute the null hypothesis, based on research showing that eye movements induce a certain somatic response. They go on to discuss research surrounding the theories of a REM-like state, the OR, and reciprocal inhibition (RI); the authors conclude that their data fits well with the REM and RI hypotheses, although it is inconsistent with an OR (Söndergaard & Elofsson, 2008). However, Söndergaard and Elofsson (2008) state that EMDR may have additional mechanisms and may induce multiple ORs, in addition to activating the REM system through eye movements. They also assert that eye movements, which may or may not be necessary, may induce the parasympathetic state needed to extinguish anxiety (Söndergaard & Elofsson, 2008).

Yaggie et al. (2015), discussed in previous sections, studied eye movements via EEG and found no evidence of interhemispheric coherence, but did find increased intrahemispheric coherence between right frontal theta and beta EEG following eye movements. Their proposed model integrates the theories of imagination deflation/working memory taxation (CE and VSSP), physiological connectivity, and conditioning; conditioning is akin to RI and was also proposed by Dyck (1993) and Denny (1995), with the latter also supporting inhibition via an OR (Yaggie et al., 2015).

**Rejection of Reciprocal Inhibition.** The only article that rejected reciprocal inhibition was by Tryon (2005), who argued that EMDR presents an issue to the world of therapy, as it adds an "inert" component (eye movements) to an already established treatment: exposure. The author describes RI as the short-term effect of systematic desensitization, given the apparent incompatibility of two psychological states occurring in tandem (relaxation and distress); counterconditioning, on the other hand, is described as the long-term effect, which replaces an old response (anxiety) with a new one (relaxation) (Tryon, 2005). However, Tryon (2005) argues that the antagonistic inhibition caused by RI and counterconditioning does not have enough evidence as a mechanism for EMDR; rather, the author proposes a connectionist learning-memory model, the Parallel Distributed Processing Connectionist Neural Network (PDP-CNN) model, which is suggested to have the empirical backing of neuroscientific studies on plasticity and synaptic change.

***REM-like State***

A total of ten articles supported the REM sleep hypothesis; no articles overtly rejected it. Elofsson et al. (2008), as aforementioned, investigated theories of distraction, conditioning, the OR, and REM-like mechanisms by measuring fingertip temperature, skin conductance, heart rate, expiratory carbon dioxide, blood pulse oximeter oxygen saturation, and low-high frequency ratio of the heart rate power spectrum. The increased fingertip temperature, breathing frequency, and carbon dioxide, and decreased heart rate, skin conductance, LF/HF ratio, and oxygen saturation led them to conclude that eye movements in EMDR do not appear to induce an OR; however, they do appear to activate cholinergic systems while inhibiting sympathetic systems, similar to patterns seen during REM sleep (Elofsson et al., 2008).

In 2001, Kuiken and colleagues studied 25 undergraduates with either a loss, traumatic loss, or trauma in an effort to investigate the OR and REM sleep hypotheses; they used tasks of attentional flexibility (covert attention task) and metaphor comprehension (sentence ratings). Results indicated that eye movements, compared to the control (no eye movements) indeed created an OR, as they facilitated attentional reorienting to novel stimuli in the covert attention task and facilitated reorienting from literal meanings of sentences to more unconventional, metaphorical meanings in the second task (Kuiken et al., 2001). The eye movements appeared to shift working memory in a way that permitted faster responses to novel stimuli, while allowing access to a broader scope of metaphoric interpretations; they state that this pattern is also seen in REM sleep, where the eye movements permit working memory shifts that lead to affective dream narratives (Kuiken et al., 2001). Kuiken et al. (2001) also speculate that the altered attentional state may be accompanied by decreased noradrenergic activity, which may be due to inhibition of the locus coeruleus; thus, eye movements may suppress noradrenaline, leading to attentional disengagement.

Kuiken et al. (2010) again studied the effects of bilateral saccadic eye movements on attentional flexibility (covert attention task) and metaphor comprehension (sentence ratings) in a group of 101 undergraduates who recently experienced either a loss, traumatic loss, or trauma. Their findings supported the activation of an OR, which facilitated attention and understanding of metaphorical expressions in all conditions; specifically, they assert that eye movements via the ACC appeared to mediate startle responses and improve recognition of novel stimuli (Kuiken et al., 2010). Furthermore, eye movements seem to enhance attentional flexibility, self-monitoring, and response regulation during challenging tasks; when discussing dreams as metaphors, the authors conclude that the eye movements may be triggering the alerting mechanisms of REM sleep in a waking state (Kuiken et al., 2010).

As aforementioned, Pagani and Carletto (2017) argue that slow wave sleep (SWS), REM sleep, and working memory taxation (of VSSP and CE) likely work together in EMDR; neurobiologically, they assert that limbic neurons are depolarized at a slower rate via bilateral stimulation, which permits amygdala-bound emotional memories to move and be fully processed by higher brain areas (Pagani & Carletto, 2017). Pagani et al. (2017), also mentioned previously, reviewed how desensitization in EMDR works via depotentiation of AMPA receptors in the amygdala; if correct, they believe this could account for the effects of the orienting response, working memory taxation, and REM sleep as proposed by Stickgold (2008).

Söndergaard and Elofsson (2008), mentioned previously, discuss psychophysiological effects of eye movements and assert that research has shown that they induce a certain somatic response; in discussing research on the theories of a REM-like state, the OR, and reciprocal inhibition (RI), they conclude that the REM and RI hypotheses have sufficient evidence, although their data is inconsistent with an OR. However, the authors state that EMDR may have additional mechanisms and/or induce multiple ORs in addition to activating the REM system; furthermore, the eye movements, which may or may not be necessary, may induce the parasympathetic state needed to extinguish anxiety (Söndergaard & Elofsson, 2008).

In a review, Stickgold (2002) speculates about the distinction between hippocampal and cortical memories, stating that episodic memories are sparsely stored and rapidly formed in a strong, clear fashion; these memories are then transformed slowly into cortical semantic memories (and thus semantic knowledge) in highly overlapped networks. The author asserts that non-REM sleep is essential for the strengthening of hippocampal memories, while REM sleep states strengthen cortical memories; non-REM involves a dominating presence of serotonin and norepinephrine, compared to dominant acetylcholine seen in REM (Stickgold, 2002). Individuals with PTSD may experience neurochemical disruptions that impact REM sleep, with alterations seen in regions like the hippocampus, amygdala, ACC, orbitofrontal cortex, and visual cortex; but Stickgold (2002) suggests that bilateral stimulation in EMDR creates repeated orienting responses that may permit traumatic memories to be cortically integrated via induction of a REM-like state (with resultant memory processing). Specifically, the ponto-geniculo-occipital (PGO) waves released by the brainstem during REM sleep can be triggered by a startle response (i.e., the OR); this OR involves the ACC and superior colliculus, and evidence points to a pattern of decreased noradrenaline and increased acetylcholine that allows this attentional shift to occur (Stickgold, 2002).

In 2007, Stickgold further discussed the REM hypothesis in relation to memory enhancement following reactivation during REM sleep, based on a recent study; specifically, the author calls for more attempts to create shifts in waking brain states in order to resolve emotional memories that resist processing during sleep states. Stickgold (2008) elaborated upon the aforementioned REM model by citing multiple research studies in support of these assertions; these findings suggest that REM sleep integrates and enhances memories, strengthens implicit knowledge, and facilitates development of insight and more distant associations. With regard to EMDR research, Stickgold (2008) suggests that control conditions need to be entirely absent of any eye movements or stimulation, while set durations across conditions need to be matched, and fidelity ratings used to account for treatment bias.

Vojtova et al. (2009) also conducted a speculative review of past research on EMDR and suggest that neurobiological mechanisms have garnered the most credibility: specifically, they support dual focus attention, the OR, and REM sleep induction. They assert that EMDR down-regulates hyperarousal which permits refocusing of attention and new learning; this learning requires both memory systems and dopaminergic reward circuitry, such as the nucleus accumbens, ventral tegmental area, and lateral hypothalamus (Vojtova et al., 2009).

***The Orienting Response***

Seventeen articles found support for the OR hypothesis of EMDR, while three articles argued against the occurrence of an OR. Barrowcliff et al. (2003) examined the OR by conducting two experiments with healthy undergraduates ($n$ = 20, 20) using eye movements following auditory stimuli versus a stationary task, as well as an identification task with low and high attentional demand. They attempted to case light upon the divergent hypotheses of how the OR factors into EMDR, whether through an intensified OR (Armstrong & Vaughan, 1996), a de-arousal OR (MacCulloch & Feldman, 1996), or no OR at all (Wilson et al., 1996) following eye movements (Barrowcliff et al., 2003). They found that eye movements after auditory stimuli reduced levels of arousal based on short-latency electrodermal responses; thus, the findings of Barrowcliff et al. (2003) supported the de-arousal model proposed by MacCulloch and Feldman (1996), while rejecting the proposals of Wilson et al. (1996) and Armstrong and Vaughan (1996). Furthermore, they assert that eye movements may act as distractors that tax attentional resources, similar to the limited processing account of Andrade et al. (1997), a previously mentioned team that supports the VSSP working memory theory (Barrowcliff et al., 2003).

As discussed above, Barrowcliff et al. (2004) looked at working memory taxation and skin conductance measures and found an overall de-arousal effect produced by eye movements for negative memories. Barrowcliff et al. (2004) ultimately supported an integrative model: concurrent reciprocal inhibition, working memory taxation of the VSSP, and an OR akin to the "reassurance reflex" proposed by MacCulloch and Feldman (1996).

Bergmann (2010) reviewed and discussed various neurobiological mechanisms of EMDR, and asserted that the OR and linked neural systems are interrelated with multiple mechanisms, including temporal binding, neural mapping, hippocampal remapping, limbic depotentiation, activation of frontal lobes, reciprocal suppression of the anterior cingulate cortex, and activation of REM systems. In terms of psychophysiological changes, he states that research continues to find relaxation of the parasympathetic nervous system, increased heart rate variability and vagal parasympathetic function, and reduced electrodermal responses and EEG P3a function, which suggests that EMDR impacts systems of affect regulation. Specifically, Bergmann (2010) believes that EMDR first creates a parasympathetic state change that leads to enhanced information processing and repair of neural links, followed by a longer lasting trait change after successful completion of EMDR. Further review and discussion of Bergmann's findings will follow in subsequent sections, especially under the topic of Neurobiological Mechanisms and Correlates of EMDR.

As aforementioned, Denny (1995) discusses an orienting reflex (OR) model that also appears to support reciprocal inhibition (i.e., a conditioning model): via external inhibition, the OR blocks the maintenance of conditioned responses. Repeatedly eliciting the aversive memory (conditioned stimulus) and simultaneously inducing an OR attenuates the conditioned fear response; this permits the occurrence of new learning and new meaning attributions to the traumatic memory (Denny, 1995). This model is supported by Yaggie et al. (2015), as discussed later in this section.

In a review, Kaye (2007) discusses how to integrate traumatic memories into semantic information; the author details how severe reciprocal suppression of the dorsal ACC (responsible for cognitive processing) can be caused by an overly activated ventral ACC (due to negative affect), thus disallowing the integration of new contextual information. Kaye (2007) asserts that tasks of error monitoring or divided attention (i.e., eye movements in EMDR) may reverse this process; furthermore, suppression of dopamine released by the ventral tegmental area (VTA) can also be reversed through evocation of positive emotions (i.e., RDI phase), which in turn may facilitate increased flexibility of cognitive switching via the ACC. Thus, the author suggests that EMDR impacts the ACC in a way that allows integration of neocortical information (Kaye, 2007). Additionally, eye movements are believed to permit error monitoring which allows for an investigatory reflex (OR) to occur when novel contextual information is brought up by the client; that is, eye movements themselves do not cause the OR, but do facilitate it (Kaye, 2007).

As mentioned previously, Kuiken et al. (2001) investigated the OR and REM sleep hypotheses using tasks of attentional flexibility (covert attention task) and metaphor comprehension (sentence ratings). Results indicated that eye movements created an OR, as they facilitated attentional reorienting to novel stimuli in the covert attention task and facilitated reorienting from literal meanings of sentences to more metaphorical meanings in the second task; they assert that this pattern is also seen in REM sleep, where the eye movements permit working memory shifts that lead to affective dream narratives (Kuiken et al., 2001). Kuiken et al. (2001) also suggest that the altered attentional state may be associated with decreased noradrenergic activity, possibly due to inhibition of the locus coeruleus; thus, eye movements may suppress noradrenaline, leading to attentional disengagement.

Also mentioned above, Kuiken et al. (2010) used a similar study design to again show that eye movements appeared to activate an OR, which facilitated attention and understanding of metaphorical expressions; specifically, they suggest that eye movements via the ACC may mediate startle responses and improve recognition of novel stimuli (Kuiken et al., 2010). They also propose that eye movements enhance attentional flexibility, self-monitoring, and response regulation during challenging tasks; in discussing dreams as metaphors, they assert that eye movements may be triggering the alerting mechanisms of REM sleep in a waking state (Kuiken et al., 2010).

MacCulloch and Feldman (1996) conducted a theoretical analysis of previous research and proposed a model that was supported by Barrowcliff et al. (2003) and Barrowcliff et al. (2004); specifically, they discuss the investigatory reflex proposed by Pavlov in 1927, as distinguished from the alerting reflex that precedes it. According to the authors, the OR is generally attributed to the reticular formation of the brain stem (MacCulloch & Feldman, 1996). MacCulloch and Feldman (1996) assert that when the environmental search prompted by an investigatory reflex does not identify danger, a safety signal is induced that causes de-arousal, a positive visceral response, exploration, and social behavior; they term this response the "reassurance reflex" (MacCulloch & Feldman, 1996). However, if danger is detected, avoidance is triggered by the corresponding negative visceral response, leading to either fight, flight, or freeze behavior; these two circuits (exploratory versus avoidance) mutually inhibit each other (MacCulloch & Feldman, 1996). The authors suggest that EMDR evokes this investigatory reflex while assuring environmental safety, thus leading to de-arousal and a pleasant visceral response (the reassurance reflex); by overwriting previously conditioned fear responses with positive feelings and linking them to the original conditioned stimulus, EMDR is effectively replacing the original unpleasant unconditioned response (MacCulloch & Feldman, 1996).

Miller et al. (2018) offer a speculative argument on the biological phenomenon of stochastic resonance (SR) as a potential mechanism in EMDR: SR works by boosting random noise in order to amplify a signal that is too weak to be picked up on its own. The authors apply SR to dual attention stimuli in EMDR via the thalamocortical temporal binding model, which is discussed in greater detail in the neurobiological mechanism section of this manuscript (Miller et al., 2018). Essentially, they argue that a weakened traumatic memory signal is boosted by SR via eye movements (which create white noise) in the thalamus (specifically, the ventrolateral and central-lateral thalamic nuclei), and is then transferred onward to limbic structures and the neocortex; activation of the dorsolateral prefrontal cortex is caused by the activated ventrolateral thalamic nucleus (Miller et al., 2018). Thus, eye movements appear to induce restoration and integration of somatosensory networks, memory, cognition, and synchronized hemispheric functioning; an OR is believed to lead to this increased cortico-thalamic signal, which eventually heals a dysfunctional memory network (Miller et al., 2018).

As aforementioned, Pagani et al. (2017), speculate that EMDR works via depotentiation of amygdala based AMPA receptors; if correct, they believe this could account for the effects of the orienting response, working memory taxation, and the REM sleep hypothesis proposed by Stickgold (2008).

Although they also did not use a control group, Sack, Lempa, et al. (2008) investigated the psychophysiological effects (i.e., OR and de-arousal) of eye movements by measuring autonomic tone and heart rate changes in 10 clinical PTSD patients with a single trauma; specific measures included ECG, impedance cardiogram (ICG), pre-ejection period (PEP), heart rate variability (HRV), respiration rate (RR), and heart rate (HR). They found evidence of substantial de-arousal brought on by within-session habituation of psychophysiological arousal, as evidenced by decreased HR and RR and increased parasympathetic tone within-session (Sack, Lempa, et al., 2008). The authors attributed the psychophysiological changes at the beginning of eye movements to the occurrence of an orienting response, given the relaxation observed, and assert that their findings fit with an emotion-processing model: short-term de-arousal due to OR(s) may facilitate the integration of adaptive and corrective information related to the traumatic event (Sack, Lempa, et al., 2008).

Similarly, Sack, Hofman, et al. (2008) also investigated psychophysiological changes via ECG (heart rate, heart rate variability, and root mean square of successive differences of interbeat intervals/RMSSD) during EMDR in 10 clinical patients with single trauma PTSD, without the use of a control group. They found reductions in both subjective distress and psychophysiological reactivity in response to individualized trauma scripts; the pattern during sessions indicated an increase in parasympathetic tone and the habituation of psychophysiological activation, indicating overall de-arousal (Sack, Hofman, et al., 2008). Sack, Hofman, et al. (2008) concluded that orienting responses elicited by bilateral eye movements permit memory processing via an increase in parasympathetic tone, which may be responsible for the efficacy of EMDR.

Schubert et al. (2011), as previously discussed, looked at the OR using heart rate (HR), heart rate variability (HRV), respiration rate (RR), and skin conductance (SC), and found evidence of a significant within-session de-arousal (HR decreased at EM onset; SC decreased during EM sets, while HRV and RR increased). They ultimately argued for a combined OR and RI model: repeated ORs via eye movements cause short-term de-arousal, while combining relaxation with exposure to a distressing memory weakens negative appraisals, thus decreasing avoidance of trauma processing (Schubert et al., 2011). In a later experiment, Schubert et al.

(2016) investigated psychophysiological activity via ECG (HR, SC, RR) in a group of 20 patients with PTSD from Timor-Leste, but did not use a comparison control group. They found PTSD symptom reduction accompanied by psychophysiological de-arousal: HR decreased at eye movement outset, and both HR and SC decreased within sets; however, RR did not significantly increase as expected during sets, although there was a trend (Schubert et al., 2016). The drop in heart rate and the habituation of SC responses indicated the presence of an OR; furthermore, resting levels of all three variables decreased significantly after desensitization sessions (Schubert et al., 2016).

Stickgold (2002), as discussed previously, speculates about the roles of non-REM and REM sleep in the strengthening of hippocampal and cortical memories, respectively; the author asserts that bilateral stimulation in EMDR creates repeated ORs that may permit traumatic memories to be cortically integrated via induction of a REM-like state (with resultant memory processing). This OR is believed to involve the ACC and superior colliculus, and research points to a pattern of decreased noradrenaline and increased acetylcholine that allows this attentional shift to occur (Stickgold, 2002). In their speculative review, Vojtova et al. (2009), mentioned above, asserted that the theories of dual focus attention, the OR, and REM sleep induction had garnered the most empirical support; they suggest that EMDR down-regulates hyperarousal which permits refocusing of attention and new learning.

Yaggie et al. (2015), mentioned in previous sections, found no evidence of interhemispheric coherence following eye movements, but did find increased intrahemispheric coherence between right frontal theta and beta EEG. Their model integrates the accounts of imagination deflation/working memory taxation (CE and VSSP), physiological connectivity, and conditioning/reciprocal inhibition (Yaggie et al., 2015).

**Rejection of the Orienting Response.** Three articles rejected the OR theory. Elofsson et al. (2008), discussed above, found evidence of increased fingertip temperature, breathing frequency, and carbon dioxide, and decreased heart rate, skin conductance, LF/HF ratio, and oxygen saturation, which led them to conclude that eye movements do not appear to induce an OR; however, eye movements did seem to activate cholinergic systems while inhibiting sympathetic systems, similar to patterns seen during REM sleep (Elofsson et al., 2008). Gunter and Bodner (2008), also discussed previously, evaluated working memory taxation versus the investigatory reflex (OR), working memory taxation versus interhemispheric communication, and taxation degree of horizontal or vertical eye movements versus an auditory shadowing task and a Rey-O drawing task; their results supported working memory taxation while rejecting the OR and interhemispheric communication. In their review, also aforementioned, Söndergaard and Elofsson (2008) argue in support of the REM and RI hypotheses, but their data was inconsistent with an OR; however, they concede that EMDR may have other mechanisms and may induce multiple ORs in addition to activating REM systems.

Overall, the psychophysiological changes accounts appear to have garnered a substantial amount of support. The orienting response has received the greatest support, followed by general psychophysiological changes, REM-like state induction, and reciprocal inhibition. It appears likely that these mechanisms are not only intertwined with each other but may also be operating in tandem with other mechanisms during EMDR (i.e., working memory taxation).

**Neurobiological Mechanisms and Correlates**

A total of 38 articles either discussed neurobiological underpinnings of EMDR or proposed a neurobiological mechanism of action. Aubert-Khalfa et al. (2008), as aforementioned, discuss the impact of EMDR on sympathetic arousal; they suggest that EMDR may be altering how the amygdala functions, given that this structure is believed to amplify electrodermal activity, while the hippocampus inhibits it (Aubert-Khalfa et al., 2008).

