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Attention and Memory Networks as Basic Mechanisms of Change in Psychotherapy*

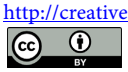
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Abstract

Cognitive neuroscience may present a new opportunity to examine the mechanisms common to psychotherapy. In this paper, we define psychotherapy and then discuss some forms of psychotherapy and efforts to seek a common psychological basis for their practice such as the effort to improve alliance with the therapist and the agency of the patient. We then consider cognitive neuroscience using imaging and other methods to seek brain networks underlying changes induced by different forms of psychotherapy. Learning, including during verbal and behavior therapy, may induce changes in the brain networks related to attention and memory. This is accomplished through improved connectivity by increases in synaptic plasticity and myelination. This common change may also be induced by enhanced theta rhythm. We consider how neuromodulation via theta burst stimulation using EEG or transcranial magnetic stimulation (TMS) may be a more direct way to produce brain changes or enhance psychotherapy through improved agency or enhanced connectivity in disordered networks. We believe that these methods provide the needed common scientific basis for improvements that occur in all forms of psychotherapy.

Keywords

ACC, Agency, Attention, Integrative Psychotherapy, Meditation, Memory, Optogenetics, Psychotherapy, Theta

1. Psychotherapy

In a recent review article, Smith (2025) developed a framework aimed at unifying a science-based view of psychotherapy from the bottom up. In his discussion, the

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ultimate action of psychotherapy has been identified as "new learning", "extinction" and "memory reconsolidation". Another new paper shows the common biology at the molecular level of diverse disorders including bipolar disorder, major depression and schizophrenia (Worf et al., 2025). If a common biology underlies very different disorders, that could also be true of different forms of psychotherapy, all of which provide improvements in the symptoms of diverse pathologies in some proportion of the patients tested. Our paper is a conceptual review of these issues based upon our examination of the more limited literature from the perspective of cognitive neuroscience (mostly related to the neuroimaging literature (Posner & Raichle, 1994; Raichle, 2009)). Since some of the effects of therapy occur in just a few days, they could not involve the altered genetics discussed by Worf et al. (2025), but they might involve some other form of improvement that occurs in pathways affected by the various disorders. While we concur with certain aspects of Smith's discussion we have gone further, outlining psychotherapy including cognitive, emotional, behavioral and dynamic models as a process in which new learning and appropriate brain stimulation induce changes in the brain networks associated with attention and memory. The terms structural connectivity, functional connectivity, and effective connectivity are all due to changes in the white matter based on synaptic plasticity and myelination. We measure these changes indirectly by use of diffusion tensor imaging which measures the degree to which water molecules indicate a dominant direction or pathway between brain areas (Le Bihan, 2003).

In our paper, we limit the term psychotherapy to the informed and intentional application of clinical methods derived from established psychological principles. These have a common purpose of assisting people to modify their behaviors, cognitions, emotions, and/or other personal characteristics in directions that the participants deem desirable (Norcross, 1990: p. 218). We do consider some of the forms of psychotherapy that are based on psychological principles and have been studied in multiple scientific ways (e.g. APA, 2020; Gabbard, 2001). We do not include the use of various drugs in treatment.

Psychotherapy as a system of mental health as well as an evolving system of knowledge has gone through different stages in its modern history (Marks, 2017; Fleuridas & Krafcik, 2019). There are many sources for studying this history (e.g. Prochaska & Norcross, 2018). But the most applied, analyzed and scientifically investigated ones as Lane et al. (2015) have proposed include: 1) *Behavior therapy* based on the mechanisms of conditioning, exposure, response prevention, habituation and extinction (Eysenck, 1983; Rachman, 1980; Wolpe, 1958, 1982; Foa & McLean, 2016; Foa et al., 2019); 2) *Cognitive-behavior therapy* that focuses on identifying and changing irrational ideas—that induce automatic thoughts—underlying assumptions and core beliefs about self, the world and the future (Beck, 1976; Beck, 2020; Wright et al., 2006); 3) *Emotion-focused therapy* in which the main target of change is conceived as an emotion response revised through the elicitation of a new emotion(Greenberg, 2010, 2017); and 4) *Psychodynamics and psychoanalysis* in which the main emphasis is put on the retrieval, discussion and reconsideration of memories related to the past events that cause a pattern of feeling and responding

to situations at the present time(Freud, 1966; Safran, 2012; Strupp,1971).

