Chapter 2
The Theoretical Basis for Neurocognitive Learning Therapy

Neurocognitive learning therapy is based on contributions from three branches of science; learning theory, small world hub models of cognitive processing, and epigenetics. Before we proceed to further discuss the didactics of the model, it would be wise to spend some time discussing the foundation science upon which NCLT rests. This will serve two purposes. The first is to have the reader understand that there are solid and empirically valid reasons for the practice of NCLT. The second is more pragmatic. The second purpose is to enable the reader to understand the reasons for the choice of goals and learning objectives in therapy.

Learning Theory and NCLT

NCLT is heavily indebted to the unified learning model (ULM) (Shell et al., 2010), and also combines elements from constructivist, but especially connectionist cognitive learning models, neuropsychology, and basic learning theory.

What Is the Unified Learning Model?

The unified learning model (ULM) integrates three aspects of cognition: (a) crystallized intelligence (knowledge) as represented by accumulated knowledge stored in long-term memory, (b) fluid intelligence as represented by working memory capacity, and (c) motivation, which is considered to be a driver of working memory allocation. Like the ULM, NCLT is based on a rather simple premise that these three components underlie all of human learning.

Working memory is defined as temporary storage and processing of information. Critical to the understanding of how NCLT operates is the idea that how working memory is constructed and operates, determines how things are learned. Working

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memory stores information in identifiable patterns (schemas in constructivist models) that are retrieved from long-term store when new information is encountered. Working memory is based on prior knowledge, which is in turn based on the network's response to a novel stimuli it receives. Remember, motivation is the driving force behind working memory. Very simply, if I am motivated by something, I will be willing to allocate my working memory to attending to and learning it.

Knowledge

Knowledge essentially is defined as every piece of information we have stored within long-term memory. Knowledge has a twofold role. Remembering that the purpose of learning is to increase the data in long-term storage (increase or change knowledge), knowledge is what results from the proper functioning of working memory. Knowledge also reciprocally influences the functioning of working memory. That is because the way working memory encodes new information is directly constrained by the existing knowledge base in long-term memory. This is because new knowledge is constantly being compared to, and appended upon, old knowledge. New and old knowledge meet in memory store. The result of this meeting is that each works upon the other and produces new knowledge, which is then returned to long-term memory. This is important to understand for the therapeutic process, because knowing this accounts for the individuality and uniqueness of each person who creates knowledge. Because individual experiences vary, no two sets of knowledge stores are identical.

Motivation

While there are many definitions and models of motivation, the ULM and NCLT define motivation quite specifically as the impetus for directing working memory and attention, to a particular task. Motivation is therefore, along with attention, an essential component of working memory.

The interplay of the components results in the three basic principles of learning for the ULM, and for NCLT, which have their implications for therapeutic learning. They are:

1. Learning is a product of working memory allocation
2. Working memory's capacity for allocation is affected by prior knowledge
3. Working memory allocation is directed by motivation

In clinical practice terms, people only learn what they pay attention to, and what they pay attention to is directed by what they already know and what they find reinforcing. Clinically speaking, this means that if I determine that the pattern match of a new incoming stimulus is reinforcing, I will allocate my working memory to it and learn it. It also means, however, that if I perceive the new stimuli to pattern match as a threat then I will feel anxious and threatened.

General Rules of Learning in NCLT

NCLT has principles of learning that are based upon the neurobiology of learning and are incorporated into the therapeutic interaction for a vertical brain model. These are as follows:

1. New learning requires attention. Only those items that are being attended to will be candidates for working memory store.
2. Learning is pattern recognition. Those patterns that are recognized and routinely retrieved from store are utilized and generalized. We would add that those patterns are also associated by repetition and reinforcement to the arousal centers located in the limbic system. When retrieved from memory store, they are accompanied by their associated emotional response set. Any new learning is attached to existing schemas, and each set of these existing schemas has a motivational and emotional response associated with it.
3. Learning is about connection. What is learned together is stored together in memory. What is stored together stays together in memory. Appropriate or socially acceptable responses can be stored with socially unacceptable responses should that association be reinforced. Given the right set of motivational circumstances, inappropriate responses can be stored.
4. The goal of learning is automaticity. That is, the goal of learning is to have complex connections between elements of data available to the learner without effort. Clinically speaking, that means that once a response pattern is automatized, people will automatically associate and continue to associate emotional states with events, without cognitive effort to change those associations. One goal of therapy is to make new, essential connections as efficient and automatic as possible. This is because active working memory and transfer of information involves effort, and the amount of effort that people can expend is physiologically limited (Callicott et al., 1999).