Bergmann (1998, 2000, 2008, 2010, 2019) has discussed the neurobiology of EMDR extensively in his speculative reviews over the past two decades. In 1998, Bergmann suggested that EMDR alters the relationships between the amygdala, other limbic structures (portions of the thalamus, hypothalamus, hippocampus, caudate nucleus, septum, mesencephalon, and cingulate gyrus), and the prefrontal cortex (PFC). He reviews the role of eye movements and the contemporary hypotheses of REM sleep, the OR, and psychophysiological changes; in relation to REM sleep, he discusses how the locus coeruleus (LC) activates the Gigantocellular Tegmental Field (GTF) neurons, which are believed to control dreaming during sleep (Bergmann, 1998). In REM sleep, high amplitude electrical potentials can be seen in the reticular formation of the pons, the lateral geniculate nucleus of the thalamus, and the occipital cortex; these potentials are known as Pontine Geniculate Occipital (PGO) waves and originate in the GTF neurons of the pons (Bergmann, 1998). To induce and maintain REM sleep, the LC must utilize noradrenergic cells to suppress norepinephrine; furthermore, GTF cells have been discussed in previous research as being activated during eye movements in wakefulness, which may have implications for EMDR (Bergmann, 1998).

Bergmann (1998) asserts that the left PFC and some temporal regions contain a switch that dampens the amygdala's emotional memory and modulate its reactivity by integrating a more logical and appropriate response; during trauma, amygdala-driven emotions overwhelm the serotonin receptors that relay signals from limbic regions to the PFC, which creates white noise that hinders working memory and homeostasis. Accordingly, the amygdala encodes memory in a very affective and somatic manner, as hippocampally mediated semantic information is unable to be consolidated along with it; thus, Bergmann (1998) proposes that EMDR, via its use of bodily sensations as language, may be able to interface directly with the amygdala.

In 2000, Bergmann again discusses the potential mechanisms of RI, REM-like state induction, II, and the OR. By consistently alternating attentional shifts, he asserts that EMDR enables a surge of acetylcholine that activates the REM sleep system, as filtered by the anterior cingulate cortex (ACC); this ultimately permits the integration of traumatic memories into more general semantic networks (Bergmann, 2000). He suggests that the role of EMDR in activating the anterior cingulate gyrus (ACG) needs to be further evaluated, and states that EMDR stimulation involves the pons, limbic regions, lateral cerebellum, gyral cortical structures, and neocortex (Bergmann, 2000). Similar to other researchers, Bergmann (2000) asserts that REM sleep is crucial for strengthening neocortical memories, while non-REM sleep appears to strengthen hippocampal memories; he again mentions how eye movements upregulate acetylcholine and trigger PGO waves, which activate the REM sleep system, frontal cortical regions, and areas of the ACG.

Calancie et al. (2018) reviewed potential neurobiological mechanisms of EMDR involving working memory, interhemispheric communication, de-arousal, and memory reconsolidation; they also discussed the neurocircuitry of eye movements, the oculomotor network, which includes the default mode network (DMN) and dorsal attention network (DAN), cerebellar activity, and the neurophysiology of PTSD. In their model, they propose that EMDR activates the DMN, which permits traumatic memories to be recalled into working memory, modified using phases like desensitization, installation, and the body scan, and finally reconsolidated in less vivid and emotional forms; additionally, the authors suggest that the cerebellum is involved in event timing, associative learning, and the reconsolidation process

(Calancie et al., 2018). They assert that the frontoparietal attention network is deactivated during predictive eye movements, which induces a relaxation response that is simultaneous with memory recall; thus, they encourage future studies to measure the metrics of eye movements in order to optimize EMDR effects via the recruitment of neural circuitry (Calancie et al., 2018).

In their 2016 review, Carletto and Pagani discuss how single-positron emission computed tomography (SPECT) studies have demonstrated significant blood flow changes in the limbic system and prefrontal cortex following EMDR. They mention how other neuroimaging studies have shown that individuals who do not benefit from EMDR or CBT tend to show reduced grey matter density in areas like the posterior cingulate, parahippocampal cortex, and insular cortex, with increased activation seen in the ventral ACC and amygdala (Carletto & Pagani, 2016). These regions are responsible for cognitive and affective integration, autobiographical and episodic memory encoding and retrieval, emotion processing, interoceptive and self-referential awareness, and fear extinction; thus, corresponding deficiencies in these areas can inhibit the efficacy of EMDR and other treatment interventions (Carletto & Pagani, 2016).

Corrigan (2002) speculates about the ACC in relation to EMDR, asserting that two subdivisions exist: the dorsal cognitive subdivision (ACcd) and the rostral ventral affective subdivision (ACad); these regions reciprocally inhibit each other, as cognitive tasks activate ACcd and deactivate ACad, while affective tasks activate ACad and deactivate ACcd. The author states that successful EMDR treatment rebalances this reciprocal inhibition via bilateral activation of ACcd, in line with SPECT findings of bilateral anterior cingulate gyrus activation following treatment; thus, ACad activity is reduced and ACcd activity is amplified, permitting greater inhibition of unpleasant emotions and cognitions (Corrigan, 2002). Furthermore, it is suggested that many mindfulness tasks used for emotion regulation activate ACcd while deactivating ACad, and this mechanism may also manifest during EMDR (Corrigan, 2002).

De Voogd et al. (2018), mentioned previously, used fMRI to show that working memory tasks (including eye movements) deactivated the amygdala while altering connectivity between the amygdala and dorsal frontoparietal network, and between the amygdala and ventromedial prefrontal cortex. They assert that the effects observed were likely due to concurrent amygdala deactivation and dorsofrontal parietal activation via pathways in ventromedial prefrontal regions, which are also seen in the cognitive process of emotion regulation (De Voogd et al., 2018). Fleck et al. (2018), also aforementioned, found that eye movements led to significant changes in EEG coherence, thus impacting activity of the brain at rest; furthermore, the reduction in frontoparietal alpha coherence over the midline suggested that bilateral eye movements may engage the frontoparietal attention network while disengaging the default mode network, leading to increased cognitive readiness.

Harricharan et al. (2019) investigated brain activity in 19 healthy participants (control group) and 20 with PTSD to determine the relationship between episodic memory and eye movements, using three conditions: saccadic, smooth pursuit, and stationary dot (control). During aversive memory recall in both eye movement conditions, frontoparietal areas associated with emotion regulation and autobiographical memory recall were shown to be connected with the right frontal eye field (FEF) and supplementary eye field (SEF) (Harricharan et al., 2019). During smooth pursuit eye movements, there were patterns of increased connectivity between right FEF and SEF and right dorsolateral prefrontal cortex (dlPFC), and between right SEF and right dorsomedial prefrontal cortex (dmPFC) in the PTSD group; the dlPFC and dmPFC are both responsible for emotional regulation and initiation of episodic memory recall (Harricharan et al., 2019). Additionally, in the PTSD group, the right SEF connected with the right anterior insula;

this indicates that eye movements may improve one's internal sense of time during traumatic memory recall, thus assisting in the creation of a more coherent narrative (Harricharan et al., 2019). In conclusion, Harricharan et al. (2019) suggest that horizontal eye movements in PTSD work by activating the right FEF and SEF in order to promote emotion regulation via connectivity with prefrontal regions; in turn, they may foster top-down reappraisal of traumatic memories and decrease their unpleasant emotional intensity during recall.

Kapoula et al. (2010), as aforementioned, used video-oculography during EMDR to study "catch-up saccades" (CUS), a specific kind of smooth pursuit eye movement; when distress was completely reduced (SUDS = 0), frequency of CUS decreased while smooth components increased, which they attribute to better use of visual attention resources following EMDR. By reducing distress, EMDR may be activating a cholinergic effect that subsequently improves eye movements; furthermore, they assert that research on pursuit eye movements hints at a network of involved regions, including the frontal eye fields, parietal regions, cerebellum, basal ganglia, superior colliculus, and brainstem nuclei (Kapoula et al., 2010).

In a review discussed previously, Kaye (2007) details how severe reciprocal suppression of the dorsal ACC (responsible for cognitive processing) can be caused by an overly activated ventral ACC (due to negative affect), thus disallowing the integration of new contextual information. Kaye (2007) proposes that tasks of error monitoring or divided attention (i.e., eye movements in EMDR) may reverse this process; furthermore, suppression of dopamine released by the ventral tegmental area (VTA) can also be reversed through evocation of positive emotions (i.e., RDI phase), which in turn may facilitate increased flexibility of cognitive switching via the ACC. Thus, EMDR may impact the ACC in a way that allows integration of neocortical information, while eye movements permit error monitoring and facilitate an investigatory reflex

(OR) in the context of novel information (Kaye, 2007).

Keller et al. (2014), also mentioned above, used EEG and found little support for a purely interhemispheric coherence model; however, intrahemispheric coherence was enhanced by the eye movements via increased delta and low beta waves in right and left frontal regions, respectively. They therefore proposed a cortical coherence model whereby cortical pathways increase activation based on the stimulation modality, and subsequently become more easily activated upon processing of the trauma; they assert that such recruitment may involve interhemispheric network activation, or intrahemispheric coherence in localized regions (Keller et al., 2014). Brodmann areas 10 and 11 (located in the prefrontal cortex) were activated following eye movements, which the authors state is consistent with SPECT studies that revealed increased blood flow in limbic regions and prefrontal cortex (PFC) after EMDR; this increased coherence may indicate the reconnection of the amygdala, ACC, and PFC (Keller et al., 2014).

In 2001, Kuiken and colleagues (mentioned previously) studied tasks of attentional flexibility (covert attention task) and metaphor comprehension (sentence ratings) and found that eye movements indeed created an OR. Kuiken et al. (2001) also speculated that the altered attentional state may be accompanied by decreased noradrenergic activity, which may be due to inhibition of the locus coeruleus; thus, eye movements may suppress noradrenaline, leading to attentional disengagement. In 2010, Kuiken et al. conducted another similar experiment, mentioned previously, and again found support for an OR; they also asserted that eye movements via the ACC appeared to mediate startle responses and improve recognition of novel stimuli. The authors discuss two systems that may mediate the OR: (a) the amygdala-medial PFC-hippocampal circuit mediates fear- and threat-related contextualization during tasks with unexpected stimuli, and (b) the ACC mediates the monitoring of alternative responses related to loss and pain during tasks of unexpected conflicting demands (Kuiken et al., 2010). They argue that those with traumatic distress and hyperarousal may experience more dysfunction of the first alerting system, while those who have suffered a loss and separation distress may especially experience dysfunction of the second alerting system (Kuiken et al., 2010).

Landin-Romero et al. (2013), in an aforementioned experiment, studied fMRI and neuropsychological data following EMDR in a single patient with subsyndromal bipolar disorder; fMRI showed a return to normalization, with activations seen in frontal networks and other regions including the bilateral anterior insula, basal ganglia, thalamus (extending to the dorsolateral prefrontal cortex), supplementary motor cortex, and parietal cortex. Results also showed that EMDR can modulate the DMN, as it led to improved deactivation patterns and moved the patient closer to the mean activation value of the control group (Landin-Romero et al., 2013).

In 2018, Landin-Romero and colleagues conducted a review similar to the aims of the present investigation; they looked at research on the theories of working memory taxation, the OR, REM sleep, psychophysiological changes, RI, and neurobiological mechanisms like neural integration, the thalamic binding model, and other hypotheses. Their review indicated that the smooth pursuit eye movements in EMDR are more akin to those seen during slow wave sleep (SWS) as opposed to the saccades produced in REM sleep; the authors also suggest that eye movements may induce depotentiation of fear memory synapses, but this theory requires more empirical support (Landin-Romero et al., 2018). They discuss findings from various techniques, including EEG, single-positron emission computed tomography (SPECT), near-infrared spectroscopy (NIRS), and structural and functional magnetic resonance imaging (MRI, fMRI), but state that psychological models have not addressed the neurobiological mechanisms of

EMDR that have yet to be discovered (Landin-Romero et al., 2018). Rather, Landin-Romero et al. (2018) argue that the working memory hypothesis has garnered the most empirical support to date, while increased interhemispheric interaction is not likely contributing; furthermore, they suggest that neurobiological research is still preliminary and should be considered speculative but promising. Although the mechanisms are not agreed upon, the authors conclude that an integrative model should not be discounted, given the complexity of EMDR; additionally, the neurobiological models of temporal binding, limbic regulation, frontal lobe activation, and reciprocal anterior cingulate cortex suppression are likely interrelated, and should be investigated further (Landin-Romero et al., 2018).

Nardo et al. (2010) studied trauma load and differences in grey matter density using MRI and a Voxel-Based Morphometry (VBM) approach in 22 non-symptomatic individuals and 21 with PTSD following occupation-related trauma; they found that cortical grey matter changes were associated with the presence of PTSD, response to EMDR, and trauma load. Those with PTSD showed significantly lower grey matter density in left posterior cingulate and posterior parahippocampal cortices; EMDR non-responders also showed a lower density in bilateral posterior cingulate, as well as right amygdala, anterior insula, and anterior parahippocampal gyrus (Nardo et al., 2010). Thus, the authors suggest that PTSD may inhibit typical processing of emotional memories and stimuli, decrease extinction of conditioned trauma responses, and reduce the likelihood of changing or integrating traumatic memories; furthermore, the low grey matter density in the posterior cingulate cortex (PCC) suggests impaired recall of autobiographical aversive memories and self-referential processing (Nardo et al., 2010). Nardo et al. (2010) conclude that PTSD contributes to lower grey matter concentration in the PCC, parahippocampal cortex, and insula, which impacts responsiveness to EMDR, and trauma load is also correlated regardless of PTSD diagnosis; these findings suggest enhanced vulnerability of these structures to trauma, similar to the known vulnerabilities of the hippocampus, amygdala, and prefrontal cortex. Their findings therefore support the idea that limbic and paralimbic cortices show reduced grey matter density in PTSD, which likely contributes to dissociation and impaired memory; furthermore, EMDR responsiveness appears to be correlated with the same regions (Nardo et al., 2010).

As mentioned previously, Pagani and Carletto (2017) assert that slow wave sleep is involved in memory consolidation, transfer of hippocampal information to the neocortex, and reorganization of distant functional networks, which is further strengthened in REM sleep. Neurobiologically, they suggest that limbic neurons are depolarized at a slower rate via bilateral stimulation, such that emotional memories dysfunctionally stuck in the amygdala can move to and be fully processed by higher brain areas (Pagani & Carletto, 2017). Pagani et al. (2011), also discussed above, provided four EMDR sessions to a single patient using EEG in order to identify brain regions activated during autobiographical trauma script listening and bilateral stimulation. Before EMDR, there was dominant activation in bilateral prefrontal cortex and regions of the left parietooccipital cortex during trauma reliving; after treatment, left occipital and right temporal cortices were activated (Pagani et al., 2011). Thus, the authors assert that dominant electrical activity of lateral prefrontal cortex as well as decreased activation in the prefrontal limbic system occurred after trauma processing; their findings supported Bremner's cortical inhibitory model, Shapiro's memory reconsolidation model, the Davidson model of emotional plasticity, and the emotional asymmetry model (Pagani et al., 2011). Pagani et al. (2011) also assert that successful EMDR may require a shift from emotional reliving to cognitive reliving, which is accompanied by increased beta and gamma (fast bands) activity in the left hemisphere.

Pagani et al. (2018), as aforementioned, conducted a pilot study with two patients with PTSD who received eight sessions of EMDR; PET, EEG, and neuropsychological testing were utilized, as was a control group for PET comparison. No substantial changes were found in neuropsychological abilities, but PET and EEG showed hypermetabolic and activity increases in temporoparietal regions and in the PFC and ACC, suggesting better top-down inhibitory control of subcortical hyperarousal (Pagani et al., 2018).

Propper and Christman (2008), mentioned previously, assert that eye movements lead to increased episodic memory retrieval and reduced emotionality through interhemispheric interaction via the corpus callosum; furthermore, they suggest that individuals with PTSD have REM disturbances, less interhemispheric interaction, and smaller corpus callosa. Rousseau et al. (2019) utilized a classical fear conditioning and extinction paradigm (electric shock paired with neutral visual stimuli) in 12 patients with PTSD while measuring fMRI before and after EMDR; their results were compared to a wait-list supportive therapy control group ($n$ = 12). Results showed greater fear extinction learning in the EMDR group, with changes seen in the hippocampus, right and left amygdala, right frontal eye fields, right inferior frontal gyrus and insula, left Heschl gyrus, and left dorsal posterior cingulate cortex; additionally, during an attention task, the right frontal lobe showed deactivation in the EMDR group (Rousseau et al., 2019). Furthermore, greater connectivity was seen between the left amygdala and left posterior portion of the inferior temporal gyrus; decreased connectivity was seen between the left superior parietal lobule and left hippocampus, and between the right insula and right ventral entorhinal cortex (Rousseau et al., 2019). The authors assert that the reduction of activity in the insula may be related to the individual's increased ability to monitor and manage inner bodily states, including unpleasant images and associated emotions; they conclude that EMDR improves the ability to extinguish fear via reductions in PTSD symptoms, mainly through fear-regulating structures like the left hippocampus, amygdala, and prefrontal cortex (Rousseau et al., 2019).

As aforementioned, Santarnecchi et al. (2019) used fMRI alongside TF-CBT and EMDR to measure functional connectivity (FC) of individuals with single trauma PTSD; they did not include a control group or condition. Both therapies were successful in reducing symptoms and showed some similar FC patterns: in the left hemisphere, connectivity between visual cortex and temporal areas decreased, while connectivity between right temporal pole and bilateral superior frontal gyrus increased (Santarnecchi et al., 2019). Both treatments led to a likely modification of the ventral-dorsal stream balance; furthermore, increased connectivity between prefrontal cortex regions and the right temporal pole aligns with the general neurocognitive hypothesis that psychotherapy leads to increased top-down cognitive control of limbic regions (Santarnecchi et al., 2019).

Stickgold (2002), discussed previously, speculates about the distinction between hippocampal and cortical memories, stating that episodic memories are sparsely stored and rapidly formed in a strong, clear fashion; these memories are then transformed slowly into cortical semantic memories (and thus semantic knowledge) in highly overlapped networks. The author asserts that non-REM sleep is essential for the strengthening of hippocampal memories, while REM sleep states strengthen cortical memories; non-REM involves a dominating presence of serotonin and norepinephrine, compared to dominant acetylcholine seen in REM (Stickgold, 2002). Those with PTSD may experience neurochemical disruptions that impact REM sleep, with alterations seen in the hippocampus, amygdala, ACC, orbitofrontal cortex, and visual cortex; but Stickgold (2002) suggests that bilateral stimulation in EMDR creates repeated ORs that may permit traumatic memories to be cortically integrated via induction of a REM-like state (with resultant memory processing). Specifically, the ponto-geniculo-occipital (PGO) waves released by the brainstem during REM sleep can be triggered by a startle response (i.e., the OR); this OR involves the ACC and superior colliculus, and a pattern of decreased noradrenaline and increased acetylcholine likely allows this attentional shift to occur (Stickgold, 2002). In 2007, Stickgold called for more attempts to create shifts in waking brain states in order to resolve emotional memories that resist processing during typical sleep states, citing another study as evidence (discussed previously).

Thomaes et al. (2016), as aforementioned, used fMRI to examine whether eye movements increase activity in brain regions associated with working memory, decrease activity in emotional processing areas, and how they modulate functional connectivity between these areas. Their script-driven imagery protocol activated regions of visual association cortex, emotion-processing (anterior insula, rostral anterior cingulate cortex/ACC, and dorsomedial prefrontal cortex/dmPFC), and working memory (dorsolateral prefrontal cortex/dlPFC) (Thomaes et al., 2016). Recall plus eye movements led to greater decreases in amygdala and rostral ACC activity and reduced connectivity between the right amygdala and rostral ACC; however, the authors assert that the lack of significant differences in dlPFC activation between control and eye movement conditions casts doubt on the working memory taxation theory (Thomaes et al., 2016).

Vojtova et al. (2009), also mentioned above, speculate that EMDR allows for refocusing of attention and new learning by down-regulating hyperarousal; they assert that such learning relies on memory systems as well as dopaminergic reward circuitry, such as the nucleus accumbens, ventral tegmental area, and lateral hypothalamus. Welch and Beere (2002), discussed previously, presented their own integrative theory: EMDR both enhances and reduces emotional arousal via increased interhemispheric interaction and normalization of brain activation patterns (through bilateral eye movements), while disrupting avoidance or constricted attention. They argue that patients with PTSD begin with increased right hemisphere (emotional) activation, and EMDR may help to increase left hemispheric activity while reducing PTSD symptoms (Welch & Beere, 2002).