2. The Idea of Integration in Psychotherapy

In clinical practice, one can choose from more than 400 varieties of psychotherapy (Garfield & Bergin, 1994). The idea of integration was developed in response to the many forms of psychotherapy. One approach to integration is combining various approaches "to create a more comprehensive and effective treatment plan for individuals". From this perspective, integrative psychotherapy combines different theoretical and practical orientations to provide a tailored and unique help for each client (Gold & Stricker, 2020). However, the original idea of integration was to develop a new framework for a productive dialog among different approaches (Feixas & Botella, 2004). For this purpose, the Society for the Exploration of Psychotherapy Integration (SEPI; http://www.sepiweb.org/) was established—as an international organization—with a growing membership that includes some of the world's leaders in psychotherapy practice and research. In our view, the study of the human brain through imaging has allowed us to view brain networks before and after treatment opening up potential frameworks for integrating psychotherapies.

One of the common core elements that has been discussed in almost all of the approaches to psychological treatment is the therapeutic relationship between therapist and client. This aspect of therapy has been called alliance in the literature (Wachtel et al., 2020). Some authors have introduced establishing a therapeutic alliance and a safe therapy environment as a key ingredient of all successful psychotherapy models (Horvath & Luborsky, 1993; Lane at al., 2015; Stubbe, 2018). Another common element is to improve the agency of the client. We regard a client's agency to be the degree to which he regards advice as relevant to his own perceived needs. This is obtained by asking him to describe his reactions. A part of improved agency is creation of positive expectation toward the therapy (Wampold & Imel, 2015; Norcross & Wampold, 2019).

We believe that for creating any common system of integration we need to develop a dialog pattern among various types, models and aspects of psychotherapy. The approach of Cognitive Neuroscience is to consider the common brain networks that are involved in many disorders. For example, in **Figure 1** we have shown the attention system for alerting, orienting and executive attention. We hope this will open up new ways of understanding the change process in psychological treatments in general and create and provide a stronger scientific basis for therapy, in particular. We continue the paper emphasizing first memory networks and then attention networks as the main underlying processes in any type of psychotherapy.

3. Cognitive Neuroscience Networks

Retrieval of memories is a process in all forms of psychotherapy. This process is based on two mechanisms: consolidation and re-consolidation. Memory consolidation is a complex activity involving the hippocampus and other memory areas shown in **Figure 2**. Consolidation, which may take minutes, days, or even years plays a role in psychopathologies such as PTSD, anxiety and substance abuse.

However, the underlying principle in treatment often involves re-consolidation. The term re-consolidation was introduced by Spear (1973) and refers to a post-retrieval process enabling the update of a previously consolidated memory traces after reactivation, through re-exposure to the events that caused strong reactions in the organism (Alberini & LeDoux, 2013; Nader, 2015; Nader & Hardt, 2009). On the first exposure to a traumatic event a memory trace is consolidated, including high levels of fear accompanying the trauma. Consolidation follows initial memory acquisition, whereas re-consolidation follows reactivation of a memory that already has been consolidated (Nader & Hardt, 2009: p. 224). Re-consolidation allows the memory for the event to be saved with reduced or eliminated fear thus attenuating the influence of the new memory (Alberini & LeDoux, 2013; Astill Wright et al., 2021; Monfils & Holmes, 2018).

Memory re-consolidation requires the person to repeat the traumatic experience while inhibiting the fear that formerly accompanied it. To do this it is necessary to attend to the relevant memory while avoiding attention to the fearful part of the original memory. As Lane et al. (2015) as well as Guazzo (2024) have specifically indicated memory re-consolidation allows a kind of replacement of dysfunctional emotional response with more functional ones, regardless of diversity of skills and attachment patterns observed in many psychotherapy orientations. Since the late 20th century imaging the human brain has allowed identification of areas of the brain active while a person absorbs information in verbal form, carries out a cognitive task or even rests quietly in the scanner. In general, all these activations involve a small number of widely scattered brain areas both cortical and sub-cortical in which neurons are active and connected together by pathways consisting of axons surrounded by myelin sheaths (often called white matter). These as pathways as shown in **Figure 1** carry out the primary functions of attention: alerting, orienting and executive control.