   A procedure that has achieved automaticity can run itself. When these automatic response chains produce maladaptive procedures, and we must change an automated process, we must de-automatize it. This is the process of therapy. Our model recognizes that to de-automatize a maladaptive procedure, and create a new adaptive procedure, specific, directed allocation of attentional resources is required. This concept is important as it implies a more directed and targeted process than what is used in many nondirective approaches. Without directed allocation of working memory, nondirective approaches result in many false starts, and allocation of working memory to procedures that would not, in the end, result in adaptation.

5. Learning requires repetition. Automaticity is achieved through practice and generalization.
6. Learning is learning. While all neurons learn in exactly the same way, people utilize these processes idiosyncratically.
7. Motivation is particular to the individual.

Learning is the product of a consistent and ongoing interaction between the individual's experiences and their genetically derived predispositions. This interaction has been termed epigenetics (Elman, 1993). Epigenetics basically posits that behaviors and experiences interact with physiological, cognitive, and emotional predispositions to produce current behavior (Atzaba-Poria, Pike, & Deater-Deckard, 2004; Buehler & Gerard, 2013). Available research suggests that current behavior reflects the accumulation of all these interactive events. Rutter (2006) points out that a number of factors including susceptibility genes, environmentally mediated causal risk processes, nature-nurture interplay, the effects of psychosocial adversity on the organism, the causal processes responsible for group differences in rates of disorder, and age-related changes in psychopathological characteristics all play a part in the development of complex adaptive and maladaptive behavior.

The Goal of Therapy Is Also Competence

The term competence has been used to refer to accumulated learning experiences that result in a pattern of effective adaptation within an environment. Within the NCLT clinical context, it implies that the individual has (or lacking competence does not have) the capability to perform well in the future. Like many cognitive therapy models, NCLT posits that an individual who lacks competence in an environment becomes self-aware and engages in negative self-appraisals. These negative self-appraisals are reinforced and reproduced regularly, until they are automatically associated with a class of behaviors or physiological responses. NCLT theory hypothesizes that these automatically associated physiological responses and appraisals are experienced as affect states such as depression and anxiety. That is, in part, because the physiological responses associated with these affect states are also associated, through the same principles of learning, to the cognitions associated with the appraisals. For example, imagine your client who, when in high school, on the debate team, came down with the flu and did very poorly when they had to engage in public speaking. They felt shaky, and it was hard for them to focus. These same feelings of "shakiness" and diminished focus occurred at the next debate. The student concluded that they are very anxious when they have to speak in public and tend to panic. This led to a concept of reduced competence secondary to negative self-appraisals. Through the process of therapy, the goal is to alter the competence of the client, and the self-perception of competence of the client. This in turn alters the client's physiological responses and eliminates, or reduces, maladaptive emotional associations and self-critical appraisals.

Specific learning experiences govern the development of the neural architecture to be sure, but the system's properties and functioning are governed by a constant and unchanging set of operational rules. Research has identified numerous neural structures that are involved in this network (McClure, York, & Montague, 2004). Essentially, this network governs reward processing and reward-dependent learning. McClure et al. (2004) identified a set of reward-related brain structures linked together in a small world connectionist system including the orbitofrontal cortex, amygdala, ventral striatum, and medial prefrontal cortex. Environmental experiences are evaluated in terms of their reward potential, and it is this determination that is the basis of what is learned and what isn't.

Knowledge Acquisition and Working Memory in Therapy

We can summarize what is learned in therapy. All of what is learned knowledge. NCLT offers the following as rules that govern the process of knowledge acquisition in therapy.

1. If knowledge in long-term memory is retrieved, the strength of association between all items retrieved to working memory is increased. Clinically, it must be remembered that how things are presented and grouped in working memory determines what procedures will be developed from their association.
2. If a knowledge is retrieved, all other elements of knowledge to which it is connected are retrieved, and all connections are strengthened.
3. If parts of retrieved knowledge match to working memory contents, the connection between the existing knowledge and the new material are strengthened. If parts of retrieved knowledge do not match to contents in working memory, the connections are weakened and inhibited. Establishing new pattern matches (schemata) is an essential component in therapy.
4. If an action is successful, its connection to the knowledge of the situation in which it occurred is strengthened. If an action is unsuccessful, its connection to the knowledge of the situation in which it occurred is weakened or inhibited. The therapeutic implication of this is that new procedures must be understood and conscientiously practiced.
5. If knowledge has been retrieved, new information in working memory will be connected to this knowledge. This is the basis of establishing new adaptive procedures.
6. Any active knowledge in long-term memory is accessible to working memory.