Yaggie et al. (2015), mentioned in multiple previous sections, used EEG during eye movements and found increased intrahemispheric coherence between right frontal theta and beta waves; this suggests a focus on associations more relevant to the target event, in regions responsible for higher order processing, alertness, and attention. The increased theta coherence in right frontal regions also suggests increased self-referential processing of affective memory components, ultimately leading to a two-stage cortical coherence model: bilateral stimulation facilitates increased neural interconnectivity, and permits the formation of more constructive associations between traumatic memories and positive meanings (Yaggie et al., 2015).

### ***Thalamocortical Temporal Binding***

In 2008, Bergmann discusses the role of the corpus callosum in mediating interhemispheric coherence, given that individuals with PTSD tend to show right-sided lateralization in neurobiological research. He asserts that restoring the thalamus' ability to provide binding and synchronous oscillation would permit callosal repair and re-balancing of lateralization; furthermore, the ventrolateral thalamic nucleus activates dorsolateral cortices, as seen consistently in EMDR neuroimaging, which enables integration of traumatic memories into semantic cortical networks (Bergmann, 2008).

Bergmann (2010), as aforementioned, asserted that the OR and linked neural systems are interrelated with multiple mechanisms, including temporal binding, neural mapping, hippocampal remapping, limbic depotentiation, activation of frontal lobes, reciprocal suppression of the ACC, and activation of REM systems; additionally, although findings on the psychophysiological changes associated with an OR have been inconsistent, it appears that the OR is parasympathetic in nature. Bergmann (2010) asserts that EMDR first creates a parasympathetic state change that leads to enhanced information processing and repair of neural links, followed by a longer lasting trait change after successful completion of EMDR. Neurobiologically, EMDR leads to increased activation of left frontal regions and decreased activation of occipital and temporal regions, which suggests increased emotional regulation, inhibited limbic over-arousal via increased regulation of association cortex, decreased intrusiveness and hyper-consolidation of traumatic episodic memory, reduced flashbacks, and increased limbic-prefrontal functional balance (Bergmann, 2010). Via repeated ORs, EMDR activates the ventral vagal complex of the medulla, PGO waves and REM systems via cholinergic mechanisms, and the lateral cerebellum, the latter of which activates the ventrolateral and central-lateral thalamic nuclei; Bergmann (2010) thus argues in support of a thalamocortical temporal binding model. Bergmann's speculations on the neurobiology of EMDR are further explored and consolidated along with the general AIP model in his recent book published in 2019.

Miller et al. (2018), discussed previously, suggest that the biological phenomenon of stochastic resonance (SR) may be the mechanism in EMDR; they apply SR to dual attention stimuli in EMDR via the thalamocortical temporal binding model. A weakened traumatic memory signal is boosted by SR via eye movements (creating white noise) in the thalamus (specifically, the ventrolateral and central-lateral thalamic nuclei), and is then transferred onward to limbic structures and the neocortex; activation of the dorsolateral prefrontal cortex is caused by the activated ventrolateral thalamic nucleus (Miller et al., 2018). Thus, eye movements appear to induce restoration and integration of somatosensory networks, memory, cognition, and synchronized hemispheric functioning; an OR is believed to lead to this increased cortico-thalamic signal, which eventually heals a dysfunctional memory network (Miller et al., 2018).

***Depotentiation of Fear Memory Synapses via AMPA Receptors***

Harper et al. (2009) examined EEG (qEEG) in six participants with PTSD in order to compare the effects of EMDR to the memory-changing activities seen in animal studies, and to determine whether (and if so, where) EMDR impacts fear memory synapses (i.e., via depotentiation). They found that PTSD symptoms were significantly reduced in all participants and asserted that the desensitization of EMDR results from depotentiation of fear memory synapses, as seen in animal experiments (Harper et al., 2009). They state that hyper-potentiation of basolateral amygdala complex synapses mediates PTSD-related fear memories; by activating the slow wave sleep (SWS) memory processing system, EMDR is able to achieve depotentiation via induction of a brain state similar to that seen during SWS (Harper et al., 2009).

In 2012, Pagani and colleagues conducted a study using EEG with 10 healthy controls and 10 individuals with PTSD; they measured neuropsychological scores, brain activation, and functional connectivity during EMDR. Following treatment, subjects showed an activation shift from prefrontal and limbic regions (emotional fronto-limbic cortex) to fusiform gyrus and visual cortex (associative temporooccipital cortex); subjects with PTSD also showed significantly higher bilateral limbic activation during trauma script reliving, which lateralized towards left-sided limbic regions and rostral prefrontal cortex (rPFC) during eye movements (Pagani et al., 2012). Furthermore, subjects with PTSD showed greater beta band activation in limbic areas like the orbitofrontal cortex (OFC), rPFC, ACC, parahippocampal gyrus, and posterior cingulate cortex, suggesting higher rates of selective attention to the trauma; delta wave activity was higher in patients as compared to controls, and such activity increased after EMDR for patients (Pagani et al., 2012). The authors suggest that the theory of slow wave sleep and alpha-amino-3-hydroxy-5-methyl-4-isoxazole (AMPA) over-potentiation in the amygdala may account for this phenomenon: the depolarization rate of limbic neurons is slowed by eye movements, which allows for dysfunctional amygdala-bound memories to move to and be fully processed by higher brain areas (Pagani et al., 2012).

In 2013, Pagani et al. reviewed recent research on the neurobiological mechanisms of EMDR and discuss the aforementioned theory of over-potentiation of AMPA receptors in the amygdala, which leads to dysfunctional memory storage; this dysfunction inhibits the ACC from helping to merge emotional memories into more cognitive memory traces. The authors discuss how SPECT studies have shown that limbic and prefrontal regions show significant blood flow changes following EMDR, which have been correlated with PTSD symptom reduction and improved self-referential processing; furthermore, the PFC regains its ability to inhibit hyperarousal of the amygdala upon confrontation with trauma-related stimuli (Pagani et al., 2013). Studies with MRI and fMRI have shown decreased limbic grey matter concentration in subjects who do not respond to EMDR; additionally, individuals with PTSD have lower grey matter density in the posterior cingulate cortex, parahippocampal cortex, and insula (Pagani et al., 2013). One near-infrared spectroscopy (NIRS) study showed that recall plus eye movements led to reduced oxygenated hemoglobin concentration in the lateral PFC, which was associated with symptom improvement following EMDR. Pagani et al. (2013) assert that EEG studies have shown that event-related potential P3a was lessened after EMDR, which suggests improved attentional engagement and ability to assess novel stimuli in preparation for action; additionally, EEG research has found support for amygdala-based depotentiation of fear memory synapses via frontopolar delta waves, akin to those seen during slow wave sleep.

As aforementioned, Pagani et al. (2017) further discuss their support for the amygdala AMPA depotentiation theory and suggest that this phenomenon could integrate the OR, working memory taxation, and REM sleep. In 2018, Pagani et al. conducted the aforementioned pilot study on EMDR with two patients with PTSD; they used PET, EEG, and neuropsychological testing and included a control group for PET comparison. Although there were no substantial neuropsychological changes, PET and EEG showed hypermetabolic and activity increases in temporoparietal regions as well as PFC and ACC, suggesting better top-down inhibitory control of subcortical hyperarousal (Pagani et al., 2018).

In 2006, Rasolkhani-Kalhorn and Harper conducted a speculative review that argued for the depotentiation of fear memory synapses hypothesis, which involves the amygdala, hippocampus, and ACC. Specifically, they state that EMDR impacts the emotional valence of the traumatic memory that is retrieved from the right hippocampus and right amygdala, and combined in the ACC; eye movements enable modification of the emotional memory components, and the left hemisphere (especially the hippocampus and Broca's area) is then able to provide more detailed, logical input (Rasolkhani-Kalhorn & Harper, 2006).

Ultimately, the neurobiological research on EMDR consistently highlights the reciprocal roles of frontal and limbic regions, especially the PFC, ACC, amygdala, and hippocampus. It appears likely that EMDR is facilitating a return to top-down inhibitory control of emotional hyperarousal caused by the amygdala, possibly via the depotentiation of fear memory synapses.

**Integrative Models**

Fourteen of the aforementioned articles argued for an integrative model of how EMDR works, combining various other hypotheses into an overarching theory. Barrowcliff et al. (2004) argued for concurrent reciprocal inhibition, working memory taxation of the visuospatial sketchpad, and an OR; they specifically cited the "reassurance reflex" presented by MacCulloch and Feldman (1996) as a mechanism that likely acts in tandem with visuospatial sketchpad disruption. Denny (1995) proposed an OR model that appears to include support for reciprocal inhibition (i.e., a conditioning model): via external inhibition, the OR blocks the maintenance of conditioned responses. Specifically, Denny (1995) asserts that repeatedly eliciting the aversive memory (conditioned stimulus) while inducing an OR reduces or halts the conditioned fear response, which allows for new learning and new meanings associated with the traumatic memory.

Kuiken et al. (2001) found that eye movements shifted working memory by facilitating attentional reorienting to novel stimuli and to more metaphorical interpretations; they argue in support of an OR and induction of a REM-like state, as similar reorienting patterns are seen during REM sleep (Kuiken et al., 2001). In 2010, Kuiken and colleagues again found support for OR activation, which facilitated attention and understanding of metaphorical expressions; they also assert that the eye movements may be triggering the alerting mechanisms of REM sleep in a waking state (Kuiken et al., 2010). Maxfield et al. (2008) argued for working memory taxation and a psychological distancing effect, which allows for more detached processing; specifically, they state that their findings are in line with memory consolidation via all four components of working memory (CE, PL, VSSP, and episodic buffer), as opposed to independent constructs of VSSP and PL. In a similar vein, Patel and McDowall (2016) argued that eye movements as a dual task tax working memory via the CE system, which also creates a psychological distancing effect.

Pagani and Carletto (2017) assert that slow wave sleep and working memory taxation (of VSSP and CE) likely work in tandem during EMDR; specifically, they state that slow wave sleep is involved in memory consolidation, transfer of hippocampal information to the neocortex, and reorganization of distant functional networks, which is further strengthened in REM sleep (Pagani & Carletto, 2017). Pagani et al. (2017) speculate that desensitization in EMDR occurs via depotentiation of fear memory synapses (i.e., AMPA receptors in the amygdala); if correct, they assert that such a mechanism could account for the effects explained by the OR, working memory taxation, and the hypothesis of Stickgold (2008) concerning REM sleep.

Propper et al. (2007) found decreased gamma frequency coherence and interhemispheric EEG coherence in anterior prefrontal cortex following eye movements, which opposes interhemispheric coherence hypotheses; however, they assert that changes in coherence do not necessarily reflect decreased interaction between hemispheres. Rather, they propose that eye movements may be facilitating consolidation of traumatic memories during EMDR via changing interhemispheric interaction; thus, they argue for a combined model of psychophysiological changes and interhemispheric interaction (Propper et al., 2007).

Schubert et al. (2011) found evidence of de-arousal after eye movements as evidenced by decreased heart rate (HR) and skin conductance (SC), improved heart rate variability (HRV), and increased respiration rate (RR); they stated that their findings were consistent with multiple ORs and a relaxation response, which were more common in EM conditions at exposure outset. They ultimately argue for an integrated OR and reciprocal inhibition model: repeated ORs caused by eye movements cause short-term de-arousal, while the coupling of relaxation with distressing memory exposure leads to the weakening of negative appraisals, thus decreasing avoidance of trauma processing (Schubert et al., 2011).

Söndergaard and Elofsson (2008) reviewed psychophysiological effects of eye movements and asserted that their data fits well with the REM and reciprocal inhibition hypotheses, although it is inconsistent with an OR. However, the authors concede that EMDR may have additional mechanisms and may induce multiple ORs in addition to activating the REM system through eye movements (Söndergaard & Elofsson, 2008). Stickgold (2002) speculates that EMDR creates repeated ORs that may permit traumatic memories to be cortically integrated via induction of a REM-like state (with resultant memory processing); specifically, the author asserts that ponto-geniculo-occipital (PGO) waves released by the brainstem during REM sleep can be triggered by a startle response, such as an OR. In another speculative review, Vojtova et al. (2009) assert that neurobiological mechanisms have garnered the most empirical support, including the theories of dual focus attention, the OR, and REM sleep induction; they assert that EMDR down-regulates hyperarousal, which permits refocusing of attention and new learning via memory systems and dopaminergic reward circuitry.

Following their experiment, Yaggie et al. (2015) ultimately proposed a two-stage cortical coherence model: bilateral stimulation facilitates increased neural interconnectivity, allowing for the formation of more constructive associations between traumatic memories and positive reframes. They assert that this model integrates conditioning as proposed by Dyck (1993) and Denny (1995), the latter of which includes inhibition via an OR, imagination deflation/working memory taxation (CE and VSSP), and physiological connectivity; thus, they support working memory taxation, psychophysiological changes, reciprocal inhibition via an OR, and increased intrahemispheric coherence between right frontal theta and beta EEG (Yaggie et al., 2015).

**Controversy Over the Role of Eye Movements**

A total of 75 articles included in this investigation argued in favor of some utility for eye movements, whether they were of equal or greater benefit than other forms of bilateral stimulation. Only four studies overtly rejected the use of eye movements, believing them to be an unnecessary and ineffective component. The majority of these studies have all been reviewed above and are enumerated in Appendix D. Generally speaking, studies either reviewed findings of past research, conducted experiments using isolated eye movement conditions (i.e., without following the entire eight-phase EMDR protocol), or investigated eye movements as part of EMDR by following several or all phases. The types of conditions employed by various researchers included horizontal versus vertical, saccadic versus smooth pursuit, and fast versus slow eye movements.

A small amount of studies found support for eye movements without falling into one of the other categories included in this investigation (i.e., specific theoretical support). Hornsveld et al. (2010) examined how eye movements impact emotionality of loss-related memories in 60 healthy undergraduates using three conditions: recall plus eye movements, recall plus relaxing music, and recall only (control). The eye movement condition led to greater reductions in emotionality and ability to concentrate, while subjective relaxation did not differ between conditions; the authors speculate that participants may have had concentration difficulties due to reductions in memory vividness following eye movements (Hornsveld et al., 2010).

Jeffries and Davis (2013), as discussed early on in this manuscript, reviewed literature pertaining to the role of eye movements in EMDR as well as the three mechanisms that had garnered the most support to date, according to the authors: the OR, working memory taxation, and interhemispheric interaction. They conclude that more rigorous research is needed to definitively determine whether eye movements are more beneficial than any other dual attention task; however, they assert that there is sufficient evidence to support their use in treatment

(Jeffries & Davis, 2013). Furthermore, given that the overall EMDR protocol has been proven effective, they assert that there is no justifiable reason to remove the eye movement component; although some research indicates that eye movements permit greater reductions in distress, the authors ultimately state that the client and clinician must decide whether to pursue EMDR or TF-CBT (Jeffries & Davis, 2013).

Lee and Cuijpers (2013) found methodological issues in the meta-analysis conducted by Davidson and Parker (2001), and thus endeavored to conduct their own meta-analysis that included all studies published in the previous 23 years; unlike Davidson and Parker (2001), these authors adjusted for the sample size of each included study. Their final sample included 14 treatment studies comparing EMDR with eye movements to EMDR without eye movements, and 10 laboratory studies comparing eye movements to no eye movements while focusing on an autobiographical memory (Lee & Cuijpers, 2013). The clinical studies demonstrated an average significant medium effect size for eye movements over no eye movements during EMDR, while the laboratory studies averaged a significant medium to large effect size for eye movements, with little heterogeneity. The authors speculate about how the beneficial effects of isolated eye movements may be accounted for by working memory taxation or an OR, while emphasizing that the EMDR process is more complex; specifically, they argue that EMDR incorporates other components that likely contribute to its overall therapeutic benefits, including mindfulness and cognitive restructuring (Lee & Cuijpers, 2013). Based on their results, they conclude that eye movements do in fact alter emotional memories (Lee & Cuijpers, 2013).

As aforementioned, four studies rejected eye movements altogether, believing them to be ineffective or an unnecessary addition to an individual's overall treatment. Devilly (2002) examined EMDR research over the previous several decades and concluded that there is overwhelming evidence that eye movements are not a necessary component of the therapy; specifically, the author states that 11 of the 13 dismantling studies reviewed found no significant benefits afforded by the inclusion of eye movements. Of the two studies that did find support for eye movements, there was no inclusion of standardized measures, control conditions, treatment fidelity measures, or proper follow-up for no-eye-movement conditions, according to the reviewer (Devilly, 2002). The author thus concludes that eye movements are not a curative treatment on their own, although EMDR has been proven to be as effective as any other exposure therapy (Devilly, 2002).

Dyck (1993) critiques Shapiro's original assertions about how EMDR works and instead argues in support of a conditioning model (i.e., akin to reciprocal inhibition); specifically, the author asserts that traumatic learning occurs during EMD (the precursor to EMDR) via respondent conditioning, emotional interference with learning, and operant conditioning. Although the author argues that eye movements are not essential, Dyck (1993) does suggest that they are useful as a distracting stimulus.

Novo Navarro et al. (2013), as aforementioned in the working memory section, found no beneficial effects of eye movements on recall following VSSP or PL tasks; however, they did not test working memory taxation in terms of reducing emotionality or vividness of autobiographical memories, unlike most studies related to this account. Thus, although they concluded that eye movements were not effective in improving encoding, their findings do not necessarily take away from past research that has supported the role of eye movements in working memory taxation (Novo Navarro et al., 2013).

Van Schie et al. (2019), also mentioned previously, studied whether eye movements tax working memory by using induced trauma film (analogue) memories; although the tasks of eye movements and counting were both significantly more taxing (based on reaction time) than control conditions (recall only), neither led to consistent decreases in outcome variables. However, given that non-autobiographical (analogue) memories were utilized, their results do not necessarily take away from research supporting the use of eye movements for personally relevant material, which is the focus of EMDR.

Ultimately, the extent of the aforementioned research relating to each theory is wide-ranging and warrants clinical attention. A comprehensive discussion of these findings will ensue in the next section of this manuscript.

## Chapter 5. Discussion

### General Themes

The results of this investigation reveal that the working memory taxation account appears to have garnered the most empirical support in the field; indeed, this theory was investigated more so than any of the others included in the review, based on the search strategy (see Appendix D). In terms of articles supporting each theoretical account listed by Gunter and Bodner (2009), the working memory hypothesis has accrued the most, followed by the orienting response, general psychophysiological changes, and REM-like state induction; the final three accounts (interhemispheric interaction, psychological distancing, and reciprocal inhibition) had an equal amount of articles supporting them. Thus, similar to the findings of Landin-Romero et al. (2018), this investigation has demonstrated that the theories of working memory taxation and psychophysiological changes (including the OR and REM) appear to have received the most empirical support in the field to date. Additionally, neurobiological correlates and mechanisms have been put forth by various research teams, which will be discussed further below. Although these neurobiological theories are relatively new with regard to research on the mechanisms of EMDR, they utilize novel research methods (i.e., neuroimaging techniques) and show great promise for future theoretical developments.

The next several sections will discuss the overarching themes observed for the individual accounts reviewed in this manuscript.

#### *Working Memory Taxation*

As the most researched theory of those included in this review, the working memory (WM) hypothesis has achieved the most support through experimental investigation. Many of the aforementioned research teams examined eye movements as a standalone construct and compared them to other forms of dual taxation, in order to compare their ability to reduce the vividness and emotionality of traumatic or aversive autobiographical memories. A handful of other researchers utilized the full EMDR procedure in order to measure the effects of eye movements on the same or similar variables. Many studies utilized reaction time tasks to assess degree of memory taxation. Subjects in these investigations included mostly healthy participants, primarily undergraduate students, while some assessed individuals with clinical diagnoses of PTSD or other disorders. However, clinical groups were typically smaller in sample size. Control groups and conditions were utilized by the majority of studies. Some studies investigated non-EMDR protocols, such as counting tasks instead of eye movements and aversive film fragments (analogue memories) instead of autobiographical memories. Thus, the interpretations of these studies must be considered in light of their applicability to the manualized EMDR procedure.

In certain studies, discussions revolved around the existence of a dose-response relationship of eye movement taxation versus an inverse U-curve relationship, the latter of which was originally suggested by Gunter and Bodner (2008). Multiple research teams found support for greater taxation (i.e., faster eye movements) leading to greater benefits (dose-response), while several found support for an optimal level of taxation, with too little or too much taxation leading to less beneficial effects in reducing vividness (inverted U-curve). These discussions also suggest that individuals with greater WM capacity would require a greater level of taxation in order to reap the same benefits from a dual task (i.e., titration based on capacity). The likelihood of either relationship and the concept of titration based on WM capacity both warrant further investigation, given the variable findings and methodologies employed by researchers. However, findings do consistently show that faster eye movements appear to outperform slower eye movements in reducing vividness and emotionality, with more consistent evidence of decreased vividness than decreased emotionality. Thus, the speed of eye movements does appear to have an effect on the level of taxation and the subsequent reduction in memory vividness (i.e., at least 1 Hz).