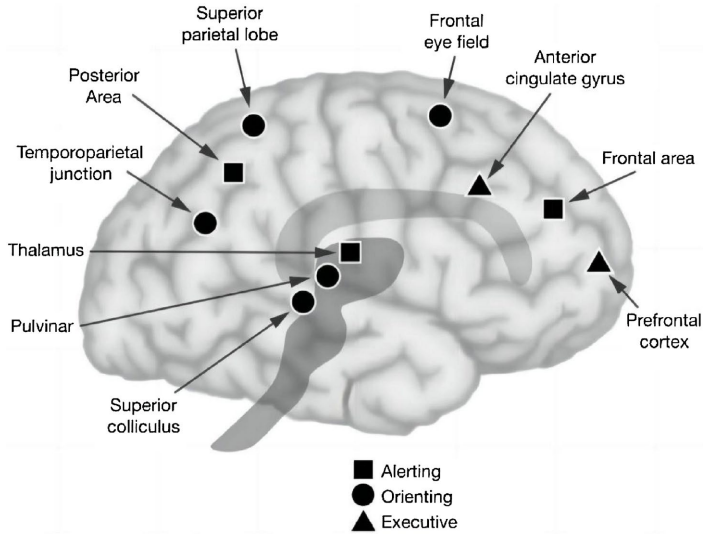


Figure 1. One view of the brain networks of attention is illustrated in this figure. It posits somewhat separate networks carrying out the functions of alerting, orienting and executive control (Fan et al., 2005; Posner & Petersen, 1990).

Alerting involves the neural modulator norepinephrine, arising in the midbrain and activating frontal and parietal lobes. Orienting consists of both a dorsal network including the frontal eye fields, and the superior parietal lobe and a ventral network that includes the temporal-parietal junction and inferior frontal cortex as well as subcortical areas (Petersen & Posner, 2012).

The executive network includes the anterior cingulate and adjacent mid-prefrontal cortex as well as parts of the underlying basal ganglia (Petersen & Posner, 2012). For a more recent closely related view of these networks, see Cook et al., 2025.

As illustrated in **Table 1** some pathological conditions show an inadequacy in one or more attention networks. In many cases multiple functions are in deficit. For example, according to one view (Halperin & Schulz, 2006). Attention Deficit Hyperactivity Disorder (ADHD) shows a deficit at first in alerting and only later in development of the executive attention network. While autism is frequently seen as a social disorder, a deficit in the orienting network even in non-social situations appears early in development (Townsend, Harris, & Courchesne, 1996; Landry & Bryson, 2004). A deficit in executive function appears in many psychopathologies in addition to addiction, including borderline personality disorder and schizophrenia. Emotion regulation is a function of the executive network. Parents influence the effect of pandemic stress on the internalizing pathology in their children due to the level of parental rumination (Kim et al., 2024). We do not believe that the evidence shows that the attention networks are the cause of these disorders but rather they may be only one of their many symptoms.

Table 1 shows the association of attention networks with some psychopathologies.

Table 1. Disorders relating to attention.

Attn Network	Condition	Symptoms
Alerting	ADHD	Sleep disorder (Halperin & Schulz, 2006)
Orienting	Autism	Disengage Deficit (Landry & Bryson, 2004; Townsend & Courchesne, 1994)
Executive	Addiction	Craving (Koob, 2016)

It has been possible to identify the pathways connecting the attention network to memory networks as shown in **Figure 2** (Posner et al., 2022). What is the use of knowing the pathways between attention and memory (Posner et al., 2022)?

A detailed knowledge of the pathways involved in psychopathology might allow the therapist to reduce or eliminate the pathological condition by successful modulation of the critical pathway, either through learning or brain stimulation. Some pathologies are known to involve specific pathways such as those shown in **Figure 2**. For example, the strong craving due to addiction involves the ACC to striatal pathway shown in **Figure 2** (George & Koob, 2013).