Core Flexible Networks

Nomi et al. (2017) found that the human brain continually cycles through patterns of neural connections. They found that, most of the time, neural connections are agile, which they describe as fluid and flexible enough to meet presented challenges or mental tasks. In NCLT one major goal of therapy is to capitalize on core flexible neural networks that can be readily adapted to newly encountered situations. The core flexible networks (schemata) are the building blocks of the complex networks (routines) that will constitute the basis of our response to the ever changing demands presenting in the environment. Our model postulates that these practiced and thereby created complex network associations can be targeted and efficiently altered through direct instruction, thereby correcting prior maladaptive network recruitment patterns. That is not the entire goal of learning. What is also critical is that we assist in the production of a response tendency in the individual that would encourage that person to bring these networks to bear on new situations. That is, we must assist our client in getting to a state of readiness to bring the newly created network adaptations online more fluidly. There is increasing evidence of the regulatory control of these core flexible networks in the regulation of emotion and the development of mental dysfunction. For example, recent research points to the existence of a frontoparietal control system consisting of flexible hubs that regulate distributed systems of response according to task specific goals. Alterations of this control system have been identified in a wide range of mental diseases (Cole, Reposv, & Anticivic, 2014). Cole et al. (2014) suggested these flexible hubs reflect a critical role for the control system in promoting and maintaining mental health in that it implements feedback control to regulate symptoms as they arise, and when functioning correctly the system is protective against a variety of mental illnesses. The mission statement of therapy then is to target and promote the adaptive use of these control systems.

The Connectome and NCLT

The connectome is a term used to describe a comprehensive map of the neural white matter, or subcortical connections in the brain. The connectome is sort of a wiring diagram of the white matter connections between and amongst structures in an individual's brain. It is important to note that these connections are not hard wired. There are pathways and routes that are travelled, which are interlinked at neurochemical intersections, called synapses. These neurochemical interchanges allow sections of the pathway to be used for different routes connecting and reconnecting depending on task demands in the system for a response. This set up permits the same structure to be recruited for differing activities depending on the requirements of the task at hand and its perceived reward value.

A human brain is an amazingly complex organ containing some 700 trillion synaptic connections (*What Is the Connectome*, 2014). The synaptome is the term for the set of synaptic connections in a brain region. Each individual synapse is in itself highly complex, and acts as an independent switch to transmit cellular information. The synaptome is believed to be the site of learning, memory, and retrieval occurring at molecular states at each synapse of the connectome.

Any discussion of the connectome includes a discussion of a second type of brain matter, grey matter, which are the regions connected in the system by the white matter. Grey matter contains the cell bodies and axon terminals of neurons. It is where all synapses are located. The white matter, made up of axons, connects various grey matter areas (the locations of nerve cell bodies) of the brain to each other, and carries nerve impulses between neurons.

Understanding how white matter contributes to the information processing capabilities of the human brain has taken on increasing importance in the last 10 years as it is now recognized that it actively affects how the brain learns and functions. While grey matter is primarily associated with processing and cognition, white matter modulates the distribution of action potentials, acting as a relay and coordinating communication between different brain regions. White matter tracts are the structural highways of our brain, enabling information to travel quickly from one brain region to another region (van den Heuvel, Mandl, & Hulshoff-Pol, 2009).

The development of the connections of the human connectome is in large part, but not absolutely, due to the experiences that connectome has with the environment. As a result, the connectome is being continually shaped, formed, and altered by learning.

The Development of the Connectome and Psychopathology

The human connectome is the result of a complex developmental trajectory that insures the development of key neural networks that govern all aspects of cognition (Menon, 2013). Aberrations in the development of any of the networks contribute to psychopathology.

Humans are born with a functional but rudimentary connectome, organized in a stable, small world fashion, which integrates key networks to insure initial survival and support for future learning. Research also demonstrates heterogeneous pattern of changes across developing functional systems that map the external world onto the brain's attentional, sensory, emotional, and motivational subsystems (Menon, 2013).

NCLT recognizes that both environmental interaction and experience play a role in the development of the networks. The result of this interplay can lead to adaptive outcomes in learning and skills development, or to poor outcomes that are labeled as psychopathology.