General WM taxation was supported by many teams. However, various teams asserted that eye movements impact distinct systems of WM, including the central executive (CE) and/or the three slave systems: the phonological loop (PL), visuospatial sketchpad (VSSP), and episodic buffer. Most of these researchers were in support of a VSSP model, wherein dual tasks (i.e., eye movements) effectively taxed WM by loading onto the VSSP exclusively. Others found additional support for verbal and auditory dual tasks, which may load onto the PL. Few studies actually implicated the PL as a possible site of taxation, despite the widespread use of counting paradigms; rather, these researchers opted for support of CE or general WM taxation. Those who found support for both of these theories (i.e., VSSP and PL) typically included discussions about modality-specific interference, as discussed below. The CE hypothesis was touted by a handful of researchers, including a team that found support for three distinct visual and auditory distractors that taxed WM (i.e., drawing a complex figure, eye movements, and counting). Others suggested that the CE hypothesis was more likely than the others, given that complex counting effectively degraded primarily visual memories (i.e., without requiring modality-specificity).

In mentioning the viability of modality-specific interference, certain research teams suggested that auditory taxation (i.e., a counting paradigm) is better suited to aversive memories that are largely auditory in nature, while visual taxation (i.e., eye movements) works best for primarily visual aversive memories. If this concept is correct, researchers assert that eye movements would theoretically load onto the VSSP, while counting tasks would load onto the PL. Some studies found evidence for this concept, while others did not; additionally, various research teams suggested that the broader CE system is taxed, or that a combination of all four WM systems (i.e., CE, VSSP, PL, episodic buffer) is involved. Given the variability in both methodologies and findings, it is unclear whether the theory of modality-specific interference is valid; however, what does seem apparent is that eye movements as well as counting paradigms are both effective in taxing the WM system, regardless of the specific pathway.

Some researchers called the use of eye movements into question for certain parts of the EMDR procedure. Specifically, Hornsveld et al. (2011) found that eye movements tax WM and therefore reduce vividness of pleasant memories as well; thus, they assert that eye movements may be detrimental to the overall goal of Resource Development and Installation (RDI) and question their use during this phase.

A few researchers incorporated structural neuroimaging techniques (e.g., MRI) and found that eye movements contribute to safety learning, tax WM, and lead to concurrent amygdala deactivation and dorsofrontal parietal activation via pathways in ventromedial prefrontal regions, which is also seen in the cognitive process of emotion regulation (De Voogd et al., 2018).

One team used fMRI and found that eye movements reduced connectivity between the right amygdala and rostral ACC; however, the lack of differences in dlPFC activation between control and eye movement conditions led them to discount the likelihood of the WM hypothesis. In addition to these researchers, two other studies rejected the WM hypothesis; however, one research team was not studying reductions in vividness and emotionality, but rather investigated recall ability following eye movements. The other team exclusively studied reductions in emotionality and found no differences between eye movements and a control condition; however, given that vividness was not studied, this finding fits with the inconsistent results that have been found across research teams for emotionality reductions.

Overall, the vast majority of studies found support for this hypothesis in one form or another; thus, it is likely that this mechanism at least partially contributes to the effectiveness of EMDR. Of note, several teams also suggest that WM taxation may permit memory reappraisal.

***Psychological Distancing***

Six studies were in support of this theory while none overtly rejected it; however, this theory is clearly more difficult to investigate experimentally. Given its metaphorical nature, it is more challenging to operationalize the distancing effect felt by clients and the supposed detached processing that is thought to succeed it. Lee and colleagues have consistently argued that EMDR is more than just imaginal exposure in their various experiments with both healthy individuals and those diagnosed with PTSD. They have found that distancing and detached processing are both triggered by eye movements as opposed to therapist instruction, and that eye movements led to reductions in emotionality following instructions to relive *or* distance; however, vividness only decreased following eye movements with an instruction to distance (Lee et al., 2006; Lee, 2008; Lee & Drummond, 2008). Thus, there are some parallel methodologies and findings between research on this theory and research in support of WM taxation.

Indeed, the other three research teams argued for integrative models that incorporate both WM taxation and distancing into the overall mechanism of EMDR. These include the following: concurrent WM taxation (VSSP, PL, CE, and episodic buffer) and psychological distancing/detached processing; WM taxation, the OR, and detachment (i.e., distancing); and WM taxation (via the CE) that leads to distancing (Maxfield et al., 2008; Pagani et al., 2017; Patel & McDowall, 2016). Given that multiple accounts included in this investigation are in support of some form of detachment from the trauma following eye movements, the concept of psychological distancing is likely acting in tandem with other mechanisms (i.e., bilateral stimulation and WM taxation, the OR, etc.). Therefore, it deserves to be further researched in a way that optimizes the objectivity of outcome variables; once its credibility has been more widely established, it may be safe to say that psychological distancing is at least partially responsible for the effectiveness and success of EMDR. According to the aforementioned proponents of a distancing effect, EMDR may also be the therapy of choice for clients who are not yet ready to engage in more intense reliving that is characteristic of other exposure treatments.

***Interhemispheric Interaction***

It appears that the increased interhemispheric interaction hypothesis does not have sufficient evidence to back its claims, given that six articles supported it, while five rejected it. Proponents of this theory assert that saccadic horizontal eye movements are effective in improving episodic memory and decreasing false memory rates, by way of increasing communication between hemispheres. However, the six articles in support of this mechanism only used healthy samples to test their assertions, which hinders their applicability to clinical populations with PTSD and other diagnoses.

The research teams that overtly rejected increased interhemispheric interaction argued for changes in EEG coherence or in favor of vertical eye movements (which would preclude the assumptions of this theory). These researchers argue that the apparent effectiveness of vertical eye movements dismantles the idea of increased interhemispheric interaction during EMDR, as they are not bilateral in nature. However, despite the lack of consistent evidence for increased interhemispheric interaction, multiple researchers have found evidence of increased intrahemispheric coherence and alterations (not increases) to the communication between hemispheres during EMDR. For example, Yaggie et al. (2015) found increased intrahemispheric coherence between right frontal theta and beta EEG following eye movements, suggesting that a focus was placed on relevant associations in regions responsible for higher order processing, alertness, and attention; they ultimately argued for a two-stage cortical coherence model. Similarly, Keller et al. (2014) found EEG evidence of enhanced intrahemispheric coherence via increased delta and low beta waves in right and left frontal regions, respectively; thus, their cortical coherence model suggests that cortical pathways increase activation based on the modality of stimulation, and subsequently become more easily activated upon processing of the trauma. Propper et al. (2007) also found support for changes in interhemispheric coherence (not increased interaction), as they observed decreased gamma frequency coherence and interhemispheric EEG coherence in anterior prefrontal cortex following eye movements.

Thus, this hypothesis may require amending in order to account for the recent EEG studies that demonstrate such findings; it is possible that increased intrahemispheric coherence and/or changes to communication between hemispheres occur during or after bilateral eye movements, particularly in frontal regions. As it stands, the increased interhemispheric interaction theory does not appear to have consistent empirical support and is unlikely to be the sole mechanism of EMDR that accounts for its effectiveness.

***Psychophysiological Changes***

Based on the research described above, it appears that EMDR and eye movements do in fact lead to psychophysiological changes generally speaking; indeed, only one article came out against general psychophysiological changes. The three subsumed theories (reciprocal inhibition, REM-like state, and the orienting response) will be discussed in further detail below. The orienting response has garnered the most support compared to general changes and to the other two subsumed theories. Multiple research teams used the EMDR protocol while some isolated the eye movement component; additionally, many research teams used clinical samples of individuals with PTSD with appropriate control groups and/or comparisons. However, it should be noted that several research teams employed single patient case studies and/or pilot studies with very few individuals, and a few studies did not include a control group or condition. While their results appear promising, these experiments should be interpreted as preliminary and warrant further replication via randomized controlled trials in larger clinical populations.

The measures that were employed by the majority of research teams included a combination of heart rate, heart rate variability, skin conductance or electrodermal arousal, respiration rate, respiratory sinus arrhythmia, fingertip skin temperature, expiratory carbon dioxide levels, blood pulse oximeter oxygen saturation, and/or autonomic balance as measured through the ratio between low and high frequencies of the heart rate power spectrum (LF/HF). The consistency of findings across research teams suggests that EMDR and eye movements in general do impact sympathetic arousal of the autonomic nervous system, causing an overall physiological de-arousal effect, and may be altering how the brain (i.e., the amygdala) functions. Many researchers argue that EMDR/eye movements attenuate the physiological arousal that is commonly seen in PTSD, ultimately leading to habituation of arousal responses. Similarly, other researchers assert that EMDR permits re-integration of traumatic memories, which may allow regulation of limbic arousal via the reactivation of inhibitory circuits (i.e., top-down control).

The inhibition of the sympathetic system, increase in parasympathetic tone, and ultimate physiological de-arousal are typically accompanied by a shift in autonomic balance during eye movements, as evidenced by increased fingertip temperature, breathing frequency, and carbon dioxide, decreased heart rate, skin conductance, LF/HF ratio, and oxygen saturation, and heart rate variability improvement. Based on these changes, multiple researchers concluded that

EMDR and/or eye movements appear to activate cholinergic systems, which some argue is akin to the pattern seen during REM sleep. One study used fMRI to show that left hemispheric functional connectivity between visual cortex and temporal areas decreased, while connectivity between right temporal pole and bilateral superior frontal gyrus increased following EMDR; additionally, EMDR likely modified the ventral-dorsal stream balance, and findings suggested an increased top-down cognitive control of limbic regions. Using EEG, some researchers asserted that EMDR is accompanied by increased beta and gamma (fast bands) activity in the left hemisphere, which may permit a shift from emotional reliving to cognitive reliving. Additional PET and EEG findings suggested that EMDR leads to hypermetabolic and activity increases in prefrontal cortex and the ACC, suggesting better top-down inhibitory control of subcortical hyperarousal, as well as in temporoparietal regions. However, another study found decreased gamma frequency coherence and interhemispheric EEG coherence in anterior prefrontal cortex following eye movements, which opposes the aforementioned findings.

One study did not find the expected psychophysiological changes (specifically, reduced heart rate and skin conductance) following eye movements. However, they found that propranolol interfered with memory reconsolidation, blocked noradrenergic activation, and thus negated the degrading effects of eye movements; they therefore suggested that noradrenergic neurotransmission is required before desensitization via eye movements can occur, and noradrenaline may enhance reconsolidation of the degraded memory (Littel et al., 2017).

**Reciprocal Inhibition.** Multiple research teams found support for reciprocal inhibition (RI) through conditioning models or integrative theories that combined other accounts (i.e., WM taxation, the OR, or both); however, these studies were either speculative arguments, reviews, or experimental designs that used only healthy subjects. Methods employed by these teams included EEG and psychophysiological measures of skin conductance, heart rate, heart rate variability, and respiration rate. It has been suggested that repeatedly eliciting an aversive memory (conditioned stimulus) and simultaneously inducing an OR via eye movements reduces or halts the conditioned fear response, which permits new learning and new meaning attributions for the traumatic memory. Another team asserted that the repeated ORs created by eye movements lead to short-term de-arousal, while pairing relaxation with a distressing memory leads to the weakening of negative appraisals; this ultimately leads to decreased avoidance of trauma processing. Furthermore, several teams argued in support of a combined mechanism of WM taxation, the OR, and RI, thus providing consistent support for such an integrative model.

The only study that countered the RI theory was speculative in nature; although no experimental design was included in the review, it was argued that the antagonistic inhibition caused by RI and counterconditioning does not have enough evidence as a mechanism for EMDR. Rather, this author suggested a different mechanism that was not included in the purview of this investigation: a connectionist learning-memory theory known as the Parallel Distributed Processing Connectionist Neural Network (PDP-CNN) model.

In sum, although the available research on RI is limited, preliminary results appear promising and warrant further investigation. Nevertheless, the relatively consistent support for a conditioning model lends some credence to the concept of RI as a mechanism that may work in tandem with others during EMDR, such as the OR and WM taxation. Indeed, models of conditioning have been prevalent in the world of psychotherapy for many years, and EMDR may be no exception. Thus, while it is possible that this mechanism is contributing to the overall effectiveness and success of EMDR, more research is needed. Ideally, this model will be tested further in the future with larger clinical samples of individuals with PTSD.

**REM-like State.** Ten articles supported this theory while none overtly rejected it. The proponents of the REM-like state account have employed various methods of investigation, including experimentation that measures psychophysiological changes and speculative reviews. Individuals with a diagnosis of PTSD make up the sample in certain studies, while other researchers experimented with healthy subjects (typically undergraduate students). These studies have utilized measures such as fingertip skin temperature, skin conductance, heart rate, expiratory carbon dioxide, blood pulse oximeter oxygen saturation, and low-high frequency ratio of the heart rate power spectrum. However, it should be noted that only three research teams conducted experiments of their own, while the rest of the articles were speculative reviews. Some researchers argued for the occurrence of an OR that leads to a REM-like state, while others rejected the OR but argued in favor of REM-like patterns (i.e., activation of cholinergic systems and inhibition of sympathetic systems). Others argue for a combination of other theories with REM-like state induction, including WM taxation, RI, and neurobiological mechanisms.

Those who argue for a combined REM and OR model discuss several assumptions of this theory. Certain researchers argue that eye movements facilitate attentional reorienting and shift WM in a way that permits faster responses to novel stimuli, while allowing access to a broader scope of metaphoric interpretations; this pattern is believed to be similar to that of REM sleep, where eye movements permit WM shifts that lead to affective dream narratives. According to this research, eye movements may mediate startle responses and improve recognition of novel stimuli via the ACC; furthermore, they may inhibit the locus coeruleus, leading to noradrenergic suppression and subsequent attentional disengagement. In a review, a prominent supporter of the REM hypothesis also argued that eye movements in EMDR lead to decreased noradrenaline and increased acetylcholine; this permits an attentional shift via repeated ORs and allows traumatic memories to be cortically integrated through induction of a REM-like state. This mechanism may be related to ponto-geniculo-occipital (PGO) waves, which are released by the brainstem during REM sleep and can be triggered by a startle response (i.e., in this case, the OR). It has also been suggested that EMDR down-regulates hyperarousal which allows refocusing of attention and new learning; this learning may require memory systems as well as dopaminergic reward circuitry, such as the nucleus accumbens, ventral tegmental area, and lateral hypothalamus.

One review discussed the likelihood of a combined REM and RI hypothesis, but refuted the OR; however, they conceded that multiple ORs may yet be contributing to the mechanism of EMDR, despite the lack of evidence found in their review. Another review argued for the role of slow wave sleep (SWS), REM sleep, and WM taxation via the VSSP and CE; specifically, it is suggested that eye movements may permit slower depolarization rates of limbic neurons, which may allow amygdala-bound emotional memories to move and be fully processed by higher brain areas. This research was elaborated upon in a later review that proposed a neurobiological mechanism of EMDR: depotentiation of AMPA receptors in the amygdala; this model may explain the theories of the OR, WM taxation, and REM-like state induction if proven correct.

Given that only three of the aforementioned articles employed experimental designs, it is difficult to say whether or not sufficient evidence exists regarding the induction of a REM-like state in EMDR. The majority of articles in support of this theory are speculative in nature but may offer insights into future areas of research (i.e., neuroimaging to examine activation patterns). However, given the consistency with which the REM theory is integrated with others (especially the OR), it is possible that REM-like activation and deactivation patterns are induced by EMDR and/or eye movements through one or more other mechanisms. Therefore, this hypothesis requires further experimentation with more neuroimaging techniques and larger clinical samples in order to better establish its credibility as a mechanism in EMDR. Currently, it is unclear as to whether or not a REM-like state is induced during EMDR; consequently, it may or may not be contributing to the overall effectiveness of the therapy. It is also possible that some individuals may be more attuned to such a brain state, and for them, the therapy may work via these mechanisms.

**The Orienting Response.** Many controlled experimental designs were conducted on the OR theory. However, it is noted that three of the experiments in support of this account were uncontrolled (only included participants with PTSD), and some articles were merely speculative in nature. Thus, some of the interpretations should be considered with caution.

Multiple viewpoints exist regarding the orienting response (OR) and how it factors into EMDR; for example, three early research teams differed in their beliefs and argued in favor of either an intensified OR, a de-arousal OR, or no OR at all. Some researchers have followed in the footsteps of MacCulloch and Feldman (1996), who argued for a de-arousal effect via a reassurance reflex produced by eye movements. Researchers have employed various psychophysiological variables in order to support their theory on the OR, such as electrodermal arousal/skin conductance, impedance cardiogram, pre-ejection period, heart rate, heart rate variability, and respiration rate. The majority of these teams argue for a de-arousal effect achieved by eye movements via an OR, as reflected by findings like within-session habituation of psychophysiological arousal, decreased heart rate, respiration rate, and skin conductance, and increased heart rate variability and within-session parasympathetic tone. Some of these researchers argue that the OR causes a relaxation effect at the beginning of sessions and assert that short-term de-arousal caused by OR(s) may facilitate the integration of adaptive and corrective information related to the traumatic event. One researcher argued that eye movements in EMDR may not directly cause the OR but do facilitate it by permitting error monitoring that allows for an investigatory reflex (OR) to occur in the context of novel information.

As in other accounts, multiple researchers have proposed integrative models that incorporate the OR. These include the following combinations: WM taxation, RI, and an OR; conditioning models that include the RI and an OR; REM sleep and repeated ORs; WM taxation, REM sleep, and an OR; and neurobiological mechanisms involving the OR. Regarding the proposed RI and OR model, researchers have suggested that repeated ORs cause short-term de-arousal, while combining relaxation with exposure to a distressing memory weakens negative appraisals and decreases avoidance of trauma processing. The proponents of REM sleep and the OR assert that bilateral stimulation in EMDR creates repeated ORs that may permit traumatic memories to be cortically integrated via induction of a REM-like state. Those who support WM taxation, RI, and the OR have suggested that eye movements may act as distractors that place demands on attentional resources, while the OR blocks the maintenance of conditioned responses via external inhibition. It is suggested that the repeated elicitation of an aversive memory (conditioned stimulus) and simultaneously induced OR attenuates the conditioned fear response, which permits new learning and new meanings attributed to the traumatic memory.

In discussing the neurobiology of EMDR, it has been suggested that the OR and its associated neural systems are interrelated with multiple mechanisms, including temporal binding, neural mapping, hippocampal remapping, limbic depotentiation, activation of frontal lobes, reciprocal suppression of the anterior cingulate cortex, and activation of REM systems (Bergmann, 2010). Another research team argued for stochastic resonance in EMDR via the thalamocortical temporal binding model and suggested that the OR is what permits such an increased cortico-thalamic signal. Others have suggested that EMDR works via depotentiation of amygdala based AMPA receptors, which could explain the OR, WM taxation, and REM sleep hypotheses. While these assertions are made in speculative review articles, they may provide areas for future research on the OR and other neurobiological mechanisms.

Among the articles that rejected the OR, there was evidence of increased fingertip temperature, breathing frequency, and carbon dioxide, and decreased heart rate, skin conductance, LF/HF ratio, and oxygen saturation, which was believed to be inconsistent with the occurrence of an OR. Another article reviewed past research and arrived at the same conclusion: their findings did not support an OR, although they did not discount the possibility of multiple ORs and other mechanisms in EMDR. Both of these articles instead supported the REM sleep hypothesis. The third article argued in support of WM taxation instead of an investigatory reflex produced by an OR.

Based on the above, it appears that the OR has received relatively promising support via experiments that employ psychophysiological measures. The idea that the OR causes an overall de-arousal effect has been proposed most consistently and may be a likely mechanism in EMDR; furthermore, the OR may be working in tandem with other mechanisms, such as WM taxation, RI, and/or REM or slow wave sleep (SWS) activation. Therefore, it is possible that the OR is contributing to the overall effectiveness and success that EMDR has achieved over the years. Further experimentation is warranted in order to demonstrate a consistent de-arousal pattern (based on psychophysiological measures) in larger samples of individuals with PTSD that are compared to well-matched control groups. As the subsumed theory with the most support of all the psychophysiological changes accounts, it appears that the OR is most likely to be a factor in EMDR; however, RI and REM and/or SWS state activation may be simultaneously contributing to the overall de-arousal effects seen.