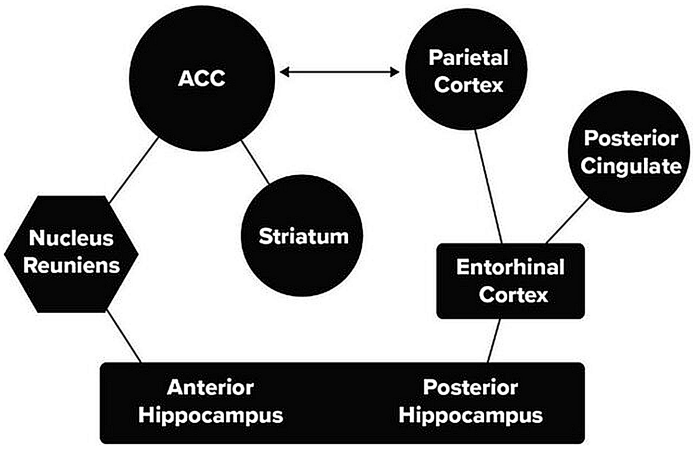


Figure 2. Two pathways between the memory and attention networks. One is a thalamic pathway that includes the hippocampus (HC), nucleus reuniens of the thalamus, and the anterior cingulate cortex (ACC). The other includes the HC, the entorhinal cortex and the parietal lobe.

There is evidence that following two to four weeks of meditation training there is improved connectivity of pathways surrounding the ACC as measured by diffusion tensor imaging DTI (see definition of DTI on page 2, also Tang et al., 2010, 2012). Meditation reduced craving for nicotine and also the amount of smoking as measured objectively (Tang et al., 2013). In the case of the tobacco study smokers and non-smokers were recruited to reduce stress. Smokers who showed normalization of the ACC to striate pathway following meditation training did not necessarily plan to reduce smoking and many did not realize they had done so. Meditation training produces a strong frontal theta as measured by EEG from scalp electrodes over frontal areas following the meditation training compared to the same persons without training (Tang, et al., 2019).

A similar result has been found for opioid addiction using a different form of mindfulness meditation (Hudak et al., 2021). In this study meditation treatment for opioid addiction (Hudak et al., 2021) it was shown that the degree of frontal theta was the best predictor of the reduced use of opioids. Studies with mice have shown directly that theta stimulation of the anterior cingulate activated dormant oligodendrocytes and improved connectivity through increased myelination (Piscopo et al., 2018).

Theta brain stimulation has been used in studies of severe depression (Cole et al., 2022; Mitra et al., 2023) and has been approved for depression treatment by the FDA since 2007. Recent work (Cole et al., 2022; Mitra et al., 2023) uses theta burst stimulation that combines TMS with theta frequency. These studies involve stimulation of the pathway between the dorsolateral prefrontal cortex and the ACC. Depressive patients show an abnormal flow of information from the ACC to the prefrontal cortex. Stimulation of the left dorsolateral prefrontal cortex by theta burst TMS changes the direction of this flow (Mitra et al., 2023). It has also been shown that theta stimulation in a double-blind randomized control study produced significant improvement in cases of severe depression (Cole et al., 2022).

Since meditation produces a strong theta rhythm over midline frontal cortex and theta rhythm can change connectivity around the ACC, it seems likely that the one mechanism by which talking psychotherapy can act may also be the use of theta. A recent review (Eisma et al., 2021) shows that a variety of tasks involving inhibition, conflict resolution and other aspects of cognitive control increase theta activity over the frontal lobe. Another form of cognitive exercise, reflection training, also works to improve executive function in school age children (Espinet et al., 2013). Since many talking therapies include elements of conflict resolution or inhibition, they would be expected to increase frontal theta (Cavanagh & Frank, 2014) and thus produce changes in connectivity. We believe improved connectivity is the main mechanism common to the therapeutic effects of various forms of therapy.

In short there is a link between various forms of psychotherapy and mechanisms that change white matter and improve brain connectivity. Studies have directly shown that theta stimulation in mice can activate dormant oligodendrocytes and improves connectivity (Piscopo et al., 2018). It has also been shown that theta stimulation can reduce fear in mice (Weible et al., 2017) and can increase attention (Reinhart, 2017) and memory (Roberts et al., 2018) in humans.

Frontal theta enhanced through meditation reduces addiction (Hudak et al., 2021) and theta stimulation delivered by TMS can help with depression. Thus cognitive neuroscience has provided both a way to relate various forms of successful psychotherapy and a tool kit for improved therapy. With this mechanism in mind clinical studies of various disorders involving attention and memory as shown in **Table 1** can be designed for better understanding of which forms of therapy provide the best chance of success.