Small World Hubs

One way to represent these networks is called graphical analysis. Graphical analysis is basically a statistically driven graph of the relationship between variables, in this case, brain regions. Bullmore and Sporns (2009) suggest that complex cognitive functioning is best represented by a connectionist small world hub model of neural networks. Small world neural network models are based on the concept of nodes which represent the confluence or connectivity points of neurons. Research has demonstrated that brain networks have characteristically small-world properties of dense or clustered local connectivity (nodes) with relatively few long-range connections to other similarly dense nodes. Nodes cluster together in small networks and vary to the degree of how central they are to the connections to other small clustered networks within the system. The nodes of a small world network have greater local interconnectivity or “cliquishness” than a random network, but the minimum path length between any pair of nodes is smaller than would be expected in a regular network.

Small-world networks are valuable models to use when evaluating the connectivity of nervous systems because the combination of high clustering and short path length between nodes provides a capability for the network to perform both specialized and modular processing in local neighborhoods and distributed or integrated processing over the entire network (Achard, Salvador, Witcher, Suckling, & Bullmore, 2006).

Is There Evidence that the Connectome Organizes Itself in Response to Learning?

A central premise of the NCLT model is that therapeutic learning impacts the organization of operation of the connectome and that the purpose of this reorganization is effective adaptation and the automatization of the more adaptive response. There is emerging research support that indicates that this premise is correct (Bar & DeSouza, 2016).

Brain imaging using magnetic resonance imaging (MRI) has revealed structural changes in white matter after learning complex tasks or behaviors. This line of research appears to indicate that white matter responds to experience in a manner that affects neuron function under normal circumstances, thereby affecting information processing and performance (Fields, 2010). There is evidence that white matter, especially myelin formation occurs during cognition, learning, development of skills, and memory. For example myelination of brain regions coincides with the development of specific academic and cognitive functions such as reading, development of vocabulary, and proficiency in executive decision making (Fields, 2008). These last two classes of skills are clearly associated with what happens in therapy. According to Fields (2010) when new skills are learned, the amount of myelin insulating an axon increases improving the ability of that neuron to signal. This leads to more efficient learning including reading, creating memories, playing a musical instrument, and more. A thicker sheath is also linked with better decision making. The purpose of learning is to improve efficiency, thereby encouraging automaticity.

Algorithms, Practice, Automatization, and NCLT

What then is automaticity in a learning theory context, and how might it be used in therapy? An automatic process is one that once initiated (regardless of whether it was initiated intentionally or unintentionally), runs to completion with no requirement for conscious guidance or monitoring (Moors & De Houwer, 2006). NCLT posits that the initiation of all automatic processes are conditional: They are all dependent on preconditions (e.g., the presence of a triggering stimulus, awareness of the stimulus, the intention that the process take place, a certain amount of attentional resources, and the salience of the stimulus). Automatic processes will vary with regard as to the specific subset of preconditions they require. The identification of these preconditions becomes an important element of the therapeutic process (Wasserman & Wasserman, 2016).

We will discuss automaticity in detail in a separate chapter, but the important thing here is that NCLT regards automatization as the goal of all learning, including the learning that occurs in therapy. This process can be represented by algorithmic models which attempt to represent brain functioning. An algorithm is a procedure or formula for solving a problem, which is based on conducting a sequence of specified actions depending upon the task it is being asked to do. A specific algorithm is a representation of a mathematically understandable and expressible specific cognitive process. These algorithmic models then represent processes as occurring in a small world hub model of brain organization. These algorithmic models support the idea that one learning mechanism accounts for the automatization of all complex cognitive routines. Algorithms have characteristics, one of which is the efficiency with which they run a particular process. The central theme of algorithm efficiency theories is that practice improves the efficiency (speed and fluidity) of the underlying algorithmic processes (Rawson, 2010). Consistent practice is therefore essential for the development of automaticity. Improvement in terms of efficiency requires algorithms to remain consistent with practice, even though aspects of the data they are practiced upon may change (Carlson & Lundy, 1992).

This principle holds in the clinical world as well, and would suggest that sound therapeutic process would involve systematic and direct practice of the new skill, which includes the complex combination of belief, emotion, and behavior, with the goal being automaticity. That is, the automatic, or the fluid and efficient ability to effortlessly utilize these new complex skills as needed. As stated, development of automaticity, or the development of the complex skill set, requires practice. This practice should include behaviors that devolve from the expression of the belief.

Change does not come from merely acknowledging some principle or idea. For example, it is not sufficient to merely agree with the statement that some charity is worthwhile. If a person develops an interest in a particular cause or charity, and begins to speak to others about its importance, as they "practice" this new skill, they will become more proficient at it. They will improve the speed at which they can recall points of view in their favor and become more efficient in their positional statements. Recalling these facts will consume less working memory effort as their speech becomes more automatic. This principle would also imply that the clearer the connection is between the belief and the practice, the more efficiently it will be learned.