*Neurobiological Mechanisms and Correlates*

Many of the proponents of neurobiological mechanisms discuss the idea that EMDR facilitates the moving of unprocessed traumatic memories that are stored in emotional limbic regions to higher order cortical areas (general semantic networks) of the brain. In doing so, logical and coherent narratives are better able to be integrated with the emotional and sensory aspects of the memory. Some researchers have suggested that limbic neurons are depolarized at a slower rate via horizontal eye movements, which permits emotional memories dysfunctionally stuck in the amygdala to move and be fully processed by higher brain areas. Indeed, EMDR may impact the amygdala and is thought to amplify electrodermal activity. Furthermore, shifting from emotional reliving to cognitive reliving may be required before EMDR succeeds, and this process is thought to be related to increased beta and gamma (fast bands) activity in the left hemisphere.

Two neurobiological theories appear to have garnered support across multiple research teams: the thalamocortical temporal binding model and the depotentiation of fear memory synapses via amygdala AMPA receptors. The four proponents of the first theory (speculative reviews) suggest that the thalamus must be restored so that it may provide binding and synchronous oscillation; this restoration would theoretically permit callosal repair and re-balancing of lateralization, as those with PTSD tend to show right-sided lateralization patterns. The ventrolateral thalamic nuclei may be crucial in this regard, as they are thought to activate dorsolateral cortices and enable integration of traumatic memories into semantic cortical networks. Through repeated ORs, EMDR may activate the ventral vagal complex of the medulla, PGO waves and REM systems via cholinergic mechanisms, and the lateral cerebellum, the latter of which activates the ventrolateral and central-lateral thalamic nuclei. Others have tied the concept of stochastic resonance (SR) to this theory, asserting that a weakened traumatic memory signal is boosted by SR via eye movements in the thalamus (specifically, the ventrolateral and central-lateral thalamic nuclei), and is then transferred onward to limbic structures and the neocortex. Activation of the dorsolateral PFC is caused by the activated ventrolateral thalamic nucleus. Thus, this model suggests that eye movements induce restoration and integration of somatosensory networks, memory, cognition, and synchronized hemispheric functioning, and an OR is believed to lead to this increased thalamocortical signal.

The second prominent theory in this domain concerns the depotentiation of fear memory synapses via AMPA receptors in the amygdala, and this model is supported by six studies included in this investigation. Multiple research teams included EEG and/or PET monitoring in their experimental designs, while others conducted reviews of past research. In PTSD, it is thought that over-potentiation of AMPA receptors in the amygdala leads to dysfunctional memory storage, which inhibits the ACC from merging emotional memories into more cognitive memory traces. Traumatic memories are reportedly retrieved from the right hippocampus and right amygdala and combined in the ACC; the eye movements in EMDR may permit modification of an emotional memory, which allows the left hemisphere (i.e., hippocampus and Broca’s area) to provide more detailed, logical input. These researchers also suggest that hyper-potentiation of basolateral amygdala complex synapses mediates PTSD-related fear memories, and EMDR is thought to achieve depotentiation via induction of a brain state similar to that of SWS, as it induces frontopolar delta waves. Eye movements are thought to slow the depolarization rate of limbic neurons, allowing for traumatic memories stuck in the amygdala to move to and be fully processed by higher brain areas. Findings of increased hypermetabolic activity via PET and EEG in temporoparietal regions as well as the PFC and ACC also point to better top-down inhibitory control of subcortical limbic hyperarousal. The depotentiation model is also suggested by some to account for the effects of WM taxation, the OR, and the REM sleep hypothesis.

The rest of this section discusses general themes that have arisen in this field of research, rather than any specific identified model or theory. Regarding the OR alerting system, certain researchers have implicated the amygdala-medial PFC-hippocampal circuit, which mediates fear- and threat-related contextualization during tasks with unexpected stimuli; dysfunction of this alerting system can be seen in those with traumatic distress and hyperarousal. Additionally, Voxel-Based Morphometry (VBM) findings have shown that individuals with PTSD have significantly lower grey matter density in left posterior cingulate and posterior parahippocampal cortices. Neuroimaging research also suggests that individuals with reduced grey matter density in the posterior cingulate, parahippocampal cortex, and insular cortex, and increased activation in the ventral ACC and amygdala may not benefit from EMDR or other treatments. Proponents of the interhemispheric interaction theory have suggested that this mechanism occurs via the corpus callosum; however, those with PTSD have been shown to have REM sleep disturbances along with smaller corpus callosa, which would inhibit the suggested increase in interhemispheric communication.

The reviews on the neurobiology of EMDR conducted by Bergmann, although speculative in nature, have shed light on multiple theories and mechanisms related to brain-behavior relationships. Some researchers speculate that EMDR may be able to interface directly with the amygdala, given the therapeutic focus on bodily sensations and the ability of the amygdala to amplify electrodermal activity. Indeed, EMDR has been suggested to alter relationships between the amygdala, other limbic and paralimbic structures (portions of the thalamus, hypothalamus, hippocampus, caudate nucleus, septum, mesencephalon, and cingulate gyrus), and the PFC. Other regions that may be impacted by eye movement stimulation include the ACC, pons, lateral cerebellum, gyral cortical structures, and neocortex. The left PFC and some temporal regions are thought to contain a dampening switch for modulating the amygdala's emotional reactivity by integrating more logical and appropriate responses. This switch may prevent the amygdala from overwhelming the serotonergic pathways that relay signals from limbic regions to the PFC, essentially countering the inhibition of working memory and homeostasis.

Several researchers have claimed REM sleep is crucial for strengthening neocortical memories, while non-REM sleep (possibly slow wave sleep or SWS) appears to strengthen hippocampal memories. To induce and maintain REM sleep, the locus coeruleus (LC) suppresses norepinephrine; the LC is also thought to activate the Gigantocellular Tegmental Field (GTF) neurons of the pons, which may control dreaming during REM sleep. Furthermore, high amplitude electrical potentials, known as Pontine Geniculate Occipital (PGO) waves, originate in the GTF neurons and have been seen in the reticular formation of the pons, the lateral geniculate nucleus of the thalamus, and the occipital cortex. Some research has shown that GTF cells may be activated by startle responses during wakefulness; thus, it is possible that PGO waves are being triggered during EMDR via repeated ORs, which inhibit the LC and induce a REM-like state. Such an OR is thought to involve the ACC and superior colliculus; additionally, EMDR is thought to enable a surge of acetylcholine that activates the REM sleep system, as mediated by the ACC.

Some fMRI studies have shown that WM tasks like eye movements may deactivate the amygdala and alter the amygdala's connectivity with both the dorsal frontoparietal network and the ventromedial PFC. Recall plus eye movements has also been associated with decreased activation of and reduced connectivity between the right amygdala and rostral ACC. Furthermore, eye movements have been shown to create significant changes in EEG coherence; specifically, the increased intrahemispheric coherence found between right frontal theta and beta waves suggests that EMDR permits the formation of more constructive associations and positive meanings of traumatic memories. Some researchers have implicated the default mode network (DMN), dorsal attention network (DAN), and cerebellar activity in EMDR; in activating the DMN, traumatic memories may be recalled, modified during therapy, and finally reconsolidated in a less vivid and emotional form. The cerebellum may be involved in event timing, associative learning, and this reconsolidation process. While memories are recalled, eye movements are thought by some to deactivate the frontoparietal attention network, causing a simultaneous relaxation response. Modulation of the DMN was also corroborated by fMRI findings of a single patient case study on subsyndromal bipolar disorder, which showed activation in regions of frontal networks, the bilateral anterior insula, basal ganglia, thalamus (extending to the dorsolateral PFC), supplementary motor cortex, and parietal cortex following EMDR. The therapy also led to improved deactivation patterns and moved the patient closer to normalized activation on fMRI. However, another EEG study concluded that the reduction in frontoparietal alpha coherence over the midline suggests that bilateral eye movements engage the frontoparietal attention network while disengaging the DMN, contrary to the aforementioned assertions.

Certain SPECT studies have shown that EMDR leads to significant blood flow changes in the limbic system and PFC. Findings suggest that Brodmann areas 10 and 11 (located in the PFC) may be activated following eye movements, and this increase in intrahemispheric coherence suggests the reconnection of the amygdala, ACC, and PFC. Through the ACC, eye movements are thought to mediate startle responses and improve recognition of novel stimuli. Some researchers suggest that the dorsal cognitive subdivision (ACcd) and the rostral ventral affective subdivision (ACad) of the ACC reciprocally inhibit each other, with cognitive tasks activating ACcd and deactivating ACad, and affective tasks activating ACad and deactivating ACcd. A dysfunctional balance likely inhibits the integration of new contextual information; however, eye movements may reverse this process through error monitoring. Specifically, EMDR is thought to permit bilateral activation of ACcd, which parallels SPECT findings of bilateral anterior cingulate gyrus activation following treatment. The reduction of ACad activity and increase in ACcd activity may permit greater inhibition of unpleasant emotions and cognitions, which is also found in mindfulness treatments. Furthermore, increased flexibility of cognitive switching via the ACC may occur when positive emotional content is evoked (i.e., the RDI phase) by reversing dopamine suppression in the ventral tegmental area (VTA). Other teams have also implicated dopaminergic reward circuitry (i.e., the nucleus accumbens, VTA, and lateral hypothalamus) along with memory systems in the process of new learning during EMDR.

In reducing distress, EMDR has been suggested to improve use of visual attention resources via the activation of a cholinergic effect; this is thought to involve regions like the frontal eye fields, parietal areas, cerebellum, basal ganglia, superior colliculus, and brainstem nuclei. Indeed, some research has found that traumatic memory recall activates connections between frontoparietal areas (associated with emotion regulation and autobiographical memory recall) and the right frontal eye field (FEF) and supplementary eye field (SEF). Studies on smooth pursuit eye movements have revealed patterns of increased connectivity between right FEF and SEF and right dlPFC, and between right SEF and right dmPFC in PTSD. Additionally, the right SEF may increase its connection with the right anterior insula, indicating that eye movements may improve one's internal sense of time during traumatic memory recall and assist in creating a more coherent narrative. Others have argued that EMDR improves the ability to extinguish fear via reductions in PTSD symptoms, mainly through fear-regulating structures like the left hippocampus, amygdala, and PFC. Experiments comparing EMDR and TF-CBT have suggested that both treatments likely modify the ventral-dorsal stream balance, with an increase seen in functional connectivity between the PFC and right temporal pole. All of these findings suggest what many researchers have concluded: eye movements in EMDR may foster top-down reappraisal and control of traumatic memories and decrease their unpleasant emotional intensity during recall.

Ultimately, the amount of research on the neurobiological underpinnings and suggested mechanisms of EMDR is promising, but preliminary. As can be gleaned from the previous paragraphs, numerous brain regions have been implicated in EMDR therapy, with certain areas having garnered more consistent support than others (i.e., limbic structures, PFC, ACC, thalamus, etc.). Additionally, many of these structures correspond to the intrinsic connectivity networks (ICN) aforementioned in this manuscript, such as the DMN, salience network (SN), and central executive network (CEN); in PTSD, hyperactivity can be seen in the insula and amygdala (part of the SN), while the vmPFC and hippocampus (part of the DMN) are hypoactive (Sripada et al., 2013). The insula may integrate external information with internal signals in a way that initiates switching between the DMN and CEN (Uddin et al., 2017). The dlPFC and lateral parietal regions, also implicated, are included in the CEN, which controls higher order executive functions. Thus, the deactivation and activation patterns that appear to be caused by EMDR generally align with what is known about PTSD, and findings suggest a return to normalization following treatment. However, further research is warranted in order to gain a better understanding of which models (i.e., thalamocortical temporal binding, depotentiation of amygdala AMPA receptors, or others) have the most credibility as a mechanism of EMDR, and which brain regions are consistently involved. While it did not serve as the main focus of this investigation, a review of current research on the neurobiology of EMDR was included; however, the preliminary results highlight the fact that this domain deserves its own line of inquiry in a separate, more in-depth investigation.

***Integrative Models***

The number of integrative models that have been proposed offers a promising outlook for the direction of future research, given that many researchers have opted for an open-minded and flexible conceptualization of how EMDR works. These integrative models include the following combinations (and the amount of articles in support of each): REM-like state and ORs (4 articles); WM taxation (via one or all component systems) and psychological distancing (2 articles); RI and repeated ORs (2 articles); WM taxation (CE and VSSP), SWS, and REM sleep (1 article); RI, WM taxation (VSSP), and an OR (1 article); REM-like state and RI (1 article); depotentiation of fear memory synapses via AMPA receptors in the amygdala, which could account for the OR, WM taxation, and REM sleep hypotheses (1 article); alterations in interhemispheric interaction and concurrent psychophysiological changes (1 article); WM taxation, psychophysiological changes, reciprocal inhibition via an OR, and increased intrahemispheric coherence (1 article).

Given the breakdown of support for the models listed above, it appears that the subsumed psychophysiological changes accounts have been integrated the most often; as such, it is possible that all three mechanisms (RI, OR, and REM) occur simultaneously to some extent during EMDR. The following combination is suggested, based on the aforementioned research findings:

the eye movements in EMDR may be facilitating repeated ORs that create a relaxation response that reciprocally inhibits the fear response that would be evoked by presentation of traumatic stimuli (i.e., emotional hyperintensity and physiological arousal); this ultimately leads to deactivation of the sympathetic nervous system and an increase in parasympathetic tone. This de-arousal pattern may be akin to the activation patterns seen during REM sleep, in which cholinergic systems become activated while sympathetic systems and noradrenaline are suppressed.

Another potential mechanism includes the combination of WM taxation and psychological distancing. In thinking about what each theory asserts, it is possible that the vividness outcome variable that has been utilized across research on WM taxation may be related to the level of distance from the memory that an individual experiences. That is, it could be argued that there is an indirect relationship between these two constructs: as the vividness of an image decreases, the perceived distance from that image increases in a relatively equal manner. One way to test this theory is to combine the respective methodologies employed by each research area, for example, by including perceived distance from the memory as another outcome variable alongside vividness and emotionality of a traumatic memory.

As has been suggested by many research teams, the EMDR protocol likely employs multiple mechanisms that may work to different extents based on the individual differences and preferences of each client, on both a psychological and neurobiological level. The fact that WM taxation has also been combined with multiple accounts related to psychophysiological changes sheds light on the complexity of this line of investigation. Additionally, neurobiological mechanisms have been proposed as a component of certain integrative models, although this research requires further investigation in order to elucidate the specifics of such interactions. If both of these accounts are combined with the previous psychophysiological proposal, then the following integrated theory is suggested: the eye movements in EMDR may facilitate repeated ORs and reciprocally inhibit the fear response, which leads to depotentiation of fear memory synapses in the amygdala via AMPA receptors, while decreasing the vividness of traumatic images, and ultimately causing a de-arousal pattern similar to that of REM sleep. Ultimately, given the vast amount of methodologies and findings related to each account, it is certainly possible and likely that an integrative model may be the best fit for how EMDR works.

***The Utility of Eye Movements***

The eye movements used in EMDR do appear to be beneficial in that they serve as an effective distractor based on the research to date; however, other forms of stimulation that are substituted for horizontal eye movements require further investigation before the same can be said for their effectiveness (i.e., tapping, vertical eye movements). Furthermore, several studies have commented on the apparent ineffectiveness of binaural tones as a form of bilateral stimulation, based on recent investigations of their utility; thus, employing bilateral auditory tones in lieu of eye movements should be considered with caution or avoided completely. Other distractors that appear to tax WM (i.e., drawing a complex figure, playing Tetris, and counting), while not used during EMDR, have also been shown to aid in reducing the emotionality and vividness of unpleasant memories. While this research is promising, it is unlikely that EMDR-trained clinicians will begin to employ such dual tasks during the therapy, given the protocol's explicit instructions on the types of dual tasks that are permitted. Furthermore, horizontal eye movements have been shown in many of the aforementioned studies to successfully reduce vividness and emotional valence of traumatic autobiographical memories; thus, a change to the protocol does not appear mandated, as bilateral eye movements appear effective and offer an additive benefit to the overall EMDR procedure. The specific forms of eye movements and the support found for each can be found earlier in this manuscript. As long as an optimal speed is achieved (i.e., 1 Hz or greater), it appears that both smooth pursuit and saccadic horizontal eye movements have the potential to be effective.

**Limitations of the Investigation**

This literature review was aimed at investigating the four theoretical accounts put forth by Gunter and Bodner (2009), and as such was limited in scope. Additionally, several of these accounts have relatively few experimental investigations conducted on them, which limits the conclusions that can be drawn from their findings. Advanced techniques that assess neurobiological mechanisms are still relatively new to the field of how EMDR works; thus, further experiments need to be conducted in order to evaluate the likelihood of what may be at play on a neuronal and structural level. This manuscript delineated the neurobiological correlates that have been proposed by various research teams, whether they argue for a purely neurobiological mechanism of action (i.e., the thalamocortical binding model, or the depotentiation of AMPA receptors and fear memory synapses in the amygdala), or incorporate discussions of how other mechanisms may activate certain brain regions. Given the relative nascence of this portion of EMDR research, the information on the neurobiology of EMDR garnered in this manuscript should be viewed as preliminary and presents an opportunity for further research. Of particular note, the dysfunction seen in PTSD as it relates to a hypoactive default mode network, hyperactive salience network, and distorted central executive network may be directly modulated by EMDR, given the structures and pathways that have been implicated in neuroimaging studies. This may be achieved via the supposed induction of an orienting response, specifically in relation to the salience network.

There is an abundance of research establishing EMDR as an effective form of therapy; as such, it is noted that the author of this manuscript is operating under the assumption of said effectiveness, and this inherent bias is a limitation of the study. Furthermore, every attempt was made to scour the literature for answers to the question of how EMDR works; however, it is certainly possible that pertinent studies were not captured by the search criteria and were excluded from the investigation. Due to the large amount of studies included in this review, it is also possible that relevant assertions and findings were left out due to human error, despite attempts to control for this phenomenon. Given these limitations, the hypotheses and speculations put forth in this manuscript should be considered with caution. Future research on how EMDR works will likely elucidate and permit greater conclusiveness of such hypothetical mechanisms.

**Areas for Future Study**

It is clear that many lines of research exist into the mechanisms underlying EMDR, and while many promising investigations have been conducted thus far, there is a need for many more empirical studies. As aforementioned, the field of EMDR research is only beginning to uncover the supposed neurobiological mechanisms and correlates of the therapy through ever-developing capabilities like MRI, fMRI, SPECT, NIRS, PET, VBM, and EEG; thus, a deeper dive into the neurobiology of EMDR would offer a greater glimpse into the specific function of each brain area that has been implicated thus far. Speculations on how EMDR works via neurobiological mechanisms like the amygdala based AMPA depotentiation hypothesis and the thalamocortical temporal binding model will continue to burgeon over the coming years and will cast even more light upon all of the possible mechanisms behind the therapy. It is possible that the neurobiological theories mentioned may be intertwined with each other and with mechanisms that are not purely neurobiological in nature, such as the other accounts investigated in this manuscript.

Given that horizontal eye movements have been shown to be effective for memory degradation in isolated experiments, further investigation should be conducted on this form of bilateral stimulation as a part of the EMDR protocol in full, in order to establish greater applicability of such findings to the overall therapy. Research on binaural stimulation (i.e., alternating auditory beeps) suggests that this method of stimulation is not effective. Although tapping protocols have not received as much attention in the research, this form of bilateral stimulation presents another potential avenue for empirical investigation.

Based on the results of this investigation, the following suggestions are made regarding further research on the mechanism(s) of action in EMDR. Future research teams should conduct empirical investigations that implement the full EMDR protocol with larger clinical samples (i.e., individuals with PTSD) that are appropriately matched with control groups (i.e., healthy subjects) and/or control conditions (i.e., wait-list). If other treatment conditions are also compared (i.e., TF-CBT and/or other traditional exposure therapies), participants should be randomized into treatment groups that remain well-matched for demographics. Outcome variables related to symptoms of PTSD and subjective distress as well as vividness, emotionality, and distance from the memory should be incorporated as measures during pre-treatment, post-treatment, and follow-up phases (i.e., weeks or months later). Ideally, clinicians who are well-versed with the EMDR protocol will serve as the therapists during these experiments; however, given the difficulty of securing such clinicians, fidelity ratings should be incorporated for anyone who is acting as the clinician, along with an explanation of how they were trained in the protocol. Bilateral stimulation speeds should be standard across clinicians (i.e., 1 Hz or greater), and different speeds of stimulation should be documented in order to establish whether saccadic or smooth pursuit eye movements are occurring, and the extent of their effectiveness. The use of eye-gaze tracking software may also provide input into which form of eye movement is occurring and whether it alters effectiveness. Monitoring of psychophysiological changes (i.e., heart rate, heart rate variability, respiration rate, oxygen saturation rate, expiratory carbon dioxide, skin conductance, etc.) should be included in these experimental designs in order to establish greater consistency with regard to current findings. Additionally, research teams should incorporate some form of neuroimaging whenever possible in order to elucidate any patterns that are commonly seen in PTSD at pre-treatment, post-treatment, and follow-up; these techniques would permit localization of activation patterns that may be attributable to EMDR, while adding another layer to the observed psychophysiological changes.