4. ACC and Improved Agency

The discussion of behavioral or verbal psychotherapy has not always been consistent about what the common mechanism of success really is. In different forms of psychotherapy success was related to increased agency of the patient (Williams & Levitt, 2007), therapeutic alliance (e.g. Stubbe, 2018), a sense of control (Abelson et al., 2008), reconsolidation (Lane et al., 2015), emotion regulation (e.g. Moyal et al., 2015), and new learning (e.g. Hofmann et al., 2021).

In current cognitive neuroscience the concept of cognitive control is central to agency, sense of control, new learning and emotion regulation. Cognitive and emotional control involve different areas of the anterior cingulate gyrus (Bush et al., 2000). We regard therapeutic alliance and re-consolidation as methods that improve the chance for cognitive control to be effective.

Studies using both CBT and controls (Feurer et al., 2022) to treat patients with various forms of anxiety disorder showed that the extent of improvement irrespective of the type of therapy or anxiety was indicated by increased activity in the ACC. The authors suggested that ACC activity was a biomarker for improvement in anxiety. This study confirmed that the main predictor of improvement in symp-

toms was activity in emotional control through the ACC. The authors argued that their findings indicated ACC activity was a biomarker of improved anxiety and a neural predictor of general psychotherapy outcome. Although it was unclear whether this biomarker is related to major depressive disorder (MDD) or not, the authors' major conclusion was that "ACC activity during attentional control may be a transdiagnostic neural predictor of general psychotherapy outcome"(p.1350). In addition (Kumari et al., 2011) found that brain changes in connectivity predicted long term recovery from psychosis and similar findings occurred with patients suffering from PTSD (Santarnecchi, et al., 2019). These findings would be in accord but more limited, than our view that the ACC and more generally improved connectivity is involved in improvements common to all forms of psychotherapy whatever the diagnosis.

Our studies (Tang et al., 2010, 2012) indicate that the reason for the ACC's centrality to improvement from psychotherapy is the enhanced connectivity shown by both meditation training and theta stimulation and this provides a common mechanism related to improved agency through psychotherapy. A further example of a common mechanism is that addictions have been improved by meditation (Tang et al., 2013) and the degree of improvement is related to the increased amount of frontal theta (Hudak et al., 2021). A form of depression has been successfully treated through theta burst stimulation (Cole et al., 2022). Imaging evidence suggests that engaging in a cognitive task is also a common cause of increased theta rhythms over frontal areas. This finding suggests the likelihood that various forms of psychotherapy produce an endogenous theta rhythm and thus support a common mechanism of connectivity in critical networks underlying diverse forms of psychotherapy and provide a start toward improved treatments.

5. Conclusion

Cognitive Neuroscience is a major area in which neural network studies are an essential part of many theoretical as well as practical explorations in the area of psychopathology, psychotherapy and mental health. As Andreasen (1997: p. 1592) has indicated many years ago, "focal regions have been replaced by circuits and static changes by plasticity and molecular mechanisms". Publication of titles such as *Neuroscience for the Mental Health Clinician* (Pliszka, 2016) isn't a rare occurrence these days. There is a growing awareness of how environment shapes the working brain and how education and educational systems influence brain networks (Posner & Rothbart, 2007). From the perspective of neuroscience, psychotherapy can be conceptualized as a specific kind of enriched, safe and structured environment designed to promote the growth of the integrative activity of neural networks(Cozolino, 2002: p. 27).

We agree with Javanbakht and Alberini's editorial note (2019: p. 1) that psychotherapy "taps into all the biological regulations underlying complex brain responses. The end result of this type of intervention is a re-elaboration of the whole sense of self and others, through new learning and new experiences that encom-

pass cognitive, emotional, and internal regulation processes. Successful therapies produce comprehensive, lasting, measurable physical changes in the brain". In this paper, we have tried to introduce a possible mechanism of improved connectivity that could produce these brain changes.

Author Contributions

HG had the idea and wrote much of the paper, MKR and MIP illustrated the article with the figures and together wrote the sections on cognitive neuroscience of attention.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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