The Implications of Algorithmic Models for Clinical Practice

There are additional features of algorithmic models that have implications for therapeutic practice. The algorithm (processing) strengthening (Adaptive Control of Thought or ACT) principle hypothesizes that the same algorithms responsible for the initial, nonautomatic stage of performance are also responsible for the skilled, automatic stage of performance. As practice continues, these algorithms are executed faster and more efficiently with increasingly less conscious allocation of working memory and control required. Automatic and nonautomatic algorithms differ only with regard to the features (such as speed and efficiency) they possess (Rawson, 2010).

Understanding, conceptually, how these algorithms operate is a helpful analogy for the therapist when designating intervention strategies because it mirrors the process which occurs across the connectome. It highlights that with practice, a set of routines will become the controlling sequence of the behavior, originating during the acquisition stage and maintained during the demonstration stage. Even for those of us who are "challenged by technology," we have all come to be familiar with internet searches. These searches are designed to go through a process and produce results. These processes are based on algorithms. An algorithm is a step by step procedure designed to solve a problem. The more a particular phrase is searched, the more frequently an algorithm is set into motion, increasing its speed and efficiency. This mirrors psychological cognitive, behavioral, and emotional patterns. That is, the establishment of the algorithm or cognitive/behavioral/emotional pattern will become, with practice, more automatic. The goal of therapy then is to make the healthy routine a stronger one which can be executed more easily and flexibly, ultimately becoming automatic.

Therapy Process in General NCLT in Specific

Most forms of therapy processes try to help clients identify triggers. NCLT is specific, emphasize identifying environmental triggers and altering the automatized response to them. Different therapy approaches vary on what the triggers they might focus on, how to identify them, and how to reprogram them, but all are in agreement that the task is the same; the reprogramming of maladaptive automatized responses into adaptive ones. Returning to our algorithms for a moment, the algorithm will initiate when presented with a trigger, in the case of the algorithm that may be a search phrase. Remember, the integrity of the search is only as “healthy” as the information initially presented. And the process will become faster and more efficient no matter what the trigger is. Therefore, therapy must be designed to help identify the trigger and reprogram the process.

The therapeutic questions to be derived from this observation are apparent and are specifically addressed by NCLT. Is there more than one efficient way to obtain this desired goal? If there are several ways to achieve this end, is one more efficient than the others? Is efficiency the goal, or is one process better at producing greater knowledge acquisition at the expense of time? Finally is there a particular form of therapeutic information provision that provides information in a manner that is consistent with how the brain is going to process it? These are all questions that deserve answers based on scientific inquiry and answers that NCLT attempted to provide.

NCLT emphasizes that automatized maladaptive behavioral and cognitive responses first be made available for working memory and attention, and systematically altered with the resulting adaptive behavior re-automatized. Identifying the triggers (preconditions) is an essential part of this process. For the most part, the maladaptive responses and the reformulated adaptive ones are learned. They do not “come preprogrammed at the factory.” They represent the interaction of core temperamental characteristics (Chess & Thomas, 1967) and regulatory efficiency with environmental experiences.

Based upon small world hub models and the fact that individualized environmental experiences contribute to the development of the connectome NCLT posits that the network of connectionist hubs is unique to each human being. Some may be adaptive and some maladaptive, but the vast majority of these networks are developed based on the systems responses to the environmental stimuli it encounters. They are created by learning and are the result of that learning. In recognizing that, NCLT stresses that learning and educational processes and principles should be utilized when trying to alter them.

NCLT and Epigenetics

Recent research has made it increasingly clear that learning is based on changes in synaptic connections, and these changes in synaptic connections are effected by the products of specific genes which are expressed under specific conditions. Learning, therefore, is the product of a consistent and ongoing interaction between the individual's experiences and their genetically derived predispositions. This interaction has been termed epigenetics (Elman, 1993). Epigenetics basically posits that behaviors and experience interact with physiological, cognitive, and emotional predispositions to produce current behavior (Atzaba-Poria et al., 2004; Buehler & Gerard, 2013). Available research suggests that current behavior reflects the accumulation of all these interactive events. NCLT practice recognizes and discusses the role of epigenetics in the development and maintenance of mental health issues. NCLT recognizes that maladaptive response networks can also develop as a result of epigenetic and learning-based changes to the connectome. In these dysfunctional networks there would be no detectible structural abnormality or lesion, but rather differing patterns of connectivity leading to inefficient processing of information (Schmithorst, Wilke, Dardzinski, & Holland, 2005) or differing patterns of network activation (Thiel et al., 2014).

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