It is understood that all of these suggestions may be difficult to incorporate without a substantial amount of time, money, and effort; nevertheless, including as many of these components as possible would allow for an optimal level of empiricism, while minimizing skepticism around the findings. Methodologies should be laid-out in full in each investigation, in order to permit greater comparison with other similar studies; ideally, research teams will aim to replicate and/or expand upon the results of others by employing similar or identical methods, thus enhancing the credibility of such findings.

**Conclusion**

As many other researchers have noted, EMDR is a complex and dynamic therapy that incorporates exposure, mindfulness, cognitive restructuring, and other factors that contribute to its healing properties. It appears that horizontal eye movements tax WM, regardless of the specific system, and the observed decrease in vividness of a traumatic memory may be indirectly related to the psychological distance from it. Furthermore, psychophysiological changes likely ensue in a manner that is consistent with overall de-arousal (inhibition of sympathetic systems and increased parasympathetic tone). The precise mechanism by which this de-arousal occurs is unclear and requires further study; however, it is possible that the orienting response, reciprocal inhibition, and induction of patterns similar to sleep states (REM and/or SWS) are all contributing in some way. Neurobiological research has also consistently implicated areas like the ACC, PFC, thalamus, amygdala, and hippocampus, while suggesting that EMDR allows for top-down reappraisal and inhibitory control (i.e., via higher order cortical networks) of emotional and physiological hyperarousal caused by limbic regions. The theories of thalamocortical temporal binding and depotentiation of AMPA receptors in the amygdala may indeed be interrelated, and the intrinsic connectivity networks (DMN, SN, and CEN) may be modulated in a way that permits a return to normalized activation patterns in those with PTSD. Increased interhemispheric interaction is the only account that appears to lack the consistent support needed for inclusion as a possible mechanism of EMDR; however, the preliminary empirical support for increased intrahemispheric coherence may shed light on a more apt mechanism of EMDR, the activation patterns of which have been further supported through neurobiological research.

Thus, rather than relying on a one-size-fits-all explanation for how EMDR works, it is suggested that an integrated model of multiple mechanisms is more likely to explain the success of the therapy. It is also possible that certain mechanisms may be more salient and effective for certain individuals, just as any therapy has specific components that hold idiosyncratic appeal. Given that research on how EMDR works is continuing to burgeon, finding the answers to these and other questions is becoming increasingly possible. The current state of the literature is preliminary, but promising; only through additional empirical research can the true mechanisms of EMDR be consistently elucidated.

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**Table 1**

*Proposed Mechanism of Action Theories Across Research Teams*

| Theory | Description | Discussed in Research |
|---|---|---|
| Conditioning and Distraction; Reciprocal Inhibition | Emotional interference combined with new learning | Elofsson et al. (2008); Gunter & Bodner (2009), as part of their psychophysiological changes hypothesis |
| Interhemispheric Communication | Bilateral eye movements help stimulate communication between brain hemispheres, thereby permitting the retrieval of aversive memories without the addition of negative arousal; widely accepted in EMDR circles | Gunter & Bodner (2009); Van den Hout & Engelhard (2012) |
| Induction of a REM-like State | Neurobiological state that follows the occurrence of repeated orienting responses; leads to increased cortical integration of traumatic memories | Elofsson et al. (2008); Gunter & Bodner (2009), as part of their psychophysiological changes hypothesis |
| Working Memory Disruption/Taxation | Combining two competing tasks that both draw upon working memory (bilateral stimulation via eye movements, and recall of an aversive memory) strains working memory capacity; when an individual is asked to recall the memory while simultaneously attending to eye movements, the memory becomes less vivid and emotional; this less distressing version is reconsolidated into the individual's memory network | Gunter & Bodner (2009); Van den Hout & Engelhard (2012) |
| Orienting Response | Elicited via stimulation of dual attention, leading to reduction in avoidance and incorporation of new trauma-related information into cognitive processing system; physiologically produces a lower threshold for sensory stimuli while inhibiting somatic functions that might disturb perception of stimuli; causes a decrease in respiration, heart rate, and skin temperature, and an increase in skin conductance | Elofsson et al. (2008); Gunter & Bodner (2009), as part of their psychophysiological changes hypothesis |
| Imaginal Exposure | Causes a reduction in the vividness and emotionality of traumatic memories, and purports that eye movements are inessential; Van den Hout and Engelhard (2012) refute this theory | Van den Hout & Engelhard (2012) |
| Psychological Distancing | Accomplished as a function of eye movements and how well they permit an individual to either detach or distance themselves from a traumatic memory or experience; incorporates metacognitive awareness and attentional flexibility, which are also seen in mindfulness practices | Gunter & Bodner (2009) |

**Table 2**

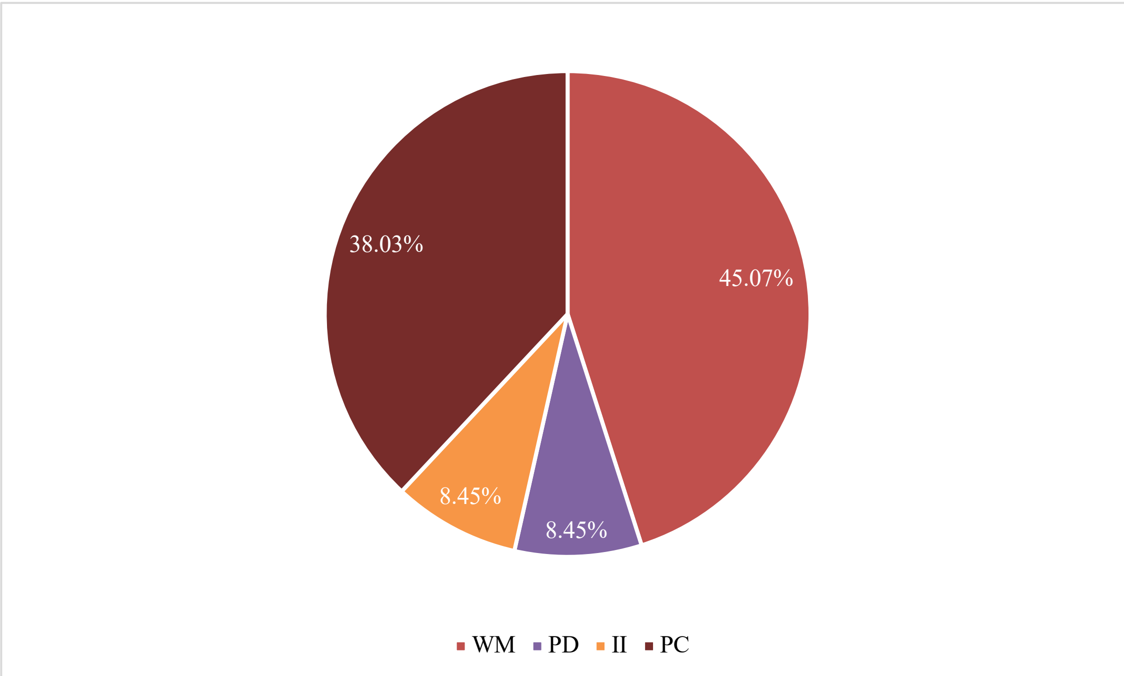
*Proposed Categorical Breakdown of Articles and Publications by Subtopic*

| Article/ Publication | WM Support | WM Rejection | PD Support | PD Rejection | II Support | II Rejection | PC Support | PC Rejection | PC (RI) Support | PC (RI) Rejection | PC (REM) Support | PC (REM) Rejection | PC (OR) Support | PC (OR) Rejection | Neurobiology | EM Support | EM Rejection | Integrative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stickgold (2007) | | | | | | | X | | | | X | | | | X | | | |

*Note:* Entry of an "X" indicates which subtopic(s) each article or publication falls under in terms of the content, objectives, and/or findings included within.

**Figure 1**

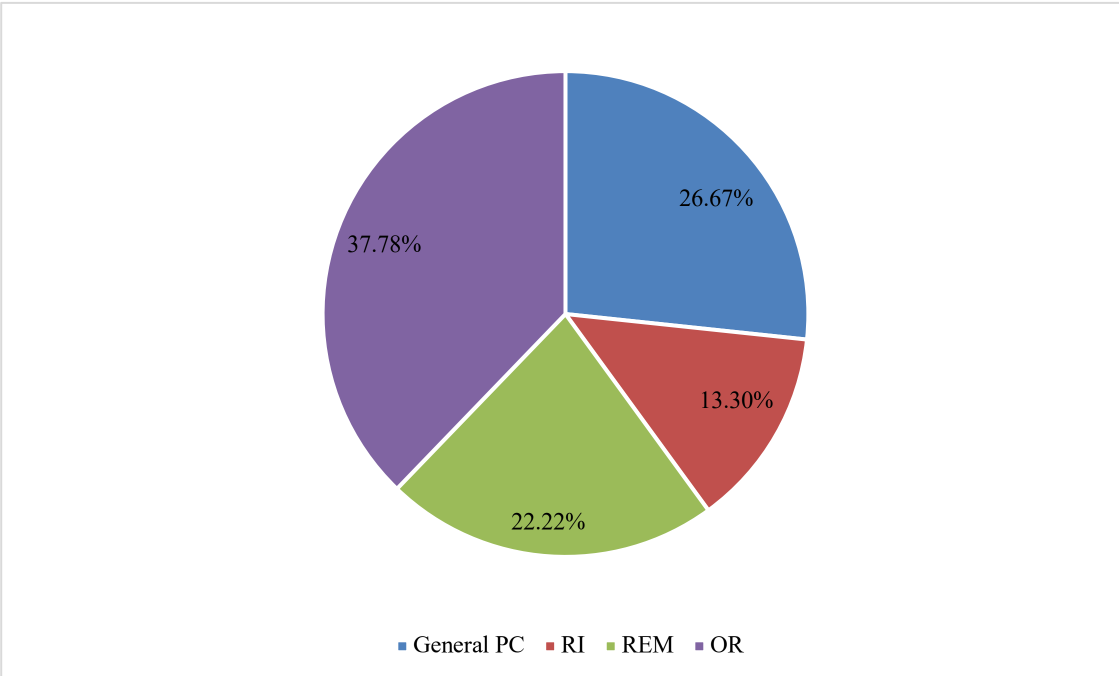
*Support Percentages for All Four Accounts*




*Note.* The acronyms are as follows: WM = working memory taxation, PD = psychological distancing, II = interhemispheric interaction, PC = psychophysiological changes.

**Figure 2**

*Support Percentages for Psychophysiological Changes Accounts*




*Note.* The acronyms are as follows: PC = psychophysiological changes, RI = reciprocal inhibition, REM = REM-sleep induction, OR = orienting response.

APPENDIX A

EMDR Protocol and Session Format

Sessions in EMDR follow a manualized protocol developed by Francine Shapiro and her colleagues. The ultimate goal of EMDR is for a client to successfully move through each of the eight phases, with each phase designed to achieve certain milestones. The first phase involves history taking, treatment planning, and target identification; targets can include affect-management resources (i.e., coping skills for any affective reactions that occur when accessing a memory network), distressing memories, current situations and triggers. Phase two deals with preparation and stabilization, and aims to enhance any resources that the client has; additionally, the therapist aids the client in creating a "safe place" using guided visualizations, which the client can draw upon throughout treatment. Phase three involves an assessment of the cognitive, affective, and sensory components of the memory that the client has chosen to target; processing begins in this stage, as the client and therapist identify a vivid image and the elicited irrational negative belief about the self (i.e., "I'm unloveable"). The client and therapist will also decide upon a valid and counteractive positive cognition ("I am loveable"), and the client will rate the "Validity of the Cognition (VOC)" when pairing this positive cognition with the image on a scale of one to seven (1 = "feels completely false," 7 = "feels completely true"). The image will also be combined with the held negative belief, and the client will rate his or her reaction to this pairing using a Subjective Units of Distress Scale (SUDS, ranging from 1-10). Finally, phase three also involves locating the body sensations evoked by the traumatic image.

Phase four involves desensitization, wherein the client is instructed to focus on the visual image, negative belief, and body sensations, and "Let whatever happens happen." In phase four, eye movements for bilateral stimulation occur, as the client follows the therapist's hand for about fifteen seconds, until therapist says something along the lines of, "Blank out the material, and take a deep breath. What do you get now?" The new material generated from this question becomes the focus for the next set of eye movements. This phase is repeated until the SUDS rating is zero for the original target memory. Phase five consists of resource development and installation (RDI), which involves the expression and consolidation of the client's cognitive insights, including self-acceptance and positive and realistic self-perceptions. These insights are paired with the original memory until the client's confidence in the new positive cognition is strong (VOC is 6 or 7). The sixth phase involves a body scan, during which the client and therapist will identify (and target) any lingering tension or unusual sensations that arise when the client thinks of the memory and positive cognition.

Phase seven is known as the closure phase, wherein the therapist assesses for adequate processing of the target memory. The client is encouraged to keep a journal of any related material that arises, as processing can continue outside of session (i.e., dreams, insights, memories, emotions, intrusions). Finally, phase eight involves reevaluation (a process that also takes place at beginning of every session after the initial session). During reevaluation, the client and therapist will determine if the previous session's treatment gains with the previously processed memory have been maintained. They will go through the client's journal to determine if generalization has occurred with regard to treatment effects, or if new issues need to be addressed. Typically, EMDR sessions will involve the repetition of phases three through eight, until the client has achieved closure for the selected target memory.

# APPENDIX B

## Brief Review of Treatment Outcome Studies

A meta-analysis conducted by Davidson and Parker (2001) asserted that EMDR is effective as a therapy when compared with pre-treatment status and when compared with no treatment at all. Furthermore, they found that EMDR is equally as effective as other exposure-based therapies, such as cognitive behavioral therapy (CBT); additional research comparing the effectiveness of EMDR with Stress Inoculation Training (SIT), Stress Inoculation Training with Prolonged Exposure (SITPE), and Trauma-Focused Cognitive Behavioral Therapy (TF-CBT) has further supported this finding (Elofsson et al., 2008; Bergmann, 2000; Lee et al. 2002; Seidler & Wagner, 2006).

The effectiveness of EMDR for treating PTSD has been demonstrated by multiple studies; according to this research, EMDR therapy promotes greater reductions in traumatic stress symptomatology, such as avoidance, intrusive symptoms, anxiety, and overall PTSD (Sprang, 2001; Shapiro & Maxfield, 2002; Bergmann, 2000; Montgomery & Ayllon, 1994). Schubert and Lee (2009) provide a concise yet effective summary of the progression of efficacy research on EMDR and its relation to PTSD treatment. They divide this progressive journey of research into three phases: demonstrating the effectiveness of EMDR in treating PTSD; demonstrating its effectiveness as compared to other trauma-focused therapies for PTSD; and investigations into the underlying mechanism of action in EMDR (Schubert & Lee, 2009). The first phase produced consistent evidence that EMDR was indeed effective as compared to waitlist or delayed treatment controls (Schubert & Lee, 2009). The second phase included the results of nine randomized controlled trials that compared EMDR to other trauma-focused therapies, such as cognitive behavioral therapy, exposure, and exposure with cognitive restructuring or stress inoculation; results showed similar effect sizes across all therapeutic modalities from pre-treatment to post-treatment (Schubert & Lee, 2009). Schubert and Lee

(2009) also mention that some research teams have found evidence of a slightly greater efficiency in EMDR as compared to exposure therapy; specifically, EMDR produced more rapid symptom reduction, required fewer treatment sessions, and was associated with fewer dropouts.

A team of researchers compared Stress Inoculation Training with Prolonged Exposure (SITPE) to EMDR in an experiment measuring symptom reduction in individuals with PTSD (Lee et al., 2002). They found that treatment conditions did not differ when comparing global PTSD outcome measures at the end of the treatment phase (Lee et al., 2002). However, upon analyzing subscales, EMDR was found to be significantly more effective than SITPE at reducing the degree of intrusion symptoms; in addition, EMDR led to greater outcome gains across all measures at follow-up (Lee et al., 2002). Sprang (2001) also found that EMDR led to greater reductions in traumatic stress symptomatology when compared to a guided mourning protocol; specifically, reductions were found to be significant for avoidance, intrusive symptoms, anxiety, and overall PTSD. According to Shapiro and Maxfield (2002), EMDR leads to a decrease in civilian PTSD diagnosis by 60-90% after three to eight sessions; a study investigating combat-related PTSD found a 78% decrease in PTSD diagnosis after twelve sessions of EMDR, the results of which were maintained at a nine-month follow-up.

Bergmann (2000) discusses the effectiveness rate of EMDR for clients diagnosed with PTSD from a single trauma. According to this analysis, which incorporates the findings of four research teams, 84 to 100 percent of clients who received four and a half hours of EMDR treatment sessions no longer met criteria for PTSD at the post-test phase (Bergmann, 2000). Bergmann (2000) also noted that a comparable treatment, Stress Inoculation Therapy (SIT), was shown to be effective in the same manner (that is, subjects no longer meeting criteria for PTSD at post-test) at a rate of 55 percent after approximately 25 hours of exposure in one study, and at a rate of 80 percent following approximately 50 hours of exposure therapy in another study. The author notes the drastic difference in percentages as well as the discrepant amounts of time spent in treatment and goes on to comment about the underlying mechanisms behind such changes, which were discussed in the main body of this manuscript (Bergmann, 2000).

The protocol of EMDR that is in use today started from a precursor protocol known as Eye Movement Desensitization, or EMD (Shapiro, 1989). Although their sample consisted of only six individuals, Montgomery and Ayllon (1994) found that the eye movement desensitization protocol used with their participants was effective at providing subjective relief from PTSD symptoms. In the eye movement condition, Montgomery and Ayllon (1994) found that psychophysiological measures corroborated any reported relief from symptoms, as evidenced by reported decreases in subjective units of distress (SUDS). Furthermore, the non-saccade condition, which utilized only cognitive restructuring and repeated exposure, did not result in significant decreases in subjective units of distress (Montgomery & Ayllon, 1994).

Arguments against the equivalently efficacious nature of EMDR include that of Taylor et al. (2003), who found that although relaxation training, EMDR, and exposure therapy all led to PTSD symptom reduction, EMDR was less effective than exposure treatments in reducing the symptoms of avoidance and re-experiencing. These researchers go on to suggest that naturalistic exposure (brought about by imaginal exposure during the protocol) may play a role in EMDR, which may account for some of the effectiveness of EMDR for patients diagnosed with PTSD (Taylor et al., 2003). In a similar vein, Sanderson and Carpenter (1992) state that EMDR appears to be no more effective as a treatment than typical imaginal exposure techniques. Schubert and Lee (2009) state that only two of the aforementioned nine randomized controlled studies included in their review did not support the theory that EMDR is roughly equal in effectiveness when compared to exposure-based therapies, and the work of Taylor et al. (2003) is one of these two studies; however, the other seven studies included in their review supported the equivalent effectiveness of EMDR and exposure-based therapies. Another study comments upon findings that discuss the difficulty of applying treatment gains made in EMDR to situations outside of sessions, suggesting that such generalization is limited when thinking of contexts outside the therapy room (Andrade et al., 1997).

APPENDIX C

Categorical Breakdown of Articles and Publications by Subtopic

| Article No. | No. of Citations | Author(s) & Publication Year | Publication Title | WM Support | WM Rejection | PD Support | PD Rejection | II Support | II Rejection | PC Support | PC Rejection | PC (RI) Support | PC (RI) Rejection | PC (REM) Support | PC (REM) Rejection | PC (OR) Support | PC (OR) Rejection | Neurobiology | EM Support | EM Rejection | Integrative |
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| 1 | 470 | Andrade et al. (1997) | Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder | X | | | | | | | | | | | | | | | X | | |
| 2 | 44 | Aubert-Khalfa et al. (2008) | Evidence of a decrease in heart rate and skin conductance responses in PTSD patients after a single EMDR session | | | | | | | X | | | | | | | | X | X | | |
| 3 | 124 | Barrowcliff et al. (2003) | Horizontal rhythmical eye movements consistently diminish the arousal provoked by auditory stimuli | | | | | | | X | | | | | | X | | | X | | |
| 4 | 240 | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories | X | | | | | | X | | X | | | | X | | | X | | X |
| 5 | 84 | Bergmann (1998) | Speculations on the neurobiology of EMDR | | | | | | | | | | | | | | | X | | | |

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| 6 | 70 | Bergmann (2000) | Further thoughts on the neurobiology of EMDR: The role of the cerebellum in accelerated information processing | | | | | | | | | | | | | | | X | | | |
| 7 | 54 | Bergmann (2008) | The neurobiology of EMDR: Exploring the thalamus and neural integration | | | | | | | | | | | | | | | X | | | |
| 8 | 68 | Bergmann (2010) | EMDR's neurobiological mechanisms of action: A survey of 20 years of searching | | | | | | | X | | | | | | X | | X | | | |
| 9 | 31 | Bergmann (2019) | Neurobiological foundations for EMDR practice | | | | | | | | | | | | | | | X | | | |
| 10 | 5 | Calancie et al. (2018) | Eye movement desensitization and reprocessing as a treatment for PTSD: Current neurobiological theories and a new hypothesis | | | | | | | | | | | | | | | X | X | | |
| 11 | 3 | Carletto & Pagani (2016) | Neurobiological impact of EMDR in cancer | | | | | | | | | | | | | | | X | | | |
| 12 | 424 | Carlson et al. (1998) | Eye Movement Desensitization and Reprocessing (EDMR) treatment for combat-related posttraumatic stress disorder | | | | | | | X | | | | | | | | | | | |
| 13 | 301 | Christman et al. (2003) | Bilateral eye movements enhance the retrieval of episodic memories | | | | | X | | | | | | | | | | | X | | |

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| 14 | 172 | Christman et al. (2004) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm | | | | | X | | | | | | | | | | | X | | |
| 15 | 59 | Corrigan (2002) | Mindfulness, dissociation, EMDR and the anterior cingulate cortex: A hypothesis | | | | | | | | | | | | | | | X | | | |
| 16 | 73 | de Jongh et al. (2013) | The impact of eye movements and tones on disturbing memories involving PTSD and other mental disorders | X | | | | | | | | | | | | | | | X | | |
| 17 | 19 | de Voogd et al. (2018) | Eye-movement intervention enhances extinction via amygdala deactivation | X | | | | | | | | | | | | | | X | X | | |
| 18 | 35 | Denny (1995) | An orienting reflex/external inhibition model of EMDR and Thought Field Therapy | | | | | | | | | X | | | | X | | | | | X |
| 19 | 83 | Devilly (2002) | Eye Movement Desensitization and Reprocessing: A chronology of its development and scientific standing | | | | | | | | | | | | | | | | | X | |

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| 20 | 83 | Dyck (1993) | A proposal for a conditioning model of eye movement desensitization treatment for posttraumatic stress disorder | | | | | | | | | X | | | | | | | | X | |
| 21 | 141 | Elofsson et al. (2008) | Physiological correlates of eye movement desensitization and reprocessing | | | | | | | X | | | | X | | | X | | X | | |
| 22 | 144 | Engelhard et al. (2010) | Eye movements reduce vividness and emotionality of 'flashforwards' | X | | | | | | | | | | | | | | | X | | |
| 23 | 95 | Engelhard et al. (2011) | Reducing vividness and emotional intensity of recurrent 'flashforwards' by taxing working memory: An analogue study | X | | | | | | | | | | | | | | | X | | |
| 24 | 13 | Engelhard et al. (2019) | Retrieving and modifying traumatic memories: Recent research relevant to three controversies. | X | | | | | | | | | | | | | | | X | | |
| 25 | 6 | Fleck et al. (2018) | Changes in brain connectivity following exposure to bilateral eye movements | | | | | | X | X | | | | | | | | X | X | | |

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| 26 | 20 | Frustaci et al. (2010) | Changes in psychological symptoms and heart rate variability during EMDR treatment: a case series of subthreshold PTSD | | | | | | | X | | | | | | | | | | | |
| 27 | 13 | Greenwald (1995) | Eye movement desensitization and reprocessing (EMDR): A new kind of dreamwork? | | | | | | | | | | | | | | | | | | |
| 28 | 363 | Gunter & Bodner (2008) | How eye movem ents affect unpleasant memo ries: Support for a working-memory account | X | | | | | X | | | | | | | | X | | X | | |
| 29 | 71 | Gunter & Bodner (2009) | EMDR works... but how? Recent progress in the search for treatment mechanisms | | | | | | | | | | | | | | | | X | | |
| 30 | 48 | Harper et al. (2009) | On the neural basis of EMDR therapy: Insights from qEEG studies | | | | | | | | | | | | | | | X | X | | |
| 31 | 1 | Harricharan et al. (2019) | Overlapping frontoparietal networks in response to oculomotion and traumatic autobiographical memory retrieval: implications for Eye Movement Desensitization and Reprocessing | | | | | | | | | | | | | | | X | X | | |

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| 32 | 18 | Homer et al. (2016) | Negative mental imagery in public speaking anxiety: Forming cognitive resistance by taxing visuospatial working memory | X | | | | | | | | | | | | | | | X | | |
| 33 | 41 | Hornsveld et al. (2010) | Emotionality of loss-related memories is reduced after recall plus eye movements but not after recall plus music or recall only | | | | | | | | | | | | | | | | X | | |
| 34 | 46 | Hornsveld et al. (2011) | Evaluating the effect of eye movements on positive memories such as those used in resource development and installation | X | | | | | X | | | | | | | | | | X | | |
| 35 | 109 | Jeffries & Davis (2013) | What is the role of eye movements in Eye Movement Desensitization and Reprocessing (EMDR) for post-traumatic stress disorder (PTSD)? A review | | | | | | | | | | | | | | | | X | | |
| 36 | 18 | Kapoula et al. (2010) | EMDR effects on pursuit eye movements | | | | | | | X | | | | | | | | X | X | | |

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| 37 | 18 | Kaye (2007) | Reversing reciprocal suppression in the anterior cingulate cortex: A hypothetical model to explain EMDR effectiveness | | | | | | | X | | | | | | X | | X | X | | |
| 38 | 23 | Keller et al. (2014) | The effects of bilateral eye movements on EEG coherence when recalling a pleasant memory | | | | | X | | | | | | | | | | X | X | | |
| 39 | 134 | Kemps & Tiggemann (2007) | Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference | X | | | | | | | | | | | | | | | X | | |
| 40 | 19 | Kristjánsdóttir & Lee (2011) | A comparison of visual versus auditory concurrent tasks on reducing the distress and vividness of aversive autobiographical memories | X | | | | | | | | | | | | | | | X | | |
| 41 | 27 | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? | | | | | | | | | | | X | | X | | X | X | | X |

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| 42 | 114 | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting | | | | | | | | | | | X | | X | | X | X | | X |
| 43 | 31 | Landin-Romero et al. (2013) | EMDR therapy modulates the default mode network in a subsyndromal, traumatized bipolar patient | X | | | | | | | | | | | | | | X | X | | |
| 44 | 16 | Landin-Romero et al. (2018) | How does eye movement desensitization and reprocessing therapy work? A systematic review on suggested mechanisms of action | | | | | | | | | | | | | | | X | | | |
| 45 | 29 | Lee (2008) | Crucial processes in EMDR: More than imaginal exposure | | | X | | | | | | | | | | | | | X | | |
| 46 | 293 | Lee & Cuijpers (2013) | A meta-analysis of the contribution of eye movements in processing emotional memories | | | | | | | | | | | | | | | | X | | |
| 47 | 111 | Lee & Drummond (2008) | Effects of eye movement versus therapist instructions on the processing of distressing memories | | | X | | | | | | | | | | | | | X | | |
| 48 | 154 | Lee et al. (2006) | The active ingredient in EMDR: is it traditional exposure or dual focus of attention? | | | X | | | | | | | | | | | | | X | | |

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| 49 | 20 | Leer et al. (2013) | Eye movements during recall of aversive memory decreases conditi oned fear | X | | | | | | | | | | | | | | | X | | |
| 50 | 63 | Leer et al. (2014) | How eye movements in EMDR work: Changes in memory vividness and emotionality | | | | | | | | | | | | | | | | X | | |
| 51 | 109 | Lilley et al. (2009) | Visuospatial wor king memory interfere nce with recollections of trauma | X | | | | | | | | | | | | | | | X | | |
| 52 | 2 | Littel & van Schie (2019) | No evidence for the inverted U-Curve: More demanding dual tasks cause stronger aversive memory degradation | X * | | | | | | | | | | | | | | | | | |
| 53 | 11 | Littel et al. (2017) | The effects of β-adrenergic blockade on the degrading effects of eye movements on negative autobiographical memories | | | | | | | | X | | | | | | | | X | | |
| 54 | 168 | MacCulloch & Feldman (1996) | Eye movement desensitisation treatment utilises the positive visceral element of the investigatory reflex to inhibit the memories of post-traumatic stress disorder: A theoretical analysis | | | | | | | | | | | | | X | | | | | |

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| 55 | 10 | Matthijssen et al. (2017) | Auditory and visual memories in PTSD patients targeted with eye movements and counting: The effect of modality-specific loading of working memory | | X | | | | | | | | | | | | | | X | | |
| 56 | 49 | Maxfield (2007) | Current status and future directions for EMDR research | | | | | | | | | | | | | | | | | | |
| 57 | 183 | Maxfield et al. (2008) | A working memory explanat ion for the effects of eye movements in EMDR | X | | X | | | | | | | | | | | | | X | | X |
| 58 | - | Mertens, Bouwman, et al. (2019) | Changing emotional visual and auditory memories: Are modality-matched dual-tasks more effective? | X | | | | | | | | | | | | | | | X | | |
| 59 | 8 | Mertens, Krypotos, et al. (2019) | Changing negative autobiographical memories in the lab: A comparison of three eye-movement tasks | X | | | | | | | | | | | | | | | X | | |
| 60 | 1 | Miller et al. (2018) | Stochastic resonance as a proposed neurobiological model for Eye Movement Desensitization and Reprocessing (EMDR) therapy | | | | | | | | | | | | | X | | X | X | | |

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| 61 | 131 | Nardo et al. (2010) | Gray matter density in limbic and paralimbic cortices is associated with trauma load and EMDR outcome in PTSD patients | | | | | | | | | | | | | | | X | | | |
| 62 | 31 | Novo Navarro et al. (2013) | No effects of eye movements on the encoding of the visuospatial sketchpad and the phonological loop in healthy participants: Possible implications for eye movement desensitization and reprocessing therapy | | X | | | | | | | | | | | | | | | X | |
| 63 | 50 | Oren & Solomon (2012) | EMDR therapy: An overview of its development and mechanisms of action | | | | | | | | | | | | | | | | | | |
| 64 | 6 | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep | X | | | | | | X | | | | X | | | | X | X | | X |
| 65 | 43 | Pagani et al. (2011) | Pretreatment, intratreatment, and posttreatment EEG imaging of EMDR: Methodology and preliminary results from a single case | | | | | | | X | | | | | | | | X | X | | |
| 66 | 115 | Pagani et al. (2012) | Neurobiological correlates of EMDR monitoring–an EEG study | | | | | | | | | | | | | | | X | X | | |

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| 67 | 45 | Pagani et al. (2013) | Correlates of EMDR therapy in functional and structural neuroimaging: A critical summary of recent findings | | | | | | | | | | | | | | | X | X | | |
| 68 | 21 | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action | X | | X | | | | X | | | | X | | X | | X | X | | X |
| 69 | 2 | Pagani et al. (2018) | Metabolic and electrophysiological changes associated to clinical improvement in two severely traumatized subjects treated with EMDR—A pilot study | | | | | | | X | | | | | | | | X | X | | |
| 70 | 1 | Patel & McDowall (2016) | The role of eye movements in EMDR: Conducting eye movements while concentrating on negative autobiographical memories results in fewer intrusions | X | | X | | | | | | | | | | | | | X | | X |
| 71 | 95 | Propper & Christman (2008) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm | | | | | X | | | | | | | | | | X | X | | |

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| 72 | 107 | Propper et al. (2007) | Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy | | | | | X | | X | | | | | | | | | X | | X |
| 73 | 31 | Rasolkhani-Kalhorn & Harper (2006) | EMDR and low frequency stimulation of the brain | | | | | | | | | | | | | | | X | X | | |
| 74 | 1 | Rousseau et al. (2019) | Fear extinction learning improvement in PTSD after EMDR therapy: an fMRI study | | | | | | | | | | | | | | | X | X | | |
| 75 | 127 | Sack, Lempa, et al. (2008) | Alterations in autonomic tone during trauma exposure using eye movement desensitization and reprocessing (EMDR)—Results of a preliminary investigation | | | | | | | X | | | | | | X | | | X | | |
| 76 | 31 | Sack, Hofman, et al. (2008) | Psychophysiological changes during EMDR and treatment outcome | | | | | | | X | | | | | | X | | | X | | |
| 77 | 51 | Sack et al. (2007) | Assessment of psychophysiological stress reactions during a traumatic reminder in patients treated with EMDR | | | | | | | X | | | | | | | | | X | | |

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| 78 | 76 | Samara et al. (2011) | Do horizontal saccadic eye movements increase interhemispheric coherence? Investigation of a hypothesized neural mechanism underlying EMDR | | | | | | X | | | | | | | | | | | | |
| 79 | 2 | Santarnecchi et al. (2019) | Psychological and brain connectivity changes following trauma-focused CBT and EMDR treatment in single-episode PTSD patients | | | | | | | X | | | | | | | | X | | | |
| 80 | 80 | Schubert & Lee (2009) | Adult PTSD and its treatment with EMDR: A review of controversies, evidence, and theoretical knowledge | | | | | | | | | | | | | | | | X | | |
| 81 | 100 | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) | | | | | | | X | | X | | | | X | | | X | | X |
| 82 | 8 | Schubert et al. (2016) | Eye movements matter, but why? psychophysiological correlates of EMDR therapy to treat trauma in timor-leste | | | | | | | X | | | | | | X | | | X | | |

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| 83 | 38 | Smeets et al. (2012) | Time-course of eye movement-related decrease in vividness and emotionality of unpleasant autobiographical memories | X | | | | | | | | | | | | | | | X | | |
| 84 | 293 | Solomon et al. (2008) | EMDR and the adaptive information processing model potential mechanisms of change | | | | | | | | | | | | | | | | X | | |
| 85 | 47 | Söndergaard & Elofsson (2008) | Psychophysiological studies of EMDR | | | | | | | X | | X | | X | | | X | | | | X |
| 86 | 8 | Stein et al. (2004) | Between innovation and tradition: the paradoxical relationship between eye movement desensitization and reprocessing and altered states of consciousness | | | | | | | | | | | | | | | | | | |
| 87 | 561 | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action | | | | | | | X | | | | X | | X | | X | X | | X |
| 88 | 45 | Stickgold (2007) | Of sleep, memories and trauma | | | | | | | X | | | | X | | | | X | | | |
| 89 | 75 | Stickgold (2008) | Sleep-dependent memory processing and EMDR action | | | | | | | X | | | | X | | | | | X | | |

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| 90 | 11 | Thomaes et al. (2016) | Degrading traumatic memories with eye movements: A pilot functional MRI study in PTSD | | X | | | | | | | | | | | | | X | X | | |
| 91 | 191 | Tryon (2005) | Possible mechanisms for why desensitization and exposure therapy work | | | | | | | | | | X | | | | | | | | |
| 92 | 132 | Van den Hout et al. (2010) | Counting during recall: Taxing of working memory and reduced vividness and emotionality of negative memories | X | | | | | | | | | | | | | | | | | |
| 93 | 95 | Van den Hout et al. (2011) | EMDR and mindfulness. Eye movements and attentional breathing tax working memory and reduce vividness and emotionality of aversive ideation | X | | | | | | | | | | | | | | | X | | |
| 94 | 168 | Van den Hout et al. (2012) | How does EMDR work? | X | | | | | | | | | | | | | | | X | | |
| 95 | 45 | Van den Hout et al. (2014) | Blurring of emotional and non-emotional memories by taxing working memory during recall | X | | | | | | | | | | | | | | | X | | |

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| 96 | 28 | Van Schie et al. (2016) | Blurring emotional memories using eye movements: Individual differences and speed of eye movements | X | | | | | | | | | | | | | | | X | | |
| 97 | 5 | Van Schie et al. (2019) | The effects of dual-tasks on intrusive memories following analogue trauma | X | | | | | | | | | | | | | | | X | X | |
| 98 | 37 | Van Veen et al. (2015) | Speed matters: Relationship between speed of eye movements and modification of aversive autobiographical memories | X | | | | | | | | | | | | | | | X | | |
| 99 | 24 | Van Veen et al. (2016) | The effects of eye movements on emotional memories: using an objective measure of cognitive load | X | | | | | | | | | | | | | | | X | | |
| 100 | 8 | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing | | | | | | | X | | | | X | | X | | X | X | | X |
| 101 | 16 | Welch & Beere (2002) | Eye movement desensitization and reprocessing: a treatment efficacy model | | | | | X | | | | | | | | | | X | X | | |

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| 102 | 15 | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing | X | | | | | X | X | | X | | | | X | | X | X | | X |

APPENDIX D

Subtopic Breakdown with Corresponding Articles

| **Subtopic** | **Authors (Year)** | **Title** |
|---|---|---|
| **WM Support** (32 articles) | Andrade et al. (1997) | Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder |
| | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |
| | de Jongh et al. (2013) | The impact of eye movements and tones on disturbing memories involving PTSD and other mental disorders |
| | de Voogd et al. (2018) | Eye-movement intervention enhances extinction via amygdala deactivation |
| | Engelhard et al. (2010) | Eye movements reduce vividness and emotionality of 'flashforwards' |
| | Engelhard et al. (2011) | Reducing vividness and emotional intensity of recurrent 'flashforwards' by taxing working memory: An analogue study |
| | Engelhard et al. (2019) | Retrieving and modifying traumatic memories: Recent research relevant to three controversies |
| | Gunter & Bodner (2008) | How eye movements affect unpleasant memories: Support for a working-memory account |
| | Homer et al. (2016) | Negative mental imagery in public speaking anxiety: Forming cognitive resistance by taxing visuospatial working memory |
| | Hornsveld et al. (2011) | Evaluating the effect of eye movements on positive memories such as those used in resource development and installation |
| | Kemps & Tiggemann (2007) | Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference |
| | Kristjánsdóttir & Lee (2011) | A comparison of visual versus auditory concurrent tasks on reducing the distress and vividness of aversive autobiographical memories |

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| | Landin-Romero et al. (2013) | EMDR therapy modulates the default mode network in a subsyndromal, traumatized bipolar patient |
| | Leer et al. (2013) | Eye movements during recall of aversive memory decreases conditioned fear |
| | Lilley et al. (2009) | Visuospatial working memory interference with recollections of trauma |
| | Littel & Van Schie (2019) | No evidence for the inverted U-Curve: More demanding dual tasks cause stronger aversive memory degradation |
| | Maxfield et al. (2008) | A working memory explanation for the effects of eye movements in EMDR |
| | Mertens, Krypotos, et al. (2019) | Changing negative autobiographical memories in the lab: A comparison of three eye-movement tasks |
| | Mertens, Bouwman, et al. (2019) | Changing emotional visual and auditory memories: Are modality-matched dual-tasks more effective? |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Patel & McDowall (2016) | The role of eye movements in EMDR: Conducting eye movements while concentrating on negative autobiographical memories results in fewer intrusions |
| | Smeets et al. (2012) | Time-course of eye movement-related decrease in vividness and emotionality of unpleasant autobiographical memories |
| | Van den Hout et al. (2010) | Counting during recall: Taxing of working memory and reduced vividness and emotionality of negative memories |
| | Van den Hout et al. (2011) | EMDR and mindfulness. Eye movements and attentional breathing tax working memory and reduce vividness and emotionality of aversive ideation |
| | Van den Hout et al. (2012) | How does EMDR work? |
| | Van den Hout et al. (2014) | Blurring of emotional and non-emotional memories by taxing working memory during recall |

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| | Van Schie et al. (2016) | Blurring emotional memories using eye movements: Individual differences and speed of eye movements |
| | Van Schie et al. (2019) | The effects of dual-tasks on intrusive memories following analogue trauma |
| | Van Veen et al. (2015) | Speed matters: Relationship between speed of eye movements and modification of aversive autobiographical memories |
| | Van Veen et al. (2016) | The effects of eye movements on emotional memories: using an objective measure of cognitive load |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **WM Rejection** (3 articles) | Matthijssen et al. (2017) | Auditory and visual memories in PTSD patients targeted with eye movements and counting: The effect of modality-specific loading of working memory |
| | Novo Navarro et al. (2013) | No effects of eye movements on the encoding of the visuospatial sketchpad and the phonological loop in healthy participants: Possible implications for eye movement desensitization and reprocessing therapy |
| | Thomaes et al. (2016) | Degrading traumatic memories with eye movements: A pilot functional MRI study in PTSD |
| **PD Support** (6 articles) | Lee (2008) | Crucial processes in EMDR: More than imaginal exposure |
| | Lee & Drummond (2008) | Effects of eye movement versus therapist instructions on the processing of distressing memories |
| | Lee et al. (2006) | The active ingredient in EMDR: is it traditional exposure or dual focus of attention? |
| | Maxfield et al. (2008) | A working memory explanation for the effects of eye movements in EMDR |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Patel & McDowall (2016) | The role of eye movements in EMDR: Conducting eye movements while concentrating on negative autobiographical memories results in fewer intrusions |

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| **PD Rejection** (none) | N/A | N/A |
| **II Support** (6 articles) | Christman et al. (2003) | Bilateral eye movements enhance the retrieval of episodic memories |
| | Christman et al. (2004) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm |
| | Keller et al. (2014) | The effects of bilateral eye movements on EEG coherence when recalling a pleasant memory |
| | Propper & Christman (2008) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm |
| | Propper et al. (2007) | Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy |
| | Welch & Beere (2002) | Eye movement desensitization and reprocessing: a treatment efficacy model |
| **II Rejection** (5 articles) | Fleck et al. (2018) | Changes in brain connectivity following exposure to bilateral eye movements |
| | Gunter & Bodner (2008) | How eye movements affect unpleasant memories: Support for a working-memory account |
| | Hornsveld et al. (2011) | Evaluating the effect of eye movements on positive memories such as those used in resource development and installation |
| | Samara et al. (2011) | Do horizontal saccadic eye movements increase interhemispheric coherence? Investigation of a hypothesized neural mechanism underlying EMDR |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **PC Support** (27 articles) | Aubert-Khalfa et al. (2008) | Evidence of a decrease in heart rate and skin conductance responses in PTSD patients after a single EMDR session |
| | Barrowcliff et al. (2003) | Horizontal rhythmical eye movements consistently diminish the arousal provoked by auditory stimuli |
| | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |
| | Bergmann (2010) | EMDR's Neurobiological Mechanisms of Action: A Survey of 20 Years of Searching |

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| | Carlson et al. (1998) | Eye Movement Desensitization and Reprocessing (EDMR) treatment for combat-related posttraumatic stress disorder |
| | Elofsson et al. (2008) | Physiological correlates of eye movement desensitization and reprocessing |
| | Fleck et al. (2018) | Changes in brain connectivity following exposure to bilateral eye movements |
| | Frustaci et al. (2010) | Changes in psychological symptoms and heart rate variability during EMDR treatment: a case series of subthreshold PTSD |
| | Kapoula et al. (2010) | EMDR effects on pursuit eye movements |
| | Kaye (2007) | Reversing reciprocal suppression in the anterior cingulate cortex: A hypothetical model to explain EMDR effectiveness |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |
| | Pagani et al. (2011) | Pretreatment, intratreatment, and posttreatment EEG imaging of EMDR: Methodology and preliminary results from a single case |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Pagani et al. (2018) | Metabolic and electrophysiological changes associated to clinical improvement in two severely traumatized subjects treated with EMDR—A pilot study |
| | Propper et al. (2007) | Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy |
| | Sack, Lempa, et al. (2008) | Alterations in autonomic tone during trauma exposure using eye movement desensitization and reprocessing (EMDR)—Results of a preliminary investigation |
| | Sack, Hofman, et al. (2008) | Psychophysiological changes during EMDR and treatment outcome |
| | Sack et al. (2007) | Assessment of psychophysiological stress reactions during a traumatic reminder in patients treated with EMDR |
| | Santarnecchi et al. (2019) | Psychological and brain connectivity changes following trauma-focused CBT and EMDR treatment in single-episode PTSD patients |
| | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) |

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| | Schubert et al. (2016) | Eye movements matter, but why? psychophysiological correlates of EMDR therapy to treat trauma in timor-leste |
| | Söndergaard & Elofsson (2008) | Psychophysiological Studies of EMDR |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Stickgold (2007) | Of sleep, memories and trauma |
| | Stickgold (2008) | Sleep-dependent memory processing and EMDR action |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **PC Rejection** (1 article) | Littel et al. (2017) | The effects of β-adrenergic blockade on the degrading effects of eye movements on negative autobiographical memories |
| **PC (RI) Support** (6 articles) | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |
| | Denny (1995) | An orienting reflex/external inhibition model of EMDR and Thought Field Therapy |
| | Dyck (1993) | A proposal for a conditioning model of eye movement desensitization treatment for posttraumatic stress disorder |
| | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) |
| | Söndergaard & Elofsson (2008) | Psychophysiological Studies of EMDR |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **PC (RI) Rejection** (1 article) | Tryon (2005) | Possible mechanisms for why desensitization and exposure therapy work |

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| **PC (REM) Support** (10 articles) | Elofsson et al. (2008) | Physiological correlates of eye movement desensitization and reprocessing |
| | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? |
| | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Söndergaard & Elofsson (2008) | Psychophysiological studies of EMDR |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Stickgold (2007) | Of sleep, memories and trauma |
| | Stickgold (2008) | Sleep-dependent memory processing and EMDR action |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| **PC (REM) Rejection** (none) | N/A | N/A |
| **PC (OR) Support** (17 articles) | Barrowcliff et al. (2003) | Horizontal rhythmical eye movements consistently diminish the arousal provoked by auditory stimuli |
| | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |
| | Bergmann (2010) | EMDR's Neurobiological Mechanisms of Action: A Survey of 20 Years of Searching |
| | Denny (1995) | An orienting reflex/external inhibition model of EMDR and Thought Field Therapy |
| | Kaye (2007) | Reversing reciprocal suppression in the anterior cingulate cortex: A hypothetical model to explain EMDR effectiveness |
| | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? |
| | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting |
| | MacCulloch & Feldman (1996) | Eye movement desensitisation treatment utilises the positive visceral element of the investigatory reflex to inhibit the memories of post-traumatic stress disorder: A theoretical analysis |

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| | Miller et al. (2018) | Stochastic resonance as a proposed neurobiological model for Eye Movement Desensitization and Reprocessing (EMDR) therapy |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Sack, Lempa, et al. (2008) | Alterations in autonomic tone during trauma exposure using eye movement desensitization and reprocessing (EMDR)—Results of a preliminary investigation |
| | Sack, Hofman, et al. (2008) | Psychophysiological changes during EMDR and treatment outcome |
| | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) |
| | Schubert et al. (2016) | Eye movements matter, but why? psychophysiological correlates of EMDR therapy to treat trauma in timor-leste |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **PC (OR) Rejection** (3 articles) | Elofsson et al. (2008) | Physiological correlates of eye movement desensitization and reprocessing |
| | Gunter & Bodner (2008) | How eye movements affect unpleasant memories: Support for a working-memory account |
| | Söndergaard & Elofsson (2008) | Psychophysiological studies of EMDR |
| **Neurobiology** (38 articles) | Aubert-Khalfa et al. (2008) | Evidence of a decrease in heart rate and skin conductance responses in PTSD patients after a single EMDR session |
| | Bergmann (1998) | Speculations on the neurobiology of EMDR |
| | Bergmann (2000) | Further thoughts on the neurobiology of EMDR: The role of the cerebellum in accelerated information processing |
| | Bergmann (2008) | The neurobiology of EMDR: Exploring the thalamus and neural integration |
| | Bergmann (2010) | EMDR's Neurobiological Mechanisms of Action: A Survey of 20 Years of Searching |

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| | Bergmann (2019) | Neurobiological foundations for EMDR practice |
| | Calancie et al. (2018) | Eye movement desensitization and reprocessing as a treatment for PTSD: Current neurobiological theories and a new hypothesis |
| | Carletto & Pagani (2016) | Neurobiological impact of EMDR in cancer |
| | Corrigan (2002) | Mindfulness, dissociation, EMDR and the anterior cingulate cortex: A hypothesis |
| | de Voogd et al. (2018) | Eye-movement intervention enhances extinction via amygdala deactivation |
| | Fleck et al. (2018) | Changes in brain connectivity following exposure to bilateral eye movements |
| | Harper et al. (2009) | On the neural basis of EMDR therapy: Insights from qEEG studies |
| | Harricharan et al. (2019) | Overlapping frontoparietal networks in response to oculomotion and traumatic autobiographical memory retrieval: implications for Eye Movement Desensitization and Reprocessing |
| | Kapoula et al. (2010) | EMDR effects on pursuit eye movements |
| | Kaye (2007) | Reversing reciprocal suppression in the anterior cingulate cortex: A hypothetical model to explain EMDR effectiveness |
| | Keller et al. (2014) | The effects of bilateral eye movements on EEG coherence when recalling a pleasant memory |
| | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? |
| | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting |
| | Landin-Romero et al. (2013) | EMDR therapy modulates the default mode network in a subsyndromal, traumatized bipolar patient |
| | Landin-Romero et al. (2018) | How does eye movement desensitization and reprocessing therapy work? A systematic review on suggested mechanisms of action |
| | Miller et al. (2018) | Stochastic resonance as a proposed neurobiological model for Eye Movement Desensitization and Reprocessing (EMDR) therapy |
| | Nardo et al. (2010) | Gray matter density in limbic and paralimbic cortices is associated with trauma load and EMDR outcome in PTSD patients |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |

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| | Pagani et al. (2011) | Pretreatment, intratreatment, and posttreatment EEG imaging of EMDR: Methodology and preliminary results from a single case |
| | Pagani et al. (2012) | Neurobiological correlates of EMDR monitoring–an EEG study |
| | Pagani et al. (2013) | Correlates of EMDR therapy in functional and structural neuroimaging: A critical summary of recent findings |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Pagani et al. (2018) | Metabolic and electrophysiological changes associated to clinical improvement in two severely traumatized subjects treated with EMDR—A pilot study |
| | Propper & Christman (2008) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm |
| | Rasolkhani-Kalhorn & Harper (2006) | EMDR and low frequency stimulation of the brain |
| | Rousseau et al. (2019) | Fear extinction learning improvement in PTSD after EMDR therapy: an fMRI study |
| | Santarnecchi et al. (2019) | Psychological and brain connectivity changes following trauma-focused CBT and EMDR treatment in single-episode PTSD patients |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Stickgold (2007) | Of sleep, memories and trauma |
| | Thomaes et al. (2016) | Degrading traumatic memories with eye movements: A pilot functional MRI study in PTSD |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| | Welch & Beere (2002) | Eye movement desensitization and reprocessing: a treatment efficacy model |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **Integrative** (14 articles) | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |

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| | Denny (1995) | An orienting reflex/external inhibition model of EMDR and Thought Field Therapy |
| | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? |
| | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting |
| | Maxfield et al. (2008) | A working memory explanation for the effects of eye movements in EMDR |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Patel & McDowall (2016) | The role of eye movements in EMDR: Conducting eye movements while concentrating on negative autobiographical memories results in fewer intrusions |
| | Propper et al. (2007) | Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy |
| | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) |
| | Söndergaard & Elofsson (2008) | Psychophysiological studies of EMDR |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **EM Support** (75 articles) | Andrade et al. (1997) | Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder |
| | Aubert-Khalfa et al. (2008) | Evidence of a decrease in heart rate and skin conductance responses in PTSD patients after a single EMDR session |
| | Barrowcliff et al. (2003) | Horizontal rhythmical eye movements consistently diminish the arousal provoked by auditory stimuli |

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| | Barrowcliff et al. (2004) | Eye-movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories |
| | Calancie et al. (2018) | Eye movement desensitization and reprocessing as a treatment for PTSD: Current neurobiological theories and a new hypothesis |
| | Christman et al. (2003) | Bilateral eye movements enhance the retrieval of episodic memories |
| | Christman et al. (2004) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm |
| | de Jongh et al. (2013) | The impact of eye movements and tones on disturbing memories involving PTSD and other mental disorders |
| | de Voogd et al. (2018) | Eye-movement intervention enhances extinction via amygdala deactivation |
| | Elofsson et al. (2008) | Physiological correlates of eye movement desensitization and reprocessing |
| | Engelhard et al. (2010) | Eye movements reduce vividness and emotionality of 'flashforwards' |
| | Engelhard et al. (2011) | Reducing vividness and emotional intensity of recurrent 'flashforwards' by taxing working memory: An analogue study |
| | Engelhard et al. (2019) | Retrieving and modifying traumatic memories: Recent research relevant to three controversies. |
| | Fleck et al. (2018) | Changes in brain connectivity following exposure to bilateral eye movements |
| | Gunter & Bodner (2008) | How eye movements affect unpleasant memories: Support for a working-memory account |
| | Gunter & Bodner (2009) | EMDR works... but how? Recent progress in the search for treatment mechanisms |
| | Harper et al. (2009) | On the neural basis of EMDR therapy: Insights from qEEG studies |
| | Harricharan et al. (2019) | Overlapping frontoparietal networks in response to oculomotion and traumatic autobiographical memory retrieval: implications for Eye Movement Desensitization and Reprocessing |
| | Homer et al. (2016) | Negative mental imagery in public speaking anxiety: Forming cognitive resistance by taxing visuospatial working memory |
| | Hornsveld et al. (2010) | Emotionality of loss-related memories is reduced after recall plus eye movements but not after recall plus music or recall only |

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| | Hornsveld et al. (2011) | Evaluating the effect of eye movements on positive memories such as those used in resource development and installation |
| | Jeffries & Davis (2013) | What is the role of eye movements in Eye Movement Desensitization and Reprocessing (EMDR) for post-traumatic stress disorder (PTSD)? A review |
| | Kapoula et al. (2010) | EMDR effects on pursuit eye movements |
| | Kaye (2007) | Reversing reciprocal suppression in the anterior cingulate cortex: A hypothetical model to explain EMDR effectiveness |
| | Keller et al. (2014) | The effects of bilateral eye movements on EEG coherence when recalling a pleasant memory |
| | Kemps & Tiggemann (2007) | Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference |
| | Kristjánsdóttir & Lee (2011) | A comparison of visual versus auditory concurrent tasks on reducing the distress and vividness of aversive autobiographical memories |
| | Kuiken et al. (2010) | Bilateral eye movements, attentional flexibility and metaphor comprehension: the substrate of REM dreaming? |
| | Kuiken et al. (2001) | Eye movement desensitization reprocessing facilitates attentional orienting |
| | Landin-Romero et al. (2013) | EMDR therapy modulates the default mode network in a subsyndromal, traumatized bipolar patient |
| | Lee (2008) | Crucial processes in EMDR: More than imaginal exposure |
| | Lee & Cuijpers (2013) | A meta-analysis of the contribution of eye movements in processing emotional memories |
| | Lee & Drummond (2008) | Effects of eye movement versus therapist instructions on the processing of distressing memories |
| | Lee et al. (2006) | The active ingredient in EMDR: is it traditional exposure or dual focus of attention? |
| | Leer et al. (2013) | Eye movements during recall of aversive memory decreases conditioned fear |
| | Leer et al. (2014) | How eye movements in EMDR work: Changes in memory vividness and emotionality |
| | Lilley et al. (2009) | Visuospatial working memory interference with recollections of trauma |

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| | Littel et al. (2017) | The effects of β-adrenergic blockade on the degrading effects of eye movements on negative autobiographical memories |
| | Matthijssen et al. (2017) | Auditory and visual memories in PTSD patients targeted with eye movements and counting: The effect of modality-specific loading of working memory |
| | Maxfield et al. (2008) | A working memory explanation for the effects of eye movements in EMDR |
| | Mertens, Krypotos, et al. (2019) | Changing negative autobiographical memories in the lab: A comparison of three eye-movement tasks |
| | Mertens, Bouwman, et al. (2019) | Changing emotional visual and auditory memories: Are modality-matched dual-tasks more effective? |
| | Miller et al. (2018) | Stochastic resonance as a proposed neurobiological model for Eye Movement Desensitization and Reprocessing (EMDR) therapy |
| | Pagani & Carletto (2017) | A hypothetical mechanism of action of EMDR: The role of slow wave sleep |
| | Pagani et al. (2011) | Pretreatment, intratreatment, and posttreatment EEG imaging of EMDR: Methodology and preliminary results from a single case |
| | Pagani et al. (2012) | Neurobiological correlates of EMDR monitoring–an EEG study |
| | Pagani et al. (2013) | Correlates of EMDR therapy in functional and structural neuroimaging: A critical summary of recent findings |
| | Pagani et al. (2017) | Eye movement desensitization and reprocessing and slow wave sleep: a putative mechanism of action |
| | Pagani et al. (2018) | Metabolic and electrophysiological changes associated to clinical improvement in two severely traumatized subjects treated with EMDR—A pilot study |
| | Patel & McDowall (2016) | The role of eye movements in EMDR: Conducting eye movements while concentrating on negative autobiographical memories results in fewer intrusions |
| | Propper & Christman (2008) | Increased interhemispheric interaction is associated with decreased false memories in a verbal converging semantic associates paradigm |
| | Propper et al. (2007) | Effect of bilateral eye movements on frontal interhemispheric gamma EEG coherence: Implications for EMDR therapy |

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| | Rasolkhani-Kalhorn & Harper (2006) | EMDR and low frequency stimulation of the brain |
| | Rousseau et al. (2019) | Fear extinction learning improvement in PTSD after EMDR therapy: an fMRI study |
| | Sack, Lempa, et al. (2008) | Alterations in autonomic tone during trauma exposure using eye movement desensitization and reprocessing (EMDR)—Results of a preliminary investigation |
| | Sack, Hofman, et al. (2008) | Psychophysiological changes during EMDR and treatment outcome |
| | Sack, Lempa, & Lamprecht (2007) | Assessment of psychophysiological stress reactions during a traumatic reminder in patients treated with EMDR |
| | Schubert & Lee (2009) | Adult PTSD and its treatment with EMDR: A review of controversies, evidence, and theoretical knowledge |
| | Schubert et al. (2011) | The efficacy and psychophysiological correlates of dual-attention tasks in eye movement desensitization and reprocessing (EMDR) |
| | Schubert et al. (2016) | Eye movements matter, but why? psychophysiological correlates of EMDR therapy to treat trauma in timor-leste |
| | Smeets et al. (2012) | Time-course of eye movement-related decrease in vividness and emotionality of unpleasant autobiographical memories |
| | Solomon et al. (2008) | EMDR and the adaptive information processing model potential mechanisms of change |
| | Stickgold (2002) | EMDR: A putative neurobiological mechanism of action |
| | Stickgold (2008) | Sleep-dependent memory processing and EMDR action |
| | Thomaes et al. (2016) | Degrading traumatic memories with eye movements: A pilot functional MRI study in PTSD |
| | Van den Hout et al. (2011) | EMDR and mindfulness. Eye movements and attentional breathing tax working memory and reduce vividness and emotionality of aversive ideation |
| | Van den Hout et al. (2012) | How does EMDR work? |
| | Van den Hout et al. (2014) | Blurring of emotional and non-emotional memories by taxing working memory during recall |

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| | Van Schie et al. (2016) | Blurring emotional memories using eye movements: Individual differences and speed of eye movements |
| | Van Schie et al. (2019) | The effects of dual-tasks on intrusive memories following analogue trauma |
| | Van Veen et al. (2015) | Speed matters: Relationship between speed of eye movements and modification of aversive autobiographical memories |
| | Van Veen et al. (2016) | The effects of eye movements on emotional memories: using an objective measure of cognitive load |
| | Vojtova et al. (2009) | Neurobiology of eye movement desensitization and reprocessing |
| | Welch & Beere (2002) | Eye movement desensitization and reprocessing: a treatment efficacy model |
| | Yaggie et al. (2015) | Electroencephalography coherence, memory vividness, and emotional valence effects of bilateral eye movements during unpleasant memory recall and subsequent free association: Implications for Eye Movement Desensitization and Reprocessing |
| **EM Rejection** (4 articles) | Devilly (2002) | Eye Movement Desensitization and Reprocessing: A chronology of its development and scientific standing |
| | Dyck (1993) | A proposal for a conditioning model of eye movement desensitization treatment for posttraumatic stress disorder |
| | Novo Navarro et al. (2013) | No effects of eye movements on the encoding of the visuospatial sketchpad and the phonological loop in healthy participants: Possible implications for eye movement desensitization and reprocessing therapy |
| | Van Schie et al. (2019) | The effects of dual-tasks on intrusive memories following analogue trauma |

APPENDIX E

IRB Documentation

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

Investigator Name: Sara Forster
Status: Faculty: ______ Student: Psy.D. Student
Faculty Chair (*if applicable*): Louis Cozolino, Ph.D.
Proposal Research Title: How Does Eye Movement Desensitization and Reprocessing (EMDR) Work? An Examination of The Potential Mechanisms of Action

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 means a 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 (*if applicable*).
- 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.

Sara Forster — 9-1-2019
Principal Investigator(s)/Student Signature — Date

Sara Forster
Print Name (s)

[signature] — 9/1/2019
Faculty Chairperson Signature *(if applicable)* — Date

Louis Cozolino, Ph.D.
Print